Effects of Vocalization When Standing-up from a Sitting Position in a Chair among Healthy Elderly People

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Aims: The effects of vocalization on standing-up movement were examined in healthy elderly people. Vocalizations, which are made frequently during sports activities, may also accompany vigorous movement in everyday situations, such as when standing-up from a seated position.

Methods: Fifteen healthy elderly men and women (71.1 ± 2.5 years old: average ± SD) performed standing-up movement from a sitting position in a chair at voluntary and maximum speeds with and without energetic vocalization. 2D kinetics and kinematics data, thigh muscle electromyographs (EMG), and timing of vocalization were acquired.

Results: Peak hip extension moment and EMG activity in the long head of the biceps femoris (BF) were significantly higher with than without vocalization in both voluntary and maximum speed standing, and no significant differences were observed both in peak knee extension moment and in EMG activity in the vastus lateralis (VL). Peak triaxial composite of ground reaction force divided by body weight was significantly higher with than without vocalization at both voluntary and maximum speeds. Almost all subjects vocalized immediately before ground reaction force reached the peak level (before 0.12 ± 0.14 s and 0.09 ± 0.12 s at voluntary and maximum speed, respectively). Standing velocity was significantly higher at voluntary speed with than without vocalization (0.86 ± 0.25 vs. 0.67 ± 0.22 m/s), and no significant change was seen with vocalization at maximum speed.

Conclusions: The results suggest that vocalization enhances hip extension muscle force exertion during standing-up movement and increases standing velocity at voluntary speed in elderly people.

Keywords: standing-up movement, vocalization, return action, kinetics, kinematics

1. Introduction

Standing-up from a sitting position in a chair or other type of seating to an upright position is one of the most frequently performed movements involving vigorous muscle exertion in daily activities. Standing-up movement requires a greater peak joint moment (Rodosky et al., 1989) and greater muscle strength (Ploutz-Snyder et al., 2002) than other common movements in daily activity, such as climbing stairs or walking. Both muscle mass and strength decrease in the elderly as they age. Sarcopenia, defined as aging-related loss of muscle mass (Evans, 1995), results in a reduction of strength, and leads to impairment of basic locomotory functions. Many elderly people experience difficulty in standing-up from a chair (Schultz, 1995). Therefore, improving the ability to stand up from a seated position is important to maintain quality of life among elderly individuals. People sometimes naturally vocalize when exerting effort during movement, not only in sports activities, but also in activities of daily life, such as standing-up, climbing stairs, and lifting luggage. In Japan, the vocalization sounds “yo” and “yoisho” are used frequently in association with strenuous movement, particularly by middle-aged and elderly people. Vocalization during movement may improve standing-up movement by enhancing muscle force exertion and making the movement more efficient.
Vocalization during standing-up movement may enhance muscle force exertion. Ikai and Steinhaus reported that vocalization led to an increase in hand grip strength (Ikai and Steinhaus, 1961), and Murakawa and Tokoro reported that shot put throwing distance increased by about 4% with vocalization compared to that without vocalization (Murakawa and Tokoro, 2007). These changes are thought to be due to the aftereffects of central nerve excitability gain, which leads to an increase in number of recruited motor units (Yabe et al., 1998). Such improvement of neuromuscular function is an important factor in muscle strength gain (Komi, 1986).

Smoothly controlled movements in both daily life and sports activities utilize stretch-shortening cycle (SSC) movement (Komi, 1984; 2000) and inertia (Mochon and McMahon, 1980; Siegler et al., 1982). SSC, which is defined as a sequence involving an eccentric muscle action followed immediately by a concentric muscle action, enhances mechanical performance by making use of the elastic properties of tendon structures and other elements (Cavagna, 1977). Vocalization may improve the efficiency of standing-up movement using SSC, e.g., by accelerating countermovements, such as trunk tilt and hip joint flexion. The intensity of countermovements is a key factor in efficient SSC movement (Moran and Wallace, 2007). In movement involving standing-up from a sitting position in a chair, hip joint flexion, a countermovement of hip extension, has a large range of motion, while knee joint flexion, a countermovement of knee extension, has almost no range (Kralj et al., 1990). The changes in hip flexion speed and range of motion, hip extension moment, and hip extensor muscle EMG activity may be useful indicators of improvement attained through efficient utilization of SSC. The present study was performed to investigate the effects of strong vocalization during standing-up movement from a sitting position in a chair among elderly people.

