Change of Physiological Cost due to Differences in Arm Position When Standing Up

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Abstract. In the present study we examined the effect on physiological cost of different arm positions when standing up using physiological measurements. Ten healthy young women were used as subjects. They stood up at their own speed from a sitting position on a seat of 40 cm and 20 cm height. Their actions were captured on video and from stills we measured the knee angles at which they found it easiest to stand up. With reference to these measurements, we then set the knee angles at 95° and 125°, respectively, and compared standing up with the arms extended forward in a horizontal position with standing up with the arms held downwards at the sides of the body in a vertical position. Each subject was required to stand at a prescribed frequency while we measured Oxygen Uptake (VO₂), Heart Rate (HR) and Ratings of Perceived Exertion (RPE). The results were, that compared with the vertical position, a reduction of the trunk flexion angle was observed when standing with the arms in the horizontal position. Also, in the case of standing from the seat of 40 cm height alone, VO₂ showed a significantly high value with the arms in the horizontal position, but no significant differences were noticed in HR or RPE. Furthermore, when standing from the seat of 20 cm height, no significant difference was seen between the two arm positions in any of the measured values. From these results we conclude that the movement of standing up with the arms held in the horizontal position does not necessarily have the effect of reducing the physiological cost.

Key words: standing up, arm position, physiological cost

(This article was submitted Sep. 21, 1997, and was accepted Nov. 20, 1997)

INTRODUCTION

Standing from a seated position is one of the most fundamental activities of daily living and many kinematic and kinetic studies have been performed in connection with the stand-up. Cases where the stand-up motion is difficult for hemiplegic patients resulting from cerebrovascular accidents are often encouraged to stand up while raising the arms forward1). The reason for this is, because it is thought that by this stance, trunk mass is transferred forward of the knee joint when standing up, relatively reducing the weight on the point of movement2). In addition, there are also reports that compared to the case in which the arms are held in the normal vertical position, standing up with this limb position increases the peak value of the hip joint extension moment3). These reports have shown that standing up in this stance is dynamically advantageous, but with regard to whether it can achieve a reduction in the physiological cost when standing up is not clear. The objective of the present study was to evaluate quantitatively, using physiological indices, the effects on physiological cost of different positions of the arms when standing up.
METHODS

Subjects
The subjects were ten healthy women (average age 20, height 158.9 ± 2.0 cm, weight 52.2 ± 4.6 kg). None of the subjects had regular exercise habits, or orthopedic problems. The objectives of the experiment were explained to the subjects and their informed consent was obtained.

Procedure
Experiment 1: Determination of the Knee Joint Angle When Standing Up
The chair used in this experiment was one with a seat, the height of which could be linearly adjusted electrically. The height of the seat was set at 40 cm, corresponding roughly to the height of an ordinary seat, and at half of that height 20 cm. The conditions for the arm positions were as follows:
1) Standing with both arms held vertically at the side of the body (downward position) (Fig. 1).
2) Standing with both hands clasped together and the arms raised forwards with a shoulder joint angle of 90° (forward position) (Fig. 2).
When standing up the gap between each subject’s feet was adjusted to the width of their shoulders, and when both arms were held vertically at the side of the body the placing of hands on the knees or seat was forbidden. In addition, for experiment 1, when returning from the standing position to the sitting position, subjects were requested to take the seated position as close as possible to that prescribed with the spine touching the back of the chair, and this was verified each time by contact of the sacrum. Markers were attached to the acromion, hip joint, knee joint and each of the foot joints in the left sagittal plane of the subjects, and standing up from the two heights of the seat took place with the legs positioned by each subject for ease of standing. These actions were filmed by a video camera set 3 m to the left of the subjects. Then, the trunk flexion angle (the angle made by the lines joining the acromion to the hip joint and the hip joint to the knee joint) and the knee flexion angle (the angle made by the lines joining the hip joint to the knee joint and the knee joint to the ankle joint) were determined on a TV screen by measurement on the recorded images of the angles formed by the lines joining the markers.

Experiment 2: Evaluation of the Physiological Cost When Standing Up
From the results of Experiment 1, the knee joint angle at the time of standing was set as follows:
- 40 cm seat height: 95°
- 20 cm seat height: 125°
Each subject performed stand-ups with these two knee joint angles using the two arm positions of Experiment 1. The other conditions when standing were the same as in Experiment 1.
The frequency of the standing motion was prescribed as 15 times per minute: i.e., one cycle of...
motion, (stand up in 2 sec, sit down in 2 sec), was synchronized to the tone of an electric metronome and completed in the space of four seconds. The speed of each two second motion was at the discretion of the individual. The exercise time was 3 minutes for each of the experimental conditions.

