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Short communication

Automated approach for quantifying the repeated sit-to-stand using one body fixed sensor in young and older adults

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ABSTRACT

Much is known about the sit-to-stand (STS) and its biomechanics. Currently, however, there is little opportunity for instrumented quantification of the STS as part of screening or diagnosis in clinical practice. The objectives of the present study were to describe the feasibility of using an automated approach for quantifying the STS using one sensor location and to start testing the discriminative validity of this approach by comparing older and younger adults. 15 older subjects recruited from a residential care home and 16 young adults performed 5 repeated sit-to-stand and stand-to-sit movements. They were instrumented with a small and lightweight measurement system (DynaPort®) containing 1 triaxial seismic accelerometer and 3 uniaxial gyroscopes fixed in a belt around the waist. Durations of the (sub-)phases of the STS were analyzed and maximum angular velocities were determined. All successful STS cycles were automatically detected without any errors. The STS duration in the older adults was significantly longer and more variable in all phases (i.e., sit-to-stand, standing, stand-to-sit and sitting) compared to the young adults. Older adults also exhibited lower trunk flexion angular velocity. The results of this first fully automated analysis of instrumented repeated STS movements demonstrate that several STS parameters can be identified that provide a basis for a more precise, quantitative study of STS performance in clinical practice.

1. Introduction

Previous work using camera-based systems and force plates in laboratory settings has quantified sit-to-stand (STS) movements to better understand their biomechanical dynamics [1,2]. Body fixed sensors (BFS) were introduced to movement analysis research in the early 1990s [3] and offer an alternative approach to quantifying the STS. Studies using BFS demonstrated the ability to identify the beginning and end of STS transitions with one gyroscope fixed to the chest [4]. Accelerometers fixed to the sternum and to the upper leg were used to detect the start and end of a STS transition in healthy subjects and stroke subjects [5]. Using accelerometers and gyroscopes, the kinematics of rising from a chair were calculated [6]. Power during STS movements has been recently analyzed by adding magnetic-field sensors [7]. Nonetheless, to date, automated algorithms for quantifying repeated sit-to-stand and stand-to-sit movements using BFS have not been described. This method is expected to be usable for collecting quantitative STS data on a routine basis in clinical practice. Since this is currently not possible, the objective of the present study was to investigate the feasibility of using an automated approach for quantifying the STS using one sensor location and to start testing the discriminative validity of this approach by comparing older and younger adults.

2. Methods

2.1. Subjects

In this experimental cross-sectional study, 15 older adults (OA), living in a residential care home (11 female, median age 88 (73–99) years; median height 162 (156–192) cm; median weight 66 (44–91) kg) and 16 healthy young adults (YA) were recruited (9 female, median age 20 (18–23) years; median height 167 (162–184) cm; median weight 62 (53–78) kg). Height and weight were not significantly different in the two groups. All participants provided informed written consent. The protocol was approved by the Ethics committee of the Free University Amsterdam.

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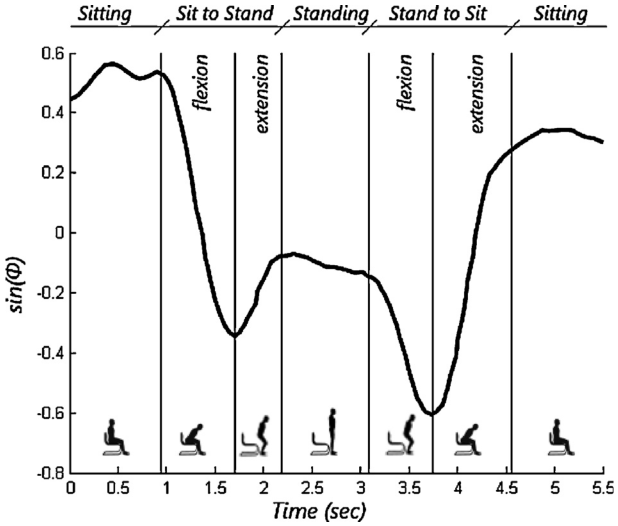

Fig. 1. The wavelet transform of the sine of the trunk angle, dw_sin(ϕ), is shown during the main sub-phases of a complete STS cycle, preceded and followed by a sitting epoch.

2.2. Instrumentation and data acquisition

A BFS system (DynaPort® Hybrid, McRoberts; 87 mm × 45 mm × 14 mm, 74 g) was inserted in an elastic belt on the lower back positioned at the lumbar vertebra. These included 3 pre-calibrated accelerometers (STM-LIS3LV02DQ), 3 gyroscopes (EPSON-XV-3500CB), sampling rate 100 Hz. The accelerometer signals have been shown to be highly reproducible [8]. Raw data were stored on a Micro-SD card (SanDisk).

