Lower Trunk Acceleration Signals Reflect Fall Risk During Walking

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SUMMARY The purpose of this study is to make available a fall risk assessment for stroke patients during walking using an accelerometer. We assessed gait parameters, normalized root mean squared acceleration (NRMSA) and berg balance scale (BBS) values. Walking dynamics were better reflected in terms of the risk of falls during walking by NRMSA compared to the BBS.

key words: stroke, gait, fall risk, balance, acceleration

1. Introduction

Post-stroke hemiplegic patients present gait disabilities due to motor paralysis, somatosensory disorder, disrupted balance, and other factors. Falls are a typical complication of such brain diseases; thus, the risk of falls must be assessed during walking for each patient to manage safety control in rehabilitation as well as prevent quality of life (QOL) decreasing in daily life. In clinical practice, the Berg balance scale (BBS) is most commonly used to evaluate balance and is considered a valid and reliable measure in stroke rehabilitation [1]. However, it is difficult to use the BBS for predicting personal fall risk during walking, because a fall-risk assessment method by using the BBS is not based on kinesiology. Although gait parameters typically including speed, stride length, and cadence have been presented by previous papers [2], [3], they cannot assess the real-time fall risk for each patient because these parameters sometimes overestimate his/her walking ability due to the lack of personal factors such as each maximal speed without falls. Several studies have reported methods to quantify body fluctuation using lower trunk acceleration [4]. We consider that this method is also available for real-time assessment for fall risks. This study investigates personal fall risk prediction for stroke patients by measuring fluctuations in body acceleration during walking.

2. Subjects and Methods

This study is cross-sectional. 19 patients with post-stroke hemiplegia participated in this study. Characteristics of this stroke group include: a composition of 12 males and 7 females; values were expressed as means ± standard deviations; the age in the group was 61.3 ± 7.1 years; BMI was 23.0 ± 3.2 kg/m²; BBS was 42.2 ± 10.9; time since stroke onset was 116.9 ± 33.9 days; and the group included 8 patients with a paralyzed right side, 18 cane users, and 16 ankle-foot orthosis users. In addition, 11 age-matched, community-dwelling, elderly males were recruited as a control group, with characteristics including: age of 64.4 ± 2.4 years and BMI of 23.0 ± 2.0 kg/m². Motor recovery was evaluated for each stroke subject using the Brunnstrom recovery stage (BRS), which numerically evaluates the stage of motor recovery after a stroke on an ordinal ranking scale [5]. Functional balance was evaluated by using the BBS, which provides 14-item scales internationally authorized for use with stroke patients. BBS ranges from 0 to 4: the minimum score of 0 indicates a maximal need for assistance while the maximum of 4 indicates safety and no need for assistance to complete the given task. The subjects were instructed to walk in two trials along a 15-m-long walkway at a comfortable speed. We measured walking time and number of steps taken to calculate gait velocity, stride length, and cadence. An accelerometer was fixed over the L3 spinous process using an elastic belt to promptly evaluate gait variables [6]. Lower trunk fluctuations were measured using a wireless tri-axial digital accelerometer (MVP-RF8-AC, Microstone Co., Ltd.), which was had a weight of 60 g, size of W 45 × D 45 × H 18.5 mm, sensitivity of ±20 m/sec², response speed of 100 Hz at 3 dB, 10-bit A/D conversion, and sampling speed of 200 Hz. The measured data were promptly transmitted to a personal computer (PC) using Bluetooth devices. Trunk linear accelerations were measured along three axes: mediolateral (ML), vertical (V), and anteroposterior (AP). The sensor was calibrated for each measurement to determine the 0-g/s² offset under the ramrod-bearing condition.

The subjects were instructed to take a 12-step walk. The overall measured data were analyzed on a PC using a fourth-order, zero-lag Butterworth filter at 20 Hz provided by Matlab (MathWorks Inc., Release 2012) [7] to calculate as root mean squared acceleration (RMSA) as the acceleration signal. The signals were normalized by the square

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of the gait velocity. Furthermore, the normalized RMS_A (NRMS_A) was transformed into non-dimensional parameters by multiplying the average step length [4]. The gait variables were compared with the Mann-Whitney U-test and Welch's t-test. Spearman's rank correlation coefficient and Pearson's product moment correlation coefficient were used to evaluate the correlation between BBS, gait parameters, and NRMS_A. The statistical significance threshold was set at 5%.

3. Results

Table 1 shows the comparison between the stroke group and control group. The BRS showed moderate motor paralysis. BBS values ranged from 22 to 56. The cadence of the stroke group was significantly lower than that for the control group (p < 0.0001). The stride length of the stroke group was shorter than that for the control group (p < 0.0001). NRMS_A, ML, V, and AP of the stroke group were higher than those for the control group (p = 0.000571, 0.000235, and 0.000928, respectively). The NRMS_A and gait parameters were significantly correlated (cadence and ML, V, and AP: r = -0.73, -0.63, -0.75; stride length and ML, V, and AP: r = -0.76, -0.76, -0.68; gait velocity and ML, V, and AP: r = -0.77, -0.77, -0.73; respectively, p < 0.0001). The BBS and gait parameters were not significantly correlated (cadence and BBS: r = 0.18; stride length and BBS: r = 0.39; and gait velocity and BBS: r = 0.34, p > 0.05). The BBS score was significantly correlated with the BRS (ρ = 0.76, p < 0.01), whereas BBS and NRMS_A were not significantly correlated. NRMS_A, ML, V, and AP were significantly correlated with the BRS (ML: ρ = -0.61, p < 0.01; V: ρ = -0.51, p < 0.01; AP: ρ = -0.52, p < 0.01, respectively) (Fig. 1).

4. Discussion

The NRMS_A value showed a clear difference in walking dynamics between the stroke group and the control group. NRMS_A and BBS showed a non-linear relationship; however, NRMS_A and gait parameters showed a strong correlation. These results suggest that BBS is generally insufficient for assessing fall risk during actual walking. Harris et al. reported that neither the BBS score nor gait ability could explain falls in community-dwelling people with chronic stroke [8]. NRMS_A was strongly correlated with the gait parameters. In contrast, the BBS and gait parameters were not correlated significantly. These results suggested that NRMS_A shows an advantage in walking dynamics and fall risk assessment during walking. The correlation of BBS and BR was stronger than that between NRMS_A and BRS. The BBS may be subject to the effects of motor paralysis. We concluded that NRMS_A is better than BBS as a method of fall risk prediction during actual walking.

References
