PC-Based Warning Mechanism System of Fall Risk in Elderly

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Abstract. It is difficult to recognize and classify movement patterns correctly. We have developed and evaluated a method to classify movement using contact forces during sit-to-stand (STS) movement in elderly people. We used the key points of the ground reaction force (GRF) to identify the sequence of important time points in the STS movement of elderly people. The data showed that the reaction forces had three distinctive patterns: typical-modal (t-modal), multi-modal (m-modal), and incompetent-modal (i-modal). This is the first study to identify STS patterns based on objective force data and key points. The STS patterns can be used to supplement the subjective Berg Balance Scale (BBS) score to provide a more precise analysis of STS movement in the elderly.

Keywords: BBS, GRF.

1 Introduction

The population is aging in all developed countries, and as a result, the number of people requiring additional strategies to remain independent is likely to increase. Performance on STS tests has been found to predict subsequent disability, illness, falls, and hip fractures [4]. Currently, STS movement is investigated using observational performance tests to assess the risk of falling or performance measurements [7]. The observational performance tests, which tend to be subjective, use several assessment tools that combine measures of balance with measures of gait and mobility to determine a person's risk of falling, e.g., the Berg Balance Scale [2] and the Tinetti Gait and Balance Assessment [8]. The BBS relies on interviews conducted by rehabilitation professionals and was developed as a performance-oriented measure of balance in elderly individuals [1]. Although the BBS has excellent test–retest reliability for the assessment of standing balance, Newton [5] reported a wide range of ability among elderly subjects who had the same mode score on the BBS. This finding suggests that the BBS score does not provide a precise measurement of performance ability. The present study describes the key points of STS movement in elderly people and introduces a PC-based approach to the assessment of STS patterns, with a view to supplementing the subjective BBS to provide a more precise analysis of STS movement in elderly people.

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2 Methods

2.1 Participants

Twenty healthy elderly subjects (age, 68.95 ± 4.59) participated in the study; their mean height, weight, and body mass index (BMI) were 158.50 ± 5.85 cm, 59.39 ± 10.24 kg, and 23.55 ± 3.91, respectively. The selection criteria were (1) over 65 years old; (2) no acute medical illness in the past 3 months; (3) no orthopedic diagnosis; (4) no muscular disease; (5) BBS score ≥41 (6) BI score ≥60 (7) MMSE score >17; and (8) IADL score of ≥7.

2.2 Apparatus

In the present study, the GRF was defined as the force applied to the ground by the buttocks and/or the feet. Vertical GRFs were recorded from two separate force platforms (size, 500 × 500 mm; accuracy, 0.20 N) composed of eight load cells. A personal computer simultaneously saved the two sets of GRF data at 1000 Hz using a 16-bit analog-to-digital converter acquisition board (NI PCI-6220; National Instruments Inc., Austin, TX, USA) and dynamic amplifiers.

2.3 Procedure

The subjects sat on an armless chair of standard height (40 cm) on a buttock-force platform with their arms folded across the chest. A back support on the chair was used to ensure that the subjects' trunks were leaning back in a standard position, and their bare feet were positioned on the leg-force platform. No other restrictions were imposed on the initial position. Each subject performed the task in a comfortable and natural manner and at a self-selected speed.

2.4 Measurements

Figure 1 shows selected GRF parameters. Two curves (B, buttock weight; L, leg weight) describing the vertical GRF as a function of time were obtained from the force platforms. Curve T was the sum of forces B and L. The time taken to stand up was calculated from these curves. B_s, L_s, T_s, the onset of the B, L, and T curves: T_p, L_p, maximal GRF at curves T and L; B_0, B at zero. Prior to analysis, the data were smoothed using the moving-average method. The force data indicated that the different sequences of the STS task exhibited specific characteristics that formed distinct patterns. B_s, L_s, and T_s occurred immediately after initiation of the action cue when the difference between the GRF at that time point and the previous value did not equal zero. Seat-off was defined as the time at which the thighs lost contact with the chair, when the instant of curve B was at B_0. T_p and L_p occurred when the GRF for curves T and L, respectively, were maximal. The GRF oscillated following seat-off, and the STS phase ended when the GRF reached body weight.

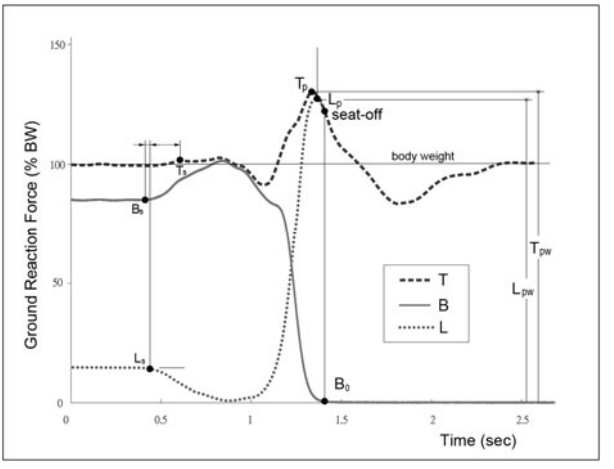

Fig. 1. The GRF parameters (N15)

2.5 Statistical Analysis

The GRF time recordings were transformed logarithmically (Box & Anderson, 1955). A normal distribution test was performed, followed by a one-way ANOVA with repeated measures to evaluate the effect of B_s, L_s, and T_s. Significant results were followed up using the least significant difference (LSD) method as a post hoc test. The mean times of T_p, L_p, and seat-off were compared in a similar manner. A P-value <0.05 was deemed statistically significant.