2.3. Procedure

Subjects performed 5 STS cycles at a self-selected speed (start and end in a sitting position), while free to swing their arms. A standard chair without arm rests was used. Subjects were video taped from the side to enable post hoc visual inspection by a single observer of successful and failed attempts. A failed STS attempt was defined as the subject not being able to end in a standing position.

2.4. Signal analysis

Data was corrected for tilt [9]. The acceleration and the angular velocity in the sagittal plane determined the trunk angle (ϕ) [10]. Subsequently, the sine of the trunk angle (sin(ϕ)) was calculated. Drift and noise were removed from the sin(ϕ) using the discrete wavelet transform dw_sin(ϕ) [4]. "True vertical acceleration" was estimated by removing the influence of ϕ from the vertical acceleration signal. Finally, vertical velocity was derived by integrating this signal.

The vertical velocity was used to differentiate between successful STS movements and failed STS attempts. The dips in dw_sin(ϕ) were used to detect a change in trunk rotation direction (Fig. 1). The start of the sit-to-stand was defined as the

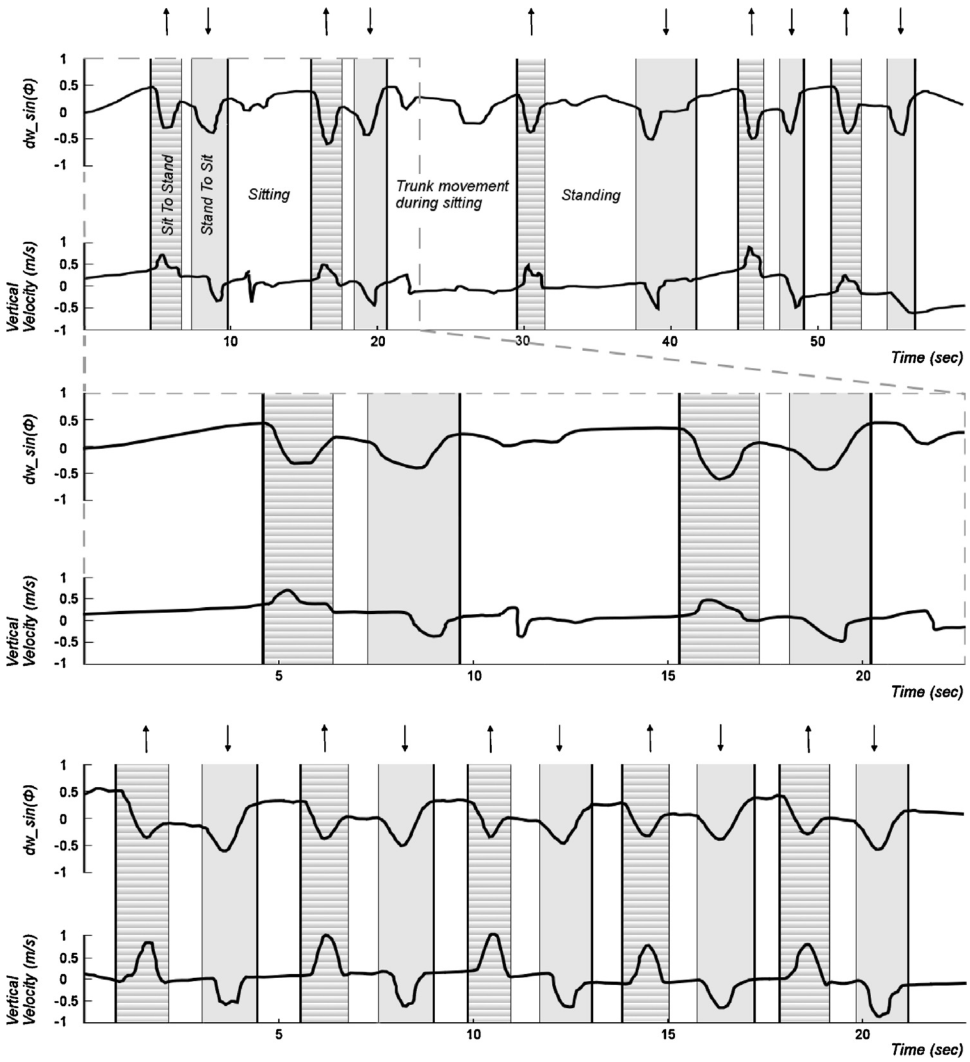

Fig. 2. Typical example of five repeated STS cycles of an older adult (top panel) and a young adult (bottom panel). In the middle panel the first 23 s of the older adult panel is stretched, indicated by a dotted line, for better comparibility to the young adult panel. In the panels dw_sin(ϕ) andvertical velocity are shown. Standing up is indicated by ↑, sitting down is indicated by ↓. Variability of the signals of the OA is highand of the YA is relatively low. Duration of standing and sitting of the OA is relatively long.