

Kinetic Analysis of Stumbling Gait in Laboratory Condition

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Key words : Stumbling Gait, VICON, Electro Myograph

Falling accidents and fractures caused by various incidents are the third leading cause of becoming bedridden, with the highest percentage being 12 in Japan. However, only a few studies are available with analysis of cases and the mechanism of falls. This paper intends to analyze the stumbling gait among the various factors leading to falls.

Methods:

Procedure: Seven healthy males participated in this study. Their average age, height and weight with standard deviation was 27 years \pm 9.4 years, 176 cms \pm 8.5 cms and 70.5 kgs \pm 14.3 kgs, respectively. Prior to this experiment, the purpose, procedure and risk were explained in detail and informed written consent was obtained from each participant.

All subjects attended a familiarization session prior to the experiment. The subjects walked on an even floor with leg cuff belts on the distal part of both their legs and the line attached to their cuffs were pulled by an experimenter to induce a stumbling gait. The subjects were not informed which of their legs would be pulled back (Fig. 1). The displacement of comfortable gait by a stumbling gait thus induced was compared using the stance of the walking cycle.

Equipment and operation: VICON system of 100Hz was used for three dimensional analysis of the movement of body parts. The system consists of 9 infrared cameras and 6 floor pressure meters and 15 marker points. The position markers were

placed at the bilateral acromion, tip of elbow, styloid process of radius, a line one third of the distance from the bottom of the anterior superior iliac of the spine and greater trochanter, lateral epicondyle of femur, lateral malleolus, head of 5th metatarsal and the right side posterior superior iliac of the spine (Fig. 1).

Disposable bipolar electrodes were placed on the skin over each muscle, using adhesive gel. The centers of electrodes were placed along the midline of muscle in a parallel direction to the muscle fibers but away from the center of muscle belly.

Surface EMG signals from muscles were recorded while the subject was in the standing phase of walking cycle with the disposable electrodes attached on the right side of biceps femoris, *rectus femoris*, lateral gastrocnemius and anterior tibial muscle (Fig. 2). The EMG sampling frequency was 1000 Hz and expressed by RFEMG (rectified filtered electromyography) which smoothes muscle potential values. This conversion from 1000Hz to 100Hz was required to be acceptable to VICON system. RFEMG using low cut filtration at 10Hz and high cut filtration at 500Hz was recorded on a personal computer. The data of RFEMG was taken as an average at maximum isometric contraction within one second. Each muscle was measured for the average of maximum isometric contraction of RFEMG and this value was considered to be 100% for normalization. The data of joint-moments recorded while the subject was in

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walking at stance phase of walking cycle were calculated with DIFF software for computers, and the maximum values from this data of percent RFEMG were presented.

Treatment of data: The parameter used was the distance from the center of pressure (COP) of the opposing side of pulled leg to the center of gravity (COG) treated by DIFF. Percent of RFEMG of non stumbling gait side was used for Muscle Myograph and Wilcoxon's signed rank sum test was applied.

Results:

A typical example of the relation between COG and COP and a minimum distance from COP to COG is shown in Fig. 3 and Fig.4, respectively. In comparison of displacement in comfortable and stumble gait, the distance decreased with a stumbling gait, with maximum joint-moment shown in Fig.5. The maximum of knee joint-moment of flexion increased with comfortable gait compared with stumbling gait. Fig. 6 shows the data from %RFEMG of several muscles. There tends to be an increase of %RFEMG of right *rectus femoris* muscle in the stumbling gait in stance phase of the walking cycle.

Discussion:

The value of COP minus COG is significantly smaller with a stumbling gait in stance phase (Fig.4). Fig.3 represents a typical example obtained from one of the subjects. The minimal distance shows the pushing force of COG forward by COP. The maximum shows the pulling force of COG backward. It is conceivable that COP comes into play as a control of COG by pushing forward. 106 points on the horizontal axis in Fig.3 are the minimal distance of stumbling gait. As the distance between COP and COG increases, the power of COP pushing COG forward also increases. At the final point where the subject becomes incapable of maintaining his COG to lower to the base of support, he will fall forward.