The measured parameters used in the evaluation of the physiological cost were Oxygen Uptake (\( \dot{V}O_2 \)), Heart Rate (HR), and Ratings of Perceived Exertion (RPE). Measurement of \( \dot{V}O_2 \) was made by the ‘Breath by Breath’ method using an gas analyzer (Oxycon BETA, Mijnhardt, Netherlands). The HR was recorded via three chest electrodes (CM5) and displayed on an Electrocardiogram monitor (CardioCare-Uni ECU-10, Fukuda, Japan), which was interfaced to the Oxycon system. The RPE was recorded for each subject from the second minute of exercise.

For both of the two seat heights, \( \dot{V}O_2 \) and HR were recorded from sitting at rest, 5 minutes before the start of the exercise until its completion, and their values for the second minute of exercise were used in evaluating physiological cost; RPE was also recorded for each subject for the second minute of exercise.

Each experiment took place in an air conditioned room, which had an average temperature of 21.2°C (19–22°C) and an average atmospheric pressure of 763.6KP (759–766KP) during the experiments.

Statistical analysis was performed to examine the difference between groups, using the Paired t test for \( \dot{V}O_2 \) and HR, and the Mann-Whitney U test for RPE.

**RESULTS**

Experiment 1: Table 1 shows the measured values of the trunk and knee joint flexion angles. A tendency for the trunk angle to decrease was seen through observation for arms in the horizontal position, rather than in the vertical position, in both the 20 cm and 40 cm seat heights. However, a statistically significant difference was not found between the measured values of the trunk flexion angle for the two arm positions in the case of the 40 cm seat height. In the case of the 20 cm seat height alone, it showed a significantly low value for the arms in the horizontal position (t=2.88, p<0.05). No significant differences were found for the knee joint flexion angle due to the different arm positions for either of the two seat heights.

Experiment 2: The values of each of the measurements made for the physiological cost are shown in Table 2. The value of \( \dot{V}O_2 \) showed a significantly high value (t=2.45, p<0.05) for the arms in the horizontal position only in the case of the seat of 40 cm height. No significant differences due to the different arm positions were found for values of HR and RPE for either the 20 cm or 40 cm seat height.

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<thead>
<tr>
<th>Table 1. Flexion angles (in degrees) in trunk and knee joint during sit-to-stand movement</th>
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<tr>
<td>40 cm</td>
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<tr>
<td>downward</td>
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<td>Trunk</td>
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<td>Knee</td>
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*; p<0.05

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<th>Table 2. Oxygen uptake, heart rate, and ratings of perceived exertion in different arm positions</th>
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<td>40 cm</td>
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<tr>
<td>downward</td>
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<tr>
<td>( \dot{V}O_2 ) (ml/kg/min)</td>
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<tr>
<td>HR (beats/min)</td>
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<td>RPE</td>
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RPE; Median (Range). *; p<0.05
DISCUSSION

The results of this experiment note a tendency for the trunk flexion angle to decrease when standing up with a posture in which the arms are held forward horizontally. On account of this, it is to be expected that the physiological cost will decline for the arms in the horizontal position, as a result of reduced muscle activities for trunk flexion. However, the physiological cost, if anything, showed a tendency to increase with the arms in the horizontal position. Namely, in the case of the 40 cm seat height, the VO$_2$ showed a significantly high value for standing up with the arms maintained in the horizontal position, while significant differences due to the different arm positions were not observed in any of the values of VO$_2$, HR and RPE for the 20 cm seat height. With regard to this, we presume that the value of VO$_2$ becomes greater in the case of the high seat position (40 cm), because although the muscle activities for moving the trunk forwards decreased, it was supplemented by additional muscle activities to maintain the arms in the horizontal position. Moreover, when standing up from the lower seat (20 cm), we presume that generally the muscle activities of the lower limbs in moving the head and trunk upwards is relatively large in comparison with that for maintaining the upper limbs in either the horizontal or vertical position.

From the movement of the trunk, the standing up motion can be mainly divided into a flexion phase and an extension phase. That is, first the head and trunk bend forward together (flexion phase), then, after the posterior has left the seat, head and trunk extension takes place (extension phase). During this action, the activity of the knee and hip joint extensor muscles account for the greater part of the total work. Pai et al.$^5,6$ have shown that the trunk is a major contributor to horizontal linear momentum of the center of body mass, with the thigh segment being the major contributor to vertical momentum. Kralj et al.$^7$ conjecture that in the flexion phase of standing, the movement of bending the body forward stores momentum in the trunk and this is used to accelerate the upward movement. If this theory is accepted, then in circumstances where the trunk flexion angle is small, as in the case of the arms in the horizontal position, as mentioned above, there is an need for energy for the upward movement which is made good mainly by the muscles of lower limbs. According to Wretenberg$^8$, work during standing is done mainly by the extensor muscles of the knee and hip joints exerting eccentric and concentric contractions. Therefore, energy expenditure will increase as a result of the augmented activity of these muscles. The posture in which the arms are held horizontally forward when standing up is executed with the intention of facilitating movement through the smooth transference of the center of gravity. From the results of this study, we conclude that this posture reduces the angle which the trunk makes in bending forward when standing up, but does not necessarily have the effect of reducing the physiological cost.

REFERENCES