Video analysis of sit-to-stand motion in the evaluation of motor function

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Abstract: Loss of muscular strength and decline of balance in older adults impairs their ability to perform activities of daily living, such as walking or moving from a sitting to a standing position (sit-to-stand). To develop care methods to maintain their quality of life, it would be useful to evaluate the changes in their movement characteristics using conventional techniques. We investigated the potential of video analysis of the sit-to-stand motion in several applications, i.e., hemiplegia, a rucksack carrying model and physical battery, in older adults. As a result, the sit-to-stand motion reflected the changes in motor function due to muscle weakness and paralysis. Motion analysis using the sit-to-stand motion could be suitable for evaluating the physical abilities of older adults. We review these examples and discuss the research direction of video analysis for both the diagnosis of motor function, as well as supporting health promotion activities.

Keywords: Video analysis, Sit-to-stand, Older adults, Motion capture, Motor function

I. Introduction
It has recently been shown that physical therapy and various kinds of group exercises that can maintain and improve the motor function of older adults are also effective interventions for age-related cognitive decline or impairment. Although physical exercises are widely employed in community programs, some older adults are not necessarily willing to participate in such activities. Therefore, it would be useful to design a protocol to support those older adults with potentially declined physical abilities, who are not sufficiently active to join community exercise programs. One solution would be the introduction of information and communication technology (ICT) to enable participation in fitness programs at home. ICT-based remote instruction would also reduce the cost and time required of an instructor to visit each of the community dwelling older adults on a door-to-door basis. At the same time, the motions for remote measurements should be as simple, easy, reproducible and safe as possible for older adults. In this review we discuss the potential of video analysis to evaluate physical ability by using the sit-to-stand motion model. These capabilities will enable real-time evaluation and intervention of the physical function to instruct older adults at home.

II. Effect of the rucksack carrying on sit-to-stand motion in the older adults
Older adults tend to lose their balance easily during the sit-to-stand movement while carrying a bag. However, few studies have reported the effect of baggage on the sit-to-stand motion in older adults. The purpose of this study was to examine the effect of rucksack carrying on the sit-to-stand motion in older adults. Eight community dwelling older adults, aged 73 ± 5 years, and 4 university students, aged 20 ± 1 years, participated in this study.

Fig. 1 The Motion capture system to record sit-to-stand motion

Fig. 2 The Motion capture system to record sit-to-stand motion

Fig. 3 The Motion capture system to record sit-to-stand motion
The physical exercise batteries employed included 5m walk speed, timed up & go test and functional reach. The sit-to-stand motion of each subject carrying a rucksack on their back was recorded using a digital video camera (CASIO EX-FH100). The total weight of the rucksack and load was set at 5% of the body weight. The video recordings were analyzed using 2D motion analysis software (Tomoko-Lite, Toso System, Saitama, Japan) to extract the trajectory of the color markers (Fig 1). The results indicated that the physical performance was significantly greater in the young subjects than in the older adults. The maximal pelvic forward tilting angle during the sit-to-stand motion in the older adults was greater than that of the younger group. With respect to the maximal trunk inclination angle in the frontal plane during the sit-to-stand motion, both groups had a trunk inclination while carrying a rucksack (Fig 2,3).

### III. The sit-to-stand motion in stroke patients

The sit-to-stand motion was analyzed in stroke patients (SP group) to determine how they perform the sit-to-stand movement with hemiplegia. The results from the SP group consisted of 9 chronic hemiparetic stroke patients aged 64±7 years (6 male, 3 female) and a control group comprised of 7 healthy subjects aged 59±6 years (5 male, 2 female). The seat heights were set at the lower leg length of each participant. The joint angles were measured using the two-dimensional motion analysis system (ToMoCo-Lite) and the muscle electric activities were recorded by a surface electromyography system (NORAXON, USA)(Fig 4). The vastus medialis muscle activities of the SP group on the non-paralyzed side were greater than those of the control group. The maximal trunk forward tilting angle during the sit-to-stand motion in the SP group was larger than the older adult group. The maximal ankle dorsiflexion angle during the sit-to-stand motion in the SP group was smaller than the older adult group (Table 1). These results suggested that the stroke patients might use a stabilization strategy that depends on the ability of the non-paralyzed knee extensor and compensates for the deteriorated functions of their ankle joints.