### 2. Methods

#### 2.1. Subjects and Experimental Protocol

The study population consisted of 15 healthy elderly men and women (71.1 ± 2.5 years old: average ± SD), all of whom were recruited after medical screening and provided informed consent prior to enrollment (Table 1). None had any orthopaedic disorders or physical function disorders that would hinder independence in daily living. All participants were fully informed about the experimental procedures and were given opportunities to practice the standing-up movements required in the trial. Each subject performed four patterns of standing-up movement from a chair, i.e., standing-up at voluntary speed with and without vigorous vocalization and standing-up at maximum speed with and without vigorous vocalization. As a short sound is appropriate for the purpose of this study because it enables identification of vocalization timing, the vocalization sound “yo” was adopted in the trials. Subjects gave the vocalization “yo” with arbitrary timing during standing-up movement. The arms were fixed in front of the chest during standing-up movement to prevent their use when standing-up. The initial posture of the standing-up movement was not restricted. Three trials were conducted as practice before each experimental trial. The four movement patterns were assigned randomly. Each standing-up movement was conducted twice, and the trial that the subject felt was better was adopted for the analysis. Obviously unnatural movements were not included in the number of trials and measurement procedures. Rest times of 30 s and 3 minutes were given between trials within the same movement pattern and between each pattern, respectively. The height of the chair was set at 0.40 m based on the Japan Industrial Standard (JIS S 1011) and British Standards Institute (Skelton et al., 1994). Subjects were given the following instruction “Please stand spontaneously in a relaxed way, as you usually do” in the voluntary condition to exclude psychological bias as much as possible.

#### 2.2. Kinetics and kinematics analyses

Kinematics and kinetics analyses were performed using the two-dimensional coordinates of landmark points of each subject’s body acquired using a 2D optical motion capture system (Frame-Dias; DKH,
with a high-speed camera at 300 Hz (Casio EXILIM HS EX-ZR200; Casio, Tokyo, Japan) and a ground reaction force sensor (TF-4060; Tec Gihan, Kyoto, Japan). The force sensor signal was stored on a personal computer system through an A/D converter with a sampling frequency of 1 kHz. The body segment inertia parameter model for Japanese elderly people reported by Okada et al. (Okada et al., 1996) was used for kinetic calculations. Six reflective markers were placed on each subject’s body (right acromion, right great trochanter, right lateral epicondyle of the femur, right malleolus lateralis, right calcaneal tuberosity, and right toe). All raw coordinate data were smoothed using a low-pass digital filter with a cutoff frequency <10 Hz determined by residual analysis (Winter, 1990). The hip joint extension flexion angle was defined as the angle between the acromion–great trochanter vector and the great trochanter–lateral epicondyle of the femur vector. Knee joint extension flexion angle was defined as the angle between the great trochanter–lateral epicondyle of the femur vector and the lateral epicondyle of femur–malleolus lateralis vector. Trunk extension flexion tilt angle was defined as the angle between the vertical axis vector and the acromion–great trochanter vector. Peak standing velocity was evaluated as the maximum vertical speed of the left acromion from the sitting position to a fully standing position. Mean standing velocity was evaluated as the mean vertical velocity of the left acromion from 10° to 90° of the acromion vertical range of motion in standing-up movement.

2.3. Electromyography

EMG was performed from the left vastus lateralis (VL) muscle and long head of the left biceps femoris (BF) using bipolar surface electrodes (Vitrode F; Nihon Kohden, Tokyo, Japan) placed over the belly of the muscle with a constant interelectrode distance of 30 mm. The EMG was amplified (DL-140; DKH, Tokyo, Japan) and fed into a full-wave rectifier through both low (30 Hz) and high (1 kHz) cut filters. These data were stored on a personal computer system through an A/D converter with a sampling frequency of 1 kHz. The mean absolute value (AV) of EMG was used as an index to estimate the mean muscle activation level during standing-up movement. The average rectified value (ARV) of EMG was used as an index to estimate the peak muscle activation level during standing-up movement. ARV was defined as the time window (50 ms) mean of the absolute value of the EMG. The values of EMG data were evaluated as relative values divided by the value in voluntary standing-up movement without vocalization.

