EFFECT OF THE TRUNK INCLINATION ON MECHANICAL ENERGY CHANGE DURING GAIT IN ELDERLY ADULTS

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The purpose of this study was to investigate effects of the trunk forward lean during gait in elderly people on effectiveness use of mechanical energy (EI). The participants were five healthy elderly and ten healthy young people. The participants walked with the trunk leaning forward at their preferred speed. The gait motion was captured with a VICON system and the ground reaction forces during stance phase were collected with two Kistler force platforms. The EI of the elderly subjects was significantly smaller than the young subjects. The results indicated that the elderly subjects did greater mechanical work by the leg joints to walk at a same speed as young subjects. The lower EI was related to a remarkable increase in the negative work at the ankle joints.

KEY WORDS: Effectiveness, Energetics, Positive work, Negative work.

INTRODUCTION: Yoshimura et al. (2009) reported that the prevalence of lumbar spondylosis in the Japanese over 40 years old was 80.6% for men and 64.4% for women. Saha, Gard, and Fatone (2008) analyzed effect of the trunk inclination during gait and found that the trunk forward lean flexed the support limb larger to keep a body balance. Kinetic study by Letunuer, Gillet, Sadegghi, Allard, and Barbier (2009) revealed that the hip extension torque increased during stance phase of walking with a trunk leaning forward and the hip flexion torque at the push-off increased in walking with a trunk leaning backward. Sakuma and Ae (2012) investigated the effect of trunk inclination on effectiveness index of mechanical energy utilization (EI), i.e. a ratio of the mechanical work done by the leg joint torques to the horizontal kinetic energy during walking, and found that EI was lower in the walking with the trunk leaning backward than the trunk leaning forward. Although these investigations indicated that the change in the trunk lean had some effects on energetics of the lower limb muscles in young people, there is little information on effects of the trunk inclination during gait in elderly people. The purpose of this study was to investigate effects of the trunk forward lean during gait in elderly people on effectiveness of mechanical energy utilization, comparing with young people.

METHODS: The participants were five healthy elderly (1 male and 4 females; age, 70.0±3.5; height, 1.64±0.05 m; weight, 61.1±8.7 kg) and ten healthy young people (10 males; age, 25.0±4.9; height, 1.74±0.04 m; weight, 68.0±4.9 kg). This study was approved by the Ethics Committee of Faculty of Health and Sport Science, University of Tsukuba and all participants signed on the written informed consent sheets. Participants walked with the trunk leaning forward at their preferred speed. In elderly subjects, the trunk inclination was fixed by a hard lumbar brace. The young subjects inclined the trunk 10°forward from the vertical line. The gait motion was captured with a VICON system (Vicon Motion System Co, Sampling rate 250Hz) and the ground reaction forces during stance phase were collected with two force platforms (Kistlar Co, Sampling rate 1000Hz). A model was 15-segment link model, both hands, forearms, upper arms, feet, shanks, thighs, head, and upper and lower torso. The coordinate data during one walking cycle were smoothed by a Butterworth digital filter with a cutoff frequency ranging from 5 to 12 Hz.
Effectiveness index of mechanical utilization (EI, Ae & Fujii, 1996) was calculated by equations (1) to (3).

$$E_{k,H} = \frac{1}{2} m V_H^2 \quad (1)$$
$$W_H = \sum |\Delta E_{k,H}| \quad (2)$$
$$\mathrm{EI} = \frac{W_H}{W_J} \quad (3)$$

where m is a body mass, V_H is the horizontal velocity of the center of mass (COM), $E_{k,H}$ is the horizontal kinetic energy of the body, W_H is the work for the horizontal COM movement during one walking cycle, W_J is the total absolute work done by the torques at both hip, knee, and ankle joints during one walking cycle. Statistical analysis between the elderly and young subjects was evaluated using the Mann-Whitney test, based on the average of five trials for each subject. The significant level was set at 5%.

RESULTS: The forward lean angle of the trunk for the elderly participants was significantly greater than that of the young participants (elderly, 12±2°; young, 7±3°). Table 1 shows basic descriptors of walking for the elderly and young groups. Walking speed, step length, cadence and braking distance for the young subjects were significantly greater than the elderly subjects. Figure 1 shows the EI of the elderly and young groups. The EI of the young subjects was significantly greater than that of the elderly subjects. Figure 2 shows percent mechanical work of the individual lower limb joints to the total work done for the elderly and young groups. The positive work at the hips and the negative work at the ankles in the elderly subjects were significantly greater than the young subjects. The positive work at the ankles and the negative work at the knees in the elderly subjects were significantly smaller than the young subjects.