The maximum of joint-moment is shown in Fig.5. The maximum of knee joint-moment of flexion increased at comfortable gait compared to the stumbling gait. When the distance between COP and COG is minimal, the difference between the axis of knee joint and the line between COP and COG increases and thus, the bending moment of knee joint also increases. From Fig.6 showing %RFEMG of an individual muscle, one can see the tendency of %RFEMG of right *rectus femoris* muscle at a stumbling gait in stance phase. Fig. 7 represents %RFEMG from one person and the time scales of left and right figures are synchronized. The right one shows a three dimensional figure from analytical equipment and the left shows the %RFEMG in the same period. The maximum of %RFEMG of right *rectus femoris* muscle superimposes with toe off of right leg in stance phase but does not match well with maximum distance from COP to COG. We have considered that right *rectus femoris* muscle works by lifting the thigh with flexor muscle of a hip joint.

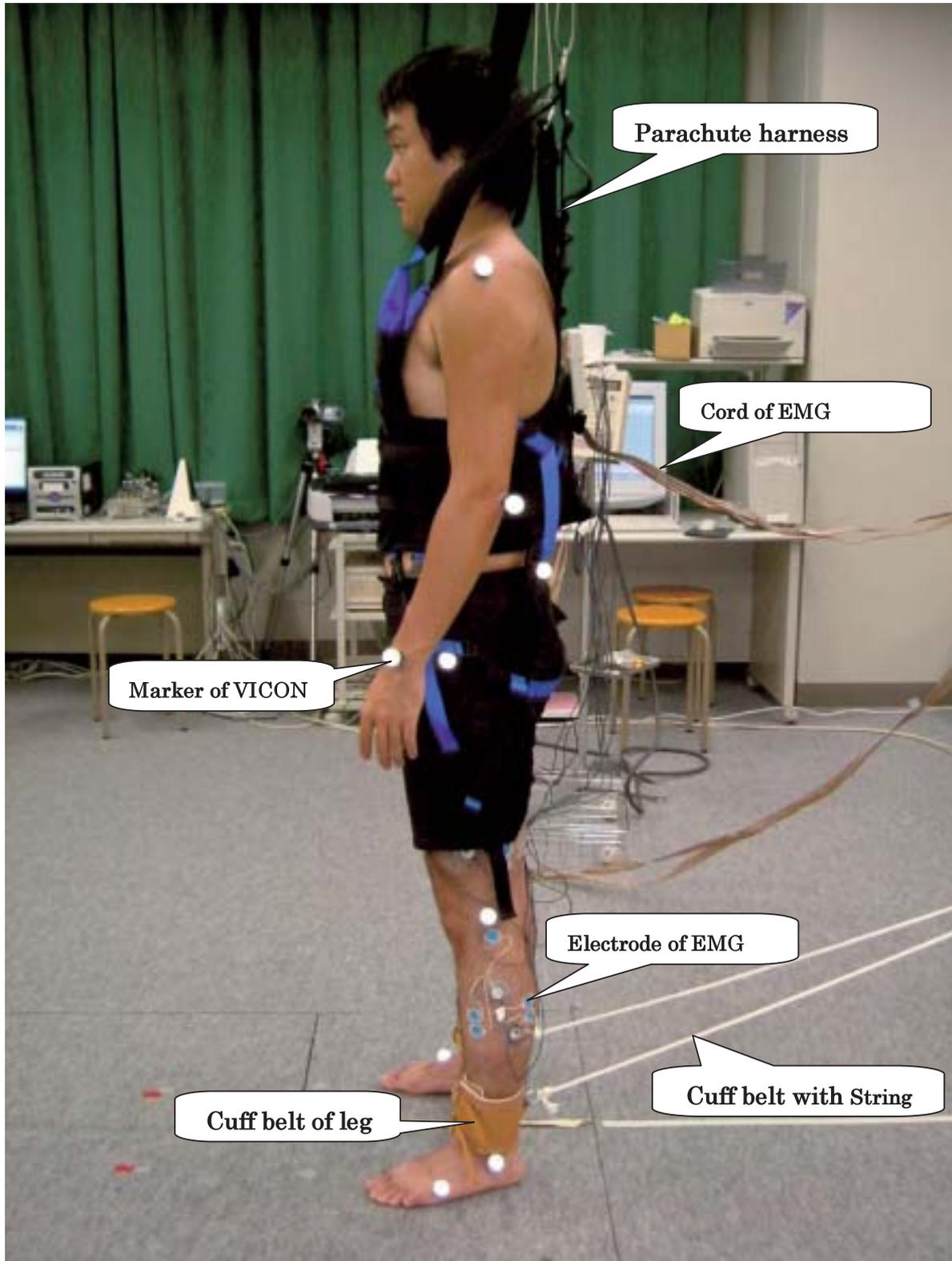


Fig.1. Position of adhesive Electrodes of EMG and Markers of VICON system

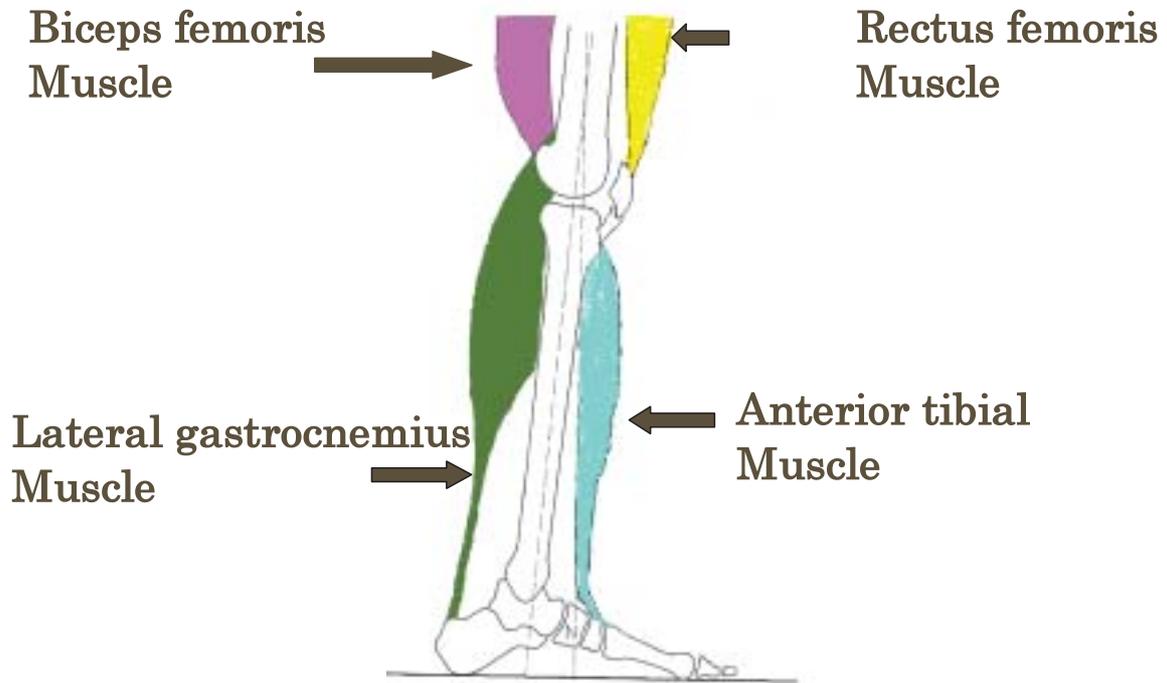


Fig.2. Lower limb muscles measured during gait

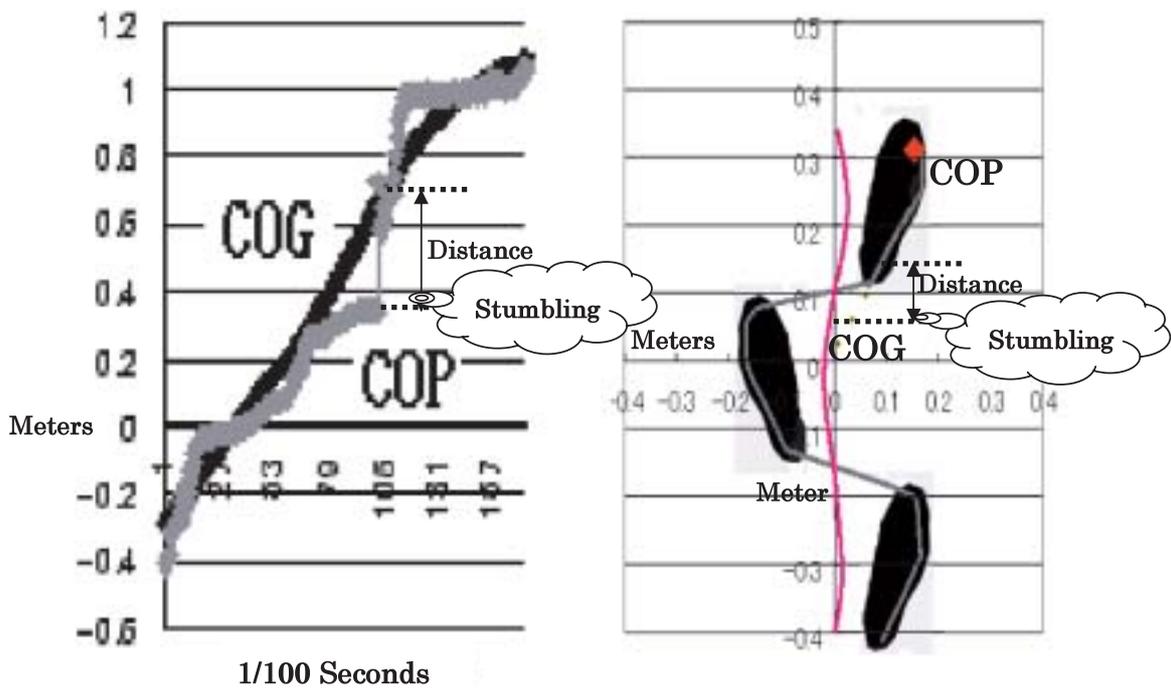


Fig.3. Relation between COP and COG of one subject
(Distance = point of COG-point of COP)

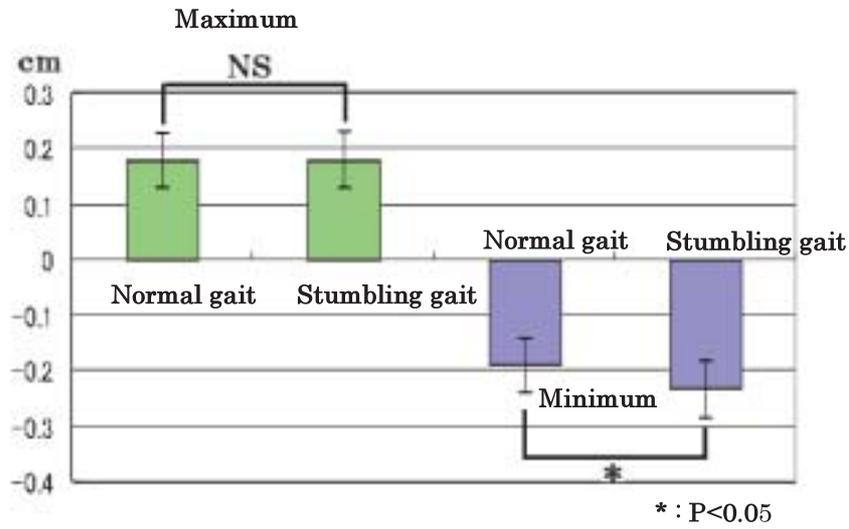


Fig.4. Comparison of the maximum and the minimum distance value of stumbling gait and normal gait in walking cycle