2.4. Vocalization timing recording

Vocalization sound signals were recorded with a voice trigger device (PH-1211; DKH, Tokyo, Japan) and stored on a personal computer system through an A/D converter with a sampling frequency of 1 kHz. The microphone of the voice trigger device was placed near the mouth using a head hook. The ARV of the sound signals, defined as the time window (50 ms) mean of the absolute value of the sound signal, was used as an index for estimation of peak vocalization time during standing-up movement. Sound, EMG, and ground reaction force data were stored on a personal computer through the same A/D converter to allow their synchronization.

2.5. Statistical analysis

All values are expressed as means ± SD. Paired t test was used to examine differences between standing-up movements with and without vocalization at voluntary speed and at maximum speed. Repeat ed measures ANOVA with two factors (vocalization condition and effort task, voluntary and maximum) with the Newman–Keuls method was used to examine differences in changes in all parameters between the two effort tasks. In all analyses, P < 0.05 was taken to indicate statistical significance.

3. Results

3.1. Standing velocity

The peak and mean standing velocity at voluntary speed were significantly higher with vocalization than without vocalization (0.98 ± 0.29 vs. 0.83 ± 0.26 m/s, 0.86 ± 0.25 vs. 0.67 ± 0.22 m/s at peak and mean, respectively). There were no significant differences between those with and without vocalization at maximum speed. The mean standing ve-
Table 2  Kinematics and kinetics data.

<table>
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<tr>
<th></th>
<th>Voluntary speed standing</th>
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<th>Maximum speed standing</th>
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<tr>
<td></td>
<td>without vocalization</td>
<td>with vocalization</td>
<td>without vocalization</td>
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<tr>
<td><strong>Standing up velocity (m/s)</strong></td>
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<tr>
<td>peak</td>
<td>0.825 ± 0.259</td>
<td>0.978 ± 0.286*</td>
<td>1.283 ± 0.413</td>
<td>1.395 ± 0.372</td>
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<tr>
<td>mean</td>
<td>0.672 ± 0.217</td>
<td>0.864 ± 0.252*</td>
<td>1.093 ± 0.346</td>
<td>1.173 ± 0.327</td>
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<tr>
<td><strong>Peak joint angle velocity (deg/s)</strong></td>
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<tr>
<td>hip extension</td>
<td>138.9 ± 28.9</td>
<td>175.4 ± 33.1*</td>
<td>223.8 ± 38.9</td>
<td>233.6 ± 43.2</td>
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<tr>
<td>knee extension</td>
<td>129.0 ± 32.2</td>
<td>153.6 ± 32.5*</td>
<td>200.3 ± 52.2</td>
<td>204.2 ± 59.7</td>
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<tr>
<td>hip flexion</td>
<td>49.1 ± 8.0</td>
<td>58.7 ± 10.3*</td>
<td>69.8 ± 11.8</td>
<td>70.3 ± 12.1</td>
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<td>trunk flexion tilt</td>
<td>64.1 ± 9.7</td>
<td>74.2 ± 12.7*</td>
<td>82.8 ± 19.1</td>
<td>88.2 ± 16.7</td>
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<td><strong>Peak joint flexion angle (deg)</strong></td>
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<tr>
<td>hip flexion</td>
<td>98.1 ± 7.4</td>
<td>100.3 ± 6.8</td>
<td>97.9 ± 8.6</td>
<td>100.7 ± 6.7</td>
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<tr>
<td>trunk flexion tilt</td>
<td>121.4 ± 7.0</td>
<td>123.9 ± 7.8</td>
<td>119.1 ± 7.3</td>
<td>122.3 ± 5.8</td>
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<td><strong>Peak joint moment/Body mass (Nm/kg)</strong></td>
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<tr>
<td>hip extension</td>
<td>1.85 ± 0.43</td>
<td>1.99 ± 0.41*</td>
<td>2.24 ± 0.52</td>
<td>2.47 ± 0.64*</td>
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<tr>
<td>knee extension</td>
<td>1.59 ± 0.43</td>
<td>1.56 ± 0.41</td>
<td>1.75 ± 0.38</td>
<td>1.68 ± 0.41</td>
</tr>
<tr>
<td>Peak GF/Body mass (kg/kg)</td>
<td>1.19 ± 0.58</td>
<td>1.26 ± 0.67*</td>
<td>1.36 ± 0.89</td>
<td>1.41 ± 0.88*</td>
</tr>
</tbody>
</table>

Means ± SD (n = 15) are shown. * Significant difference (P<0.05) between values with and without vocalization. ** Significant difference (P<0.05) between changes with vocalization at voluntary speed and maximum speed. GF3A: Triaxial composite of ground reaction force.