Table 1
Basic descriptors of walking

	Walking speed [m/s]	Step length [m/height]	Cadence [steps/min]	Braking distance [m/height]
Elderly	1.12±0.08	0.40±0.02	104±6	0.14±0.01
Young	1.52±0.14	0.46±0.02	116±5	0.16±0.02
Difference * p<0.05	*	*	*	*

The values are Mean±SD

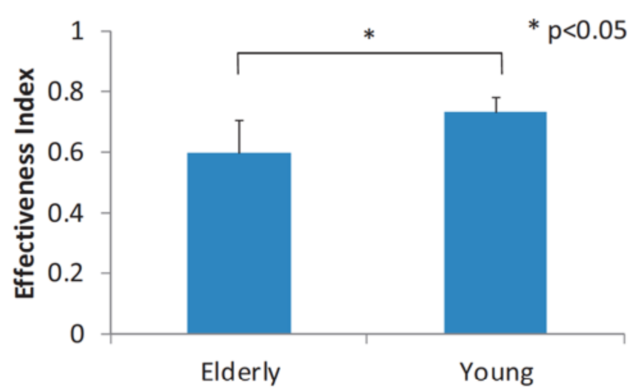
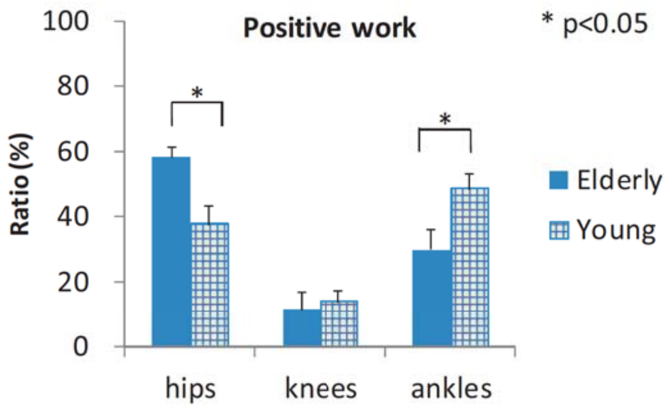


Figure 1: Effectiveness index of mechanical energy utilization.



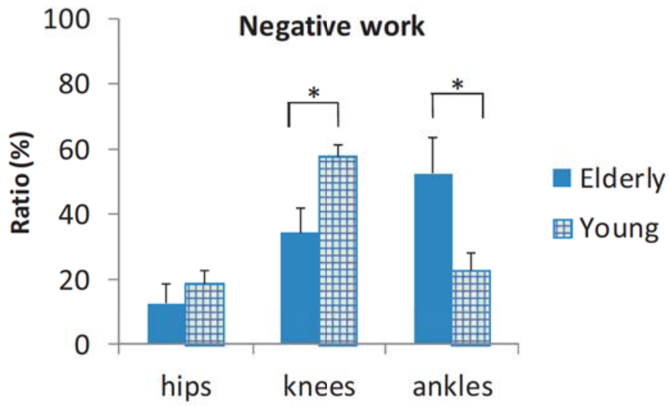


Figure 2: Percent mechanical work in the individual lower limb joints to the total work done.

DISCUSSION: The lower EI of the elderly participants indicated that the elderly subjects did greater mechanical work by the lower limb joints to walk at a same speed as the young subjects. The negative work at the ankles for the elderly subjects was greater than that of the young subjects. In normal walking, the ankle plantar flexors and the hip flexors eccentrically contract to decelerate forward lean of the shank and the thigh during the mid-stance phase, and these muscles concentrically contract to propel the body during final-stance phase（Eng & Winter, 1995）. The increase in the negative work of the ankle joint reduced the EI. The another interpretation could be that the elderly subjects might reduce the forward acceleration to control the body for safety reason because the trunk forward lean caused shorter braking distance at the heel contact (Sakuma & Ae, 2012). The positive work was greater at the hips and smaller at the ankles for elderly subjects. During the early stance phase, the large hip extension torque would have controlled the trunk position and prevented from the collapse of the support limbs（Eng & Winter, 1995）. Therefore, the greater positive work at the hip would help to maintain trunk posture and compensate the reduced positive work at the ankle.

CONCLUSION: The EI of the elderly subjects was significantly lower than that of the young subjects. The positive work at the hips and the negative work at the ankles were greater in elderly subjects than the young participants. The greater negative work at the ankles resulted in smaller EI for the elderly participants. The positive work at the hips would increase to control trunk posture and compensate the reduced positive work at the ankles for the elderly subjects. These results implied that the elderly with the trunk leaning forward due to spinal deformities would need some exercises to maintain the hip extensor muscles for their quality of life.

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