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A comparison of the movement characteristics between the kneeling gait and the normal gait in healthy adults

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ABSTRACT

Background: Trainings of the kneeling position, such as standing exercise on the knees and kneeling gait, have been anecdotally used in physical therapy to improve postural control of patients with various pathological conditions. However, clinical evidence is lacking and the movement characteristics of these kneeling trainings have not been well explored. The purpose of this study is to clarify the movement characteristics of the kneeling gait compared with the normal gait.
Methods: Twenty healthy volunteers (10 men and 10 women) aged 22–34 years were recruited. Participants were required to perform the kneeling gait and the normal gait at a self-selected comfortable speed on the treadmill. Surface electromyograms (EMG) and center of mass (COM) displacements were measured during each task.
Results: The EMGs of the gait-related proximal muscles during the kneeling gait were greater than during the normal gait, even at a comfortable speed. The COM displacement to the lateral direction was longer during the kneeling gait than it was during the normal gait. Furthermore, mechanical energy efficiency during the kneeling gait was less than that during the normal gait.
Conclusion: The results suggest that the kneeling gait is an effective exercise to strengthen the gait-related proximal muscles. The increased muscle activities during the kneeling gait were probably due to the compensatory movements of the trunk and the pelvis.

1. Introduction

Training on the knees, such as standing on the bilateral knees, standing in the half kneeling position, stepping from the kneeling position (transition from the kneeling position to the half kneeling position) and kneeling gait, has been anecdotally used in physical therapy. Several textbooks [1–3] introduce these trainings as one type of the interventions for restoration of the functional mobility. In these textbooks, the kneeling task is listed as an intervention using developmental sequence postures [1], as an activity to prepare for locomotion [2] and as one of the adjunct treatments for transitional patterns [3]. Two selective postural strategies are known for standing balance in normal adult: an ankle strategy (shifts the body's center of gravity mainly by the ankle joints movements) and a hip strategy (repositions the center of gravity by the hip joints movements.) [4,5]. In kneeling position, however, one cannot use the ankle strategy and has to rely on the hip control to maintain upright posture. In other words, the kneeling postures force one to use the trunk/hip control. This explains the clinical relevance of the kneeling trainings for enhancing trunk control and strengthening the hip stabilizers [1–3].

Despite the fact that kneeling training is frequently used and is supported, there is no clinical evidence that supports the effectiveness of these training. From these backgrounds, we recently investigated the immediate effects of the kneeling training on postural control in stroke patients [6] (article in Japanese) who often have to rely predominantly on hip strategy for controlling upright posture due to useless ankle function with distal weakness [7]. We prescribed 5–10 min kneeling exercises (upright kneeling, stepping exercise in half kneeling and kneeling gait) to fifteen chronic stroke patients and observed the immediate

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effects on postural control. The results showed that capability of moving the center of pressure (COP) to the lateral direction was significantly increased after the intervention.

Likewise, there are little reports about the movement analyses of the kneeling tasks. Gallagher reported the comparison of trunk muscle activities between normal standing and the kneeling position during trunk extension exertions in healthy subjects using surface electromyograms (EMG) [8]. The result showed that despite equivalent trunk muscle activity, reduced extensor capability exists in the kneeling posture compared to normal standing. Mezzarane and Kohn analyzed the COP in the sagittal plane during standing on knees and during standing on feet [9]. With the model simulation, they found that the differences of COP profile observed between two conditions in the experiment were resulted from neural processes as well as the biomechanical factors.

As stated above, clinical evidences as well as basic analyses of the kneeling exercises are very limited and have to be explored. In this study, we focused on the characteristics of the "kneeling gait" and investigated the differences in the muscle activities of the gait-related proximal muscles, center of mass (COM) displacements and mechanical energy recovery between the kneeling gait and the normal gait in healthy subjects.

2. Methods

2.1. Subjects

Twenty healthy volunteers (10 men and 10 women), aged 22–34 years (mean 24.0, standard deviation [SD] 4.9), were recruited. None of the participants had any neuromuscular problem as determined by a non-structured interview. The study conformed to the Declaration of Helsinki, and informed consent was obtained from all participants according to the procedures of the Ethics Committee of the Tokyo Bay Rehabilitation Hospital.