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Locomotor movement with vocalization at voluntary speed was significantly higher than that at maximum speed (Table 2).

3.2. Joint angle velocity

In standing-up movement at voluntary speed, the peak joint velocity of hip extension, knee extension, hip flexion, and trunk flexion tilt were significantly higher with than without vocalization (175.4 ± 33.1 vs. 138.9 ± 28.9 degree/s, 153.6 ± 32.5 vs. 129.0 ± 32.2 degree/s, 58.7 ± 10.3 vs. 49.1 ± 8.0 degree/s, 74.2 ± 12.7 vs. 64.1 ± 9.7 degree/s, respectively). There were no significant differences between joint velocities in standing-up movement at maximum speed with and without vocalization. The changes in peak joint velocity of hip extension and knee extension with vocalization were significantly greater at voluntary speed than at maximum speed (Table 2).

3.3. Peak joint flexion angle

There were no significant differences in the peak angle of hip flexion and trunk flexion tilt associated with standing-up movement at voluntary and maximum speed with and without vocalization (Table 2). The maximum knee flexion angle was not evaluated, because it was observed at the start standing position in almost all subjects.

3.4. Peak joint moment

The values of peak hip joint extension moment divided by body weight during standing-up movement at both voluntary and maximum speed were significantly higher with than without vocalization (1.99 ± 0.41 vs. 1.85 ± 0.43 Nm/kg, 2.47 ± 0.64 vs. 2.24 ± 0.52 Nm/kg at voluntary and maximum speed, respectively). There were no significant differences in the values of peak knee joint extension moment during standing-up movement with and without vocalization. There were no significant differences between the changes with vocalization of the peak hip joint extension moment divided by body weight at voluntary speed and at maximum speed (Table 2).

3.5. Ground reaction force

The peak triaxial composite of ground reaction force divided by body weight during standing-up movement was significantly higher with than without vocalization at both voluntary and at maximum speeds (1.26 ± 0.69 vs. 1.19 ± 0.58, 1.41 ± 0.88 vs. 1.36 ± 0.89 at peak and mean, respectively). There were no significant differences between the
3.6. Muscle electrical activity

There were no significant differences between VL and BF mean AV EMG with and without vocalization in standing-up movement at both voluntary and maximum speed. The peak ARV EMG in BF was significantly higher in standing-up movement at both voluntary and maximum speed with than without vocalization (1.23 ± 0.30 vs. 1.0, 1.64 ± 0.74 vs. 1.49 ± 0.65, at voluntary and maximum speed, respectively). There were no significant differences in VL between standing-up movement with and without vocalization. There were no significant differences between the changes with vocalization of the peak ARV EMG in BF at voluntary speed and at maximum speed (Fig. 1B).

3.7. Timing of vocalization

The peak vocalization waveform appearance time from that of peak ground reaction force was approximately 0 s. The mean value in voluntary standing-up movement was −0.12 ± 0.14 s, and that in maximum speed standing-up movement was −0.09 ± 0.12 s. These negative values indicated that the
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peak vocalization waveform appeared before the peak ground force. Almost all subjects vocalized around or immediately before the peak level of the ground reaction force (Fig. 2).

4. Discussion

The results of the present study indicated that energetic vocalization alters standing-up movement in healthy elderly people. Vocalization during stan-
ding-up movement increased muscle force exertion. The peak ground reaction force with vocalization was significantly higher than that without vocalization at both voluntary and maximum standing speeds (Table 2), in agreement with the results reported previously (Murakawa and Tokoro, 2007). These changes are considered to be aftereffects of an increase in central nerve cell excitability, leading to an increase in the number of recruited motor units (Yabe et al., 1998).