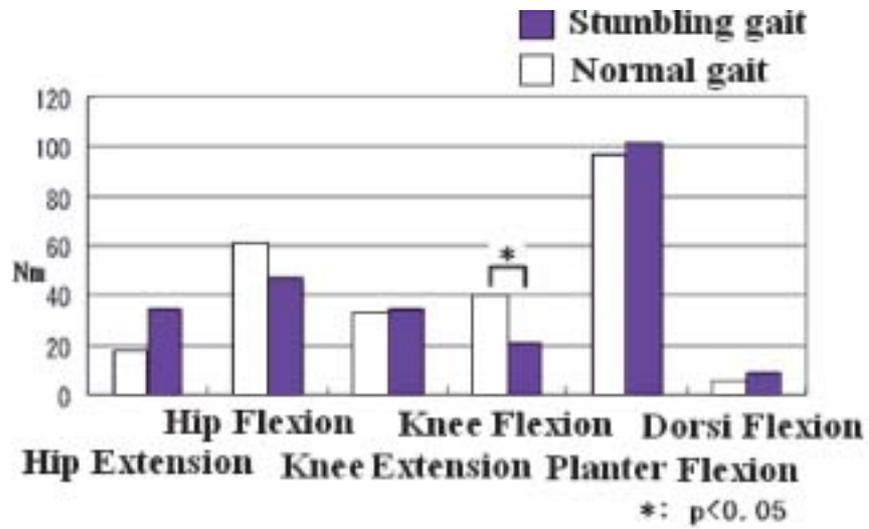


Fig.5. The maximum joint-moment of lower limb during stance phase

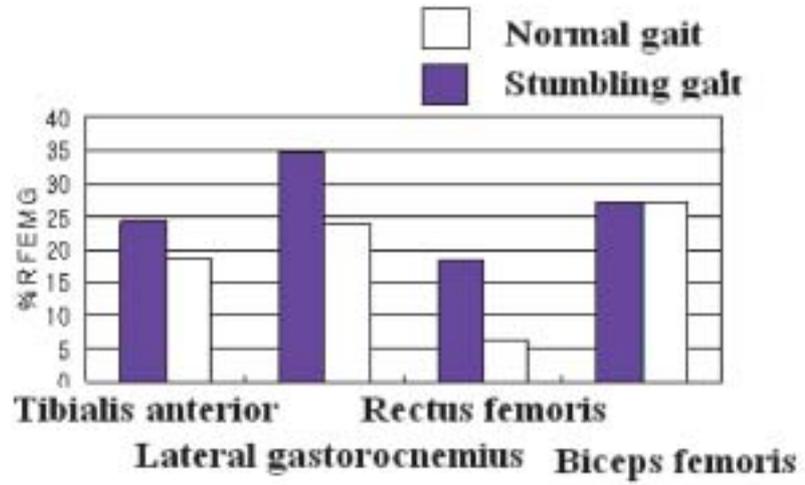


Fig.6. The maximum %RFEMG of lower limb muscles during stance phase

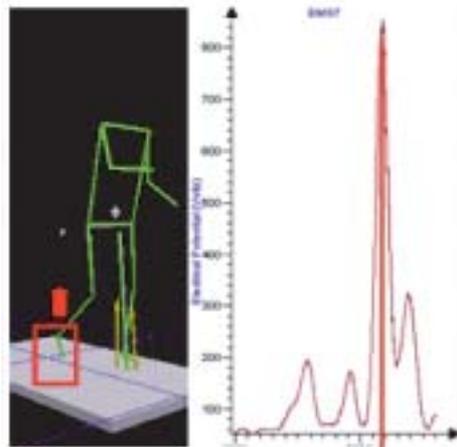


Fig.7. The maximum %RFEMG of Rectus femoris muscle and stick picture at the same time

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