INTRODUCTION
Carpal tunnel syndrome is one of the most popular diseases among workers with repetitive hand motions including computer workers, and its risk factor includes the flexion and extension motion of the wrist joint. In this study, we tried to combine the three dimensional hand motion analysis using VICON and the force plate, which we developed for measuring the finger tip force vector just as the foot force plate in the gait analysis. And using this newly developed system, we measured not only the flexion angles of the fingers and the wrist, but the moment of these joints and compared among some different hand positions, high and low position, and close and distant between the hand and computer keyboard.

METHOD
1. Marker sets for the VICON system
For measurement by the VICON of three dimensional motion analysis system, eleven micro reflective markers of 3 millimeters in diameter were placed on the dorsal surface of the index finger, dorsal hand, and dorsal side of the forearm, with spacing 4-10 mm apart (Fig. 1). The flexion angle of the distal interphalangeal (DIP) joint of the index finger was calculated as the angle between the vector M4M5 and the plane defined by markers M6, M7, and M8. The flexion angle of the 2nd proximal interphalangeal (PIP) joint was calculated as the angle between the vector joining markers M1, M2 and the vector joining markers M2, M3, using VICON Body Builder Ver. 3.55. Similarly, the flexion angle of the 2nd metacarpophalangeal (MCP) joint was calculated as the angle between the vector M4M5 and the plane defined by markers M6, M7, and M8. The flexion angle of the wrist joint was calculated with the plane M6M7M8 and the plane M9M10M11.

2. Finger force plate
The finger force plate composed of force sensor of the FES system (Nitta Co., Japan), computer key, and the pressure sensor sheet (Glove Scan, Nitta Co., Japan). The FES system is the six-axial force transducer measuring the compressive and tensile force in x, y, z-direction (Fx, Fy, Fz), and the moment around x, y, z-axis (Mx, My, Mz), and the error of measurement of the force and the moment was within ±0.1 N or ±0.1 mN. The computer key was a key of the initialized “stop” of the keyboard of the personal computer PC-98 (NEC, Co.), which was fit on the sensor platform (Fig. 2).

3. Capture the typing motion data
The typing motion with the index finger was recorded by six infrared video cameras for 15 seconds each. During the motion, the index finger was positioned parallel to the y-axis of the force plate (Fig. 2). (1) changing distance between the hand and the keyboard: 20 mm close and 20 mm distant from the basic position, under the 0 mm height on the desk.
(2) changing height of the wrist on the table: 0 and 20 mm height on the desk, under the basic hand position.

The movement of each marker was tracked in three dimensions using the VICON 612 system (Oxford Metrics Co. Ltd., UK). At the same time, the fingertip force vector at striking key was measured with force Fx, Fy, and Fz; moment Mx, My, and Mz, and a distance between the center of force plate and the fingertip striking point was measured by the pressure sensor sheet.

RESULT
1. Effect of change in the distance between the keyboard and the hand
The maximum flexion angle of the DIP joint at the close position was 24.9±8.0 degrees, which was significantly (p=0.015) larger than 15.4±7.7 degrees at the distant position, while the minimum flexion angle had no difference (Fig. 3-A). The maximum flexion angle of the PIP joint at the close position was 50.8±20.0 degrees, which was significantly (p=0.029) larger than 31.8±15.5 degrees at the distant position. Similarly, the minimum flexion angle of the PIP joint was 43.4±17.5 degrees at close position, which was significantly (p=0.036) larger than 25.7±17.7 degrees at the distant position, while the range of motion showed no differences (Fig. 3-B). The minimum flexion angle of the MP joint was 30.9±26.9 degrees at the close position, which was significantly (p=0.039) larger than 9.7±10.5 degrees at the distant position. Similarly, the range of motion of the MP joint was 4.9±1.7 degrees at close position, which was significantly (p=0.025) smaller than 7.6±10.6 degrees at the distant position, while the maximum flexion angle had no difference (Fig. 3-C).

There were no differences in the maximum and minimum flexion angle and the range of motion of the wrist joint (Fig. 3-D). The moment of the DIP, PIP, and MP joint showed no significant differences between the close and the distant position.

2. Effect of change in the height of wrist position
No significant differences in the maximum, minimum flexion angle, and the range of motion of the DIP, PIP, MP, and the wrist joint between 0 and 20 mm height of the wrist position. Similarly, there were no differences in the moment of the DIP, PIP, and MP joint.

DISCUSSION & CONCLUSION
The result of this study showed that not only wrist joint, but both the DIP and MP joint decreased flexion angle when the hand position was more distant from the computer keyboard than the neutral position. It suggested that the distance could be regulated by changing flexion angle of these joints, and that the increased and decreased distance would cause more extension and more flexion of the wrist respectively. This fact would be concerned to the factor of overuse problem among typists, including the carpal tunnel syndrome.