

Chapter 36

Evaluation of Walking Motions with the Aid of Walkers Using Acceleration Sensors

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ABSTRACT

Walkers are tools that are used to improve self-reliance when walking. In this study, the unstable motions of gait in subjects who use walkers were analyzed using tri-axial accelerometers and a motion capture system. Several markers were placed on the subjects' backs and legs, and two high-speed video cameras were employed to record the motion of these markers. The subjects were asked to walk around a test course at a comfortable speed. The activities performed on the test course consisted of standing, normal walking, fast walking, walking over a barrier, and falling down. The authors' results determined the characteristic rules of gait motion with walker use. They found that acceleration sensors are convenient for extracting characteristics from the gait motions. They believe that the methods employed with the acceleration sensors are suitable for the discovery of the average gait motions of elderly patients living in nursing homes and can be used to evaluate walking motion before and after rehabilitation.

1. INTRODUCTION

Walking aids include assistive canes (commonly referred to as walking sticks) or crutches and walkers. As appropriate to the needs of the individual user, these devices help to maintain upright

ambulation by providing improved stability, reducing lower-limb load and generating movement (e.g., Cook, & Hussey, 2002). Although walkers provide a more stable base of support compared with other ambulatory aids, they are less versatile. Walkers work well on flat, level surfaces, but they may present a problem on uneven surfaces or in narrow passages (e.g., doorways). In addition,

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walkers may be equipped with wheels so that they may be rolled instead of lifted. Most walkers with wheels incorporate either wheel locks or brakes (e.g., Cooper, 1995; Hall, Clarke, & Harrison, 1990). A number of studies have addressed the kinematics and biomechanical analyses of walking that is associated with using these devices (e.g., Crosbie, 1994; Alkjaer, Larsen, Pedersen, Nielsen, & Simonsen, 2006). Moreover, Wright et al. (1992) have investigated other factors that may mediate the usefulness of prescribing a specific type of walking aid.

Acceleration sensors may provide an effective method for the motion analysis of exercise. For example, one previous study attempted to evaluate motions such as walking, hill climbing, standing, sitting, and avoiding an obstacle by solely using accelerometers (Takenoshita, Nishiyama, Kawagoe & Makikawa, 2005). Furthermore, another study used a tri-axial acceleration sensor to compare a peculiar movement of a patient suffering from Parkinson's disease with that of a physically unimpaired person (Sekine, Akai, Tamura & Higashi, 2004).

However, little experimental rigor has been devoted to the investigation of walking motion using acceleration sensors. In this study, the walking motion while using a walker that was equipped with acceleration sensors was experimentally analyzed. The acceleration sensors were attached to the lumbar region of the subjects, and the characteristics and size of the output waveforms were identified for a range of motions that included standing, sitting, normal gait, and turning gait. In addition, the measurements were acquired simultaneously using the sensors, and video cameras were used to record the images of the signal from the sensors. Therefore, it was possible to determine the extent of rehabilitation of the elderly by comparing their motion before and after care and to estimate the effectiveness of walker use by only analyzing the output signals from the sensors.

2. EXPERIMENTAL APPARATUS AND METHODS

A full range of motion including walking was filmed in a three-dimensional (3D) image using the direct linear transform (DLT) method with two high-speed video cameras (NACHSV-1000). The two high-speed video cameras were connected in advance using cables and were synchronized. To generate the 3D images, each camera recorded from a different angle. The filming was performed with Camera A from a diagonal direction and with Camera B from a lateral direction. The lighting equipment was also installed next to the cameras. To calibrate the two cameras, a triangular pyramid calibration unit with sides of 1000 mm in length and 1450 mm in height was used. The control points were fixed to prevent the high-speed video camera from slipping, which was accomplished by attaching the high-speed video camera to the body of the apparatus with hook-and-loop fasteners and using elbow and knee pads for the joints. A total of 20 control points were attached to the body and four-wheel walker (ETAC SL four-caster walker from Sharp Training Co.). A photograph of the experimental apparatus is shown in Figure 1. Preliminary experiments that analyzed the unstable movements while using a walker employed two high-speed video cameras and three tri-axial acceleration sensors.

The three tri-axial acceleration sensors (ONO SOKKI NP3560 dimensions: $10 \times 10 \times 10$ mm, weight: 5 g, maximum acceleration: 4900 m/s^2 , impact resistance: 98000 m/s^2) were used to measure the acceleration in the three directions: X, Y, and Z. The sensors were attached to the walker, lumbar region, and the shin of the right leg to measure the acceleration of the walking motion. In this study, the acceleration sensors that were attached to the body analyzed the vertical direction, direction of motion, and lateral motion. The sensors that were mounted on to the body were attached by processing jigs and were fixed so that they would not move or detach during

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