2.2. Tasks

Two locomotion tasks on the treadmill were employed: (1) the normal gait at a self-selected comfortable speed and (2) the kneeling gait at a self-selected comfortable speed (gait on knees, Fig. 1). The participants were randomly divided into two groups. Half of the participants were allocated to the normal gait first and the other half did the kneeling gait first. Before each task, a sufficient warm-up period was given to determine a comfortable speed for each subject. All subjects wore knee pads to reduce external knee forces during the kneeling gait.

2.3. Measurements

The gait cycles were determined using the pressure sensors (FSR402, Interlink Electronics Inc, Camarillo, CA) at the sampling rate of 100 Hz. The sensors were attached to the right heel and the right forefoot for the normal gait and to the right tibial tuberosity for the kneeling gait. Stance phase was defined from the heel strike to the toe off for the normal gait and from the knee on to the knee off for the kneeling gait.

Surface EMG on the right side of the erector spinae, the rectus abdominis, the gluteus maximus, the gluteus medius, the rectus femoris and the semitendinosus were recorded at 1000 Hz by the EMG system (Delsys, Boston, MA) (Fig. 1). Electrodes were placed in accordance with the method described in Perotto (2005) [10]. For the erector spinae, the sensor was placed at three-fingers' width laterally to the spinous process 2nd lumbar vertebra. For the rectus abdominis, the sensor was placed at two-fingers' width laterally on the abdominal midline at supraumbilical portion. For the gluteus maximus, the sensor was placed at the midway between the greater trochanter and the sacrum. For the gluteus medius, the sensor was placed at one inch distal to the midpoint of the iliac crest. For the rectus femoris, the sensor was placed on the anterior aspect of the thigh, midway between the superior border of the patella and the anterior superior iliac spine. For the semitendinosus, the sensor was placed midway on a line between the medial epicondyle of the femur and the ischial tuberosity.

The COM displacement was evaluated using an optical marker at the spinous process of the third lumbar vertebra [11,12]. Motion of an optical marker was recorded at 100 Hz with the motion capture system (NDI Optotrak, Waterloo, Ontario, Canada) (Fig. 1).

All measurements were started at 15 s after beginning each task and taken for 1 min.

2.4. Data analysis

The basic gait parameters for speed [m/min], step length [m], cadence [steps/min], stance time and swing time [s] were

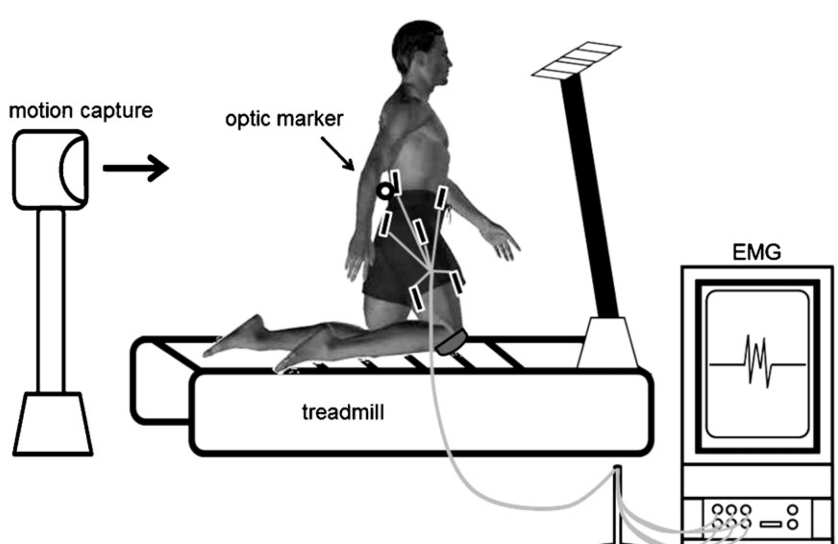

Fig. 1. Subject on the treadmill during the kneeling gait. Muscle activity was detected by a surface electromyogram (EMG) connected to an acquisition system. An optical measurement system was used to measure the center of mass (COM) displacement during the task.