### IV. Analysis of the sit-to-stand motion to evaluate the motor function of older adults using a network CCD camera

The aim of this study was to examine the availability of a sit-to-stand task for a telemetering system during motor function evaluation using a conventional video communication system that enables real-time monitoring, evaluation and intervention of the physical performance of older adults at home. The participants included 59 older adults, aged 74±3 years, and 81 university students, aged 21±1 years. The three physical exercise batteries employed in this study were arm curl, figure-eight walk test and functional reach. For motion-capture measurements, the knee extension maximum angular velocity (KEMAV) and the iliac elevation maximum velocity (IEMV) during the standing up motion from a chair, and heel rise frequency were determined. The IEMV and KEMAV values in the older adults were lower than those in the younger group due to the decreased motor ability (Fig 5, 6). The validity of the assumption was assessed with multi-group structural equation modeling between the younger and older adult groups. Throughout all of the path diagrams for IEMV and KEMAV in the older adults and the younger groups, the paths from muscular strength to skillfulness would lead to a higher correlation coefficient.
required significant effects. Furthermore, the path from IEMV to muscular strength was significant in the older adult group. As a result, it was demonstrated that video-based measurement of IEMV during sit-to-stand motion could be used to estimate muscular strength, and that remote monitoring of physical performance could be a tool to support the wellness of community-dwelling older adults.

V. Discussion and Summary

We investigated the movement of subjects with disability or declined motor function by using sit-to-stand motion as a marker of the physical status. Several papers have indicated the clinical significance of sit-to-stand motion. In a study of nursing-home residents with dementia, higher scores on the 30-second sit-to-stand and Berg Balance Scale were associated with better QOL in the late-stage dementia scale (1). The knee extensor muscles concentric strength at higher velocity and eccentric strength contributed to the sit-to-stand performance that was considered to be the factor related to the risk of fall in older adults (2). Since the iliac elevation velocity reflects the movement of the physical center of gravity, it is reasonable that the score has a high relation to lower limb muscular strength and balance. Epidemiologically, it has been reported that the chair standing test might be as useful as the complete Short Physical Performance Battery in estimating mortality risk (3). The Japanese long-term care insurance level was also associated with physical performance, including the sit-to-stand ability, cognitive function, and the ability to perform ADLs (4).

In our 3 studies, the following findings were confirmed. The posture of the older adults inclined by carrying a rucksack on their back. On the other hand the stroke patients performed the sit-to-stand motion mainly on the non-paralysis side. These results were similar to the report of Hesse (5). We also confirmed that we could predict the motor ability of older adults from the movement of a marker measured by a video. Our results indicated that the evaluation of physical ability can be performed by motion analysis using video monitoring or recording, and that sit-to-stand task testing will be potentially useful tool in assessing the balance and in assessing the risk of falls in older populations (6). The concentric strength at higher velocity, eccentric strength, and rate of torque development were important contributors to sit-to-stand performance (7). The higher the ability for sit-to-stand, the stronger the muscle strength for pushing the floor. Also, in the report of the sit-to-stand motion, the speed of the sit-to-stand motion was influenced by the muscular strength of the lower limbs (8-11). It can be hypothesized that increased body rise will be a useful index of exercise capacity for older adults. Because standing-up is a fundamental movement of the human body and it is a very common motion in daily life, it will be an appropriate task for telemetering systems. We can measure it safely, because this measurement assesses sit-to-stand motion only once. Repetition of the sit-to-stand motion may cause fatigue and increase fall risk.

In conclusion, motion analysis using conventional video cameras will become a practical method to support health promotion activities for older adults, as we can easily measure

the sit-to-stand motion in the evaluation of the motor ability of older adults anywhere.

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