Increases in muscle force exertion associated with vocalization occurred specifically in hip joint extension, with significantly higher peak hip extension moment and EMG in peak ARV of BF with vocalization compared to those without vocalization at both voluntary and maximum standing speeds (Table 2, Fig. 1). BF is associated with hip extension movement. On the other hand, there were no significant differences in the peak knee extension moment and EMG in peak ARV of VL between with and without vocalization at both voluntary and maximum standing speed. VL is associated with knee extension movement. Hip extension has a large countermovement range of motion in standing-up movement from a sitting position in a chair, whereas knee extension has almost no countermovement range of motion in this task (Kralj et al., 1990). Maximum knee flexion angle in standing-up movement was observed at the start sitting position in all subjects in this study.

In addition to the enhancement of force exertion, vocalization during standing-up movement also altered the kinematic pattern. With regard to the standing kinematics of the countermovement, there were no significant changes in the hip joint flexion range of motion and the trunk flexion tilt range of motion, although they tended to be higher with than without vocalization at both voluntary ($P=0.09$ and 0.12 at hip flexion and trunk flexion tilt, respectively) and maximum standing speeds ($P=0.10$ and 0.08 at hip flexion and trunk flexion tilt, respectively) (Table 2). The hip joint flexion angle velocity and the trunk flexion tilt angle velocity were significantly higher with than without vocalization during standing at voluntary speed, and were almost the same with and without vocalization during standing at maximum speed (Table 2). Vocalization during standing-up movement at voluntary speed tended to slightly increase the countermovement range of motion and significantly increased the countermovement velocity. Vocalization at maximum speed tended to slightly increase the countermovement range of motion, while the countermovement velocity remained approximately the same.

The intensity of countermovement is a key factor in efficient SSC movement (Moran and Wallace, 2007). The SSC uses the elastic properties of tendon structures and other elements to enhance power generation (Cavagna, 1977). Vocalization during standing-up movement may improve kinematic patterns through beneficial use of SSC by increasing the countermovement range of motion and motion velocity at voluntary speed and the countermovement range of motion at maximum speed.

The timing of vocalization was around or immediately before the peak ground reaction force and occurred after countermovement (Fig. 2). Vocalization during standing-up movement would affect the countermovement before the moment of vocalization. It was reported previously that an intensive countermovement enhances the return action force (Moran and Wallace, 2007). The increase in ground reaction force may be induced not only by enhancement of nerve excitability for force generation, but by countermovement inducing efficient use of the SSC.

On muscle EMG, no significant differences were observed in VL mean AV or peak ARV during standing-up movement with and without vocalization at voluntary and maximum speed (Fig. 1). VL is associated with knee extension movement, which had little countermovement when standing-up. In BF, EMG increased in peak ARV and no change was observed in mean AV with vocalization. As noted above, BF is associated with hip extension, which shows countermovement when standing-up from a seated position. Thus, vocalization during standing-up movement resulted in an instantaneous BF EMG pattern. In sports movements, such as a smash stroke in badminton (Sakurai and Ohtsuki, 2000) or in road bike cycling (Chapman et al., 2007), the muscle EMG pattern in well-trained skilled participants is more instantaneous than that in unskilled subjects. These reports suggested that changes in muscle activity pattern instantaneously following vocalization may have a favorable effect on standing-up movement.

The main limitation of this study was psychological bias. Subjects were instructed to stand-up spontaneously as they would under normal conditions to
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exclude psychological bias as much as possible. However, complete exclusion of this bias remains a challenge for future studies.

The peak and mean standing velocity at voluntary speed increased significantly with vocalization due to the kinematic and kinetic changes associated with vocalization outlined above. However, there were no significant changes at maximum speed, but the peak and mean standing values tended to increase with vocalization ($P=0.10$ and 0.14, respectively) (Table 2).

In conclusion, energetic vocalization was suggested to improve standing-up movement in elderly people. This effect may be due to enhancement of force exertion as an aftereffect of an increase in central nerve cell excitability and effective use of kinematic pattern changes.

5. Compliance with ethical standards

Conflict of interest: All of the authors declare that they have no conflicts of interest regarding this paper.

Ethical approval: This project was performed with the approval of the University Ethics Committee (approval number H27-1-003).

Informed consent: All participants gave written informed consent prior to commencement of the study.

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