3 Results

The mean time ± the standard deviation (SD) for B_s, L_s, and T_s were 6.40 ± 0.24, 6.52 ± 0.27, and 6.60 ± 0.35, respectively. Different aspects of onset significantly affected the time of the activating moment ($F = 5.67$, $P < 0.05$). The LSD indicated that Bs occurred significantly earlier than L_s and T_s, and that L_s and T_s did not significantly affect the activating moment. The mean times for T_p, L_p, and seat-off were 7.53 ± 0.20, 7.59 ± 0.24, and 7.62 ± 0.21, respectively. These different time points significantly affected the time of the activating moment ($F = 14.62$, $P < 0.001$). T_p, L_p, and seat-off appeared in sequence; the LSD analyses indicated that the time of T_p, L_p, and seat-off were all significant. Based on the characteristics indicated by the force data, the STS movement sequences were classified into three patterns (Figure 2). The mean BBS score of the t-modal, m-modal, and i-modal patterns were 49.88 ± 2.64, 46.29 ± 4.54, and 43 ± 2, respectively. Figure 3 shows the relationship between the force pattern and the BBS score.

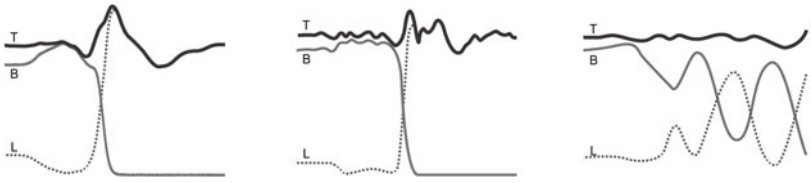

Fig. 2. The three characteristic force patterns observed during the STS movement in elderly participants. From left to right: typical-modal (t-modal), multi-modal (m-modal), and incompetent-modal (i-modal).

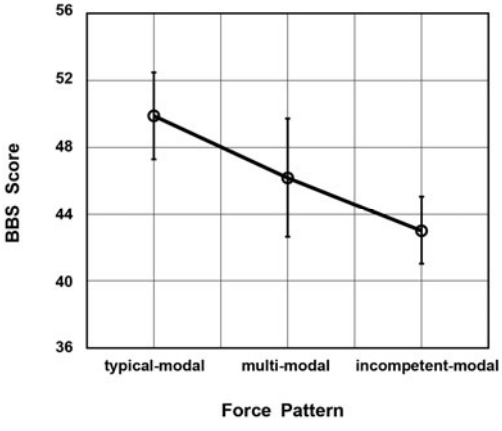

Fig. 3. The relationship between the force pattern and the BBS score

4 Discussion

Our data indicate that B_s is the onset of the STS movement in elderly people and that L_s and T_s are less accurate indices in comparison with B_s. Thus, using L_s or T_s to identify STS onset may underestimate the duration of the STS movement in elderly people. However, Chang and colleagues [3] reported that GRF component B_s and L_s, which were not significant in the present study, could both be used to mark the onset of the STS movement in healthy adults. The age of the participants may explain the difference between our findings and those of Chang. T_p and L_p are the maximum force points of the body and legs respectively. Their physical significance is different from that of seat-off, which represents the moment when the buttock leaves the seat. Although disagreement exists over the order of these three points [6], Chang and colleagues [3] reported the order of T_p, L_p, and seat-off in healthy adults using two high-frequency force platforms. Our findings in elderly subjects are consistent with those of Chang.

The force data indicated that the STS movement task could be divided into three distinct patterns. In general, the curves of t-modal pattern are smooth, regardless of the B, L, or T curve. The curves of the m-modal pattern have multi-peak characteristics in curves B, L, and T. The curves of the i-modal pattern oscillate

widely, particularly the B and L curves. The large amplitude swings in the i-modal pattern were caused by multiple outputs from one subject who tried, but was unable to complete the STS movements. In our study, the relationship between the BBS and STS patterns derived from the objective instrument was linear (Figure 5). Moreover, the SD of the t-modal and i-modal patterns on the BBS score was smaller than that of the m-modal pattern. Thus, the same BBS score may be associated with different STS patterns. For example, a subject with a BBS score of 48 may have shown either a t-modal (smooth movement) or m-modal (unstable movement) pattern, whereas another subject with a BBS score of 44 may have been able to stand up with no assistance (m-modal) or been unable to perform the STS task (i-modal) on the first try. Thus, the objective STS patterns provide a more precise assessment of balance in the elderly than does the more subjective BBS.

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