EFFECT OF MARKER SETS ON BETWEEN-DAY REPRODUCIBILITY OF KNEE KINEMATICS AND KINETICS IN STAIR CLIMBING AND LEVEL WALKING

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INTRODUCTION

External markers are commonly used in in-vivo human movement analysis. The Helen-Hays marker set is a commonly used external marker set for kinematic and kinetic analyses of the lower extremities. Reduced lower extremity kinematics and kinetics in level walking and stair climbing using the Helen-Hays marker set has satisfactory within-day reproducibility (Kadaba et al, 1991, Yu et al., 1997), but a low between-day reproducibility (Kadaba et al., 1991). The low between-day reproducibility is a major concern in clinical applications of motion analysis. The purpose of this study is to evaluate the between-day reproducibility of knee kinematics and kinetics in level walking and stair climbing reduced from (1) the Helen-Hay’s marker set, (2) a modified Helen-Hays marker set, and (3) a UNC-CH marker set.

METHODS

Three male and three female volunteers without any known lower extremity disorders were recruited as subjects for this study. A Peak Performance real-time videographic data acquisition system (Peak Performance Inc., Englewood, CO) with six infrared video cameras, was used to collect the three-dimensional (3-D) coordinates of external markers at a sampling rate of 120 frames/sec. Two Bectec Type 4060A force plates (Bectec Cop. Worthington, OH) were used to collect ground reaction force data at a sampling rate of 1000 Hz. A staircase of four steps, with the lowest two steps attached to the force plates, was used for the stair climbing trials, (Yu et al., 1996).

Eleven reflective markers were placed at the joint space between the 4th and 5th lumbar vertebrae (L4-L5), and bilaterally on the anterior superior iliac spine (ASIS), thighs, knees, shanks, and ankles for the Helen-Hays marker set (Kadaba et al., 1990). Four additional reflective markers were placed bilaterally at the greater trochanter (GT) and below the tibial tuberosity for the UNC-CH marker sets. All of the markers listed above remained on the subject’s body during testing. The modified Helen-Hays marker set and the UNC-CH marker set were created by adding a static calibration which consisted of four reflective markers placed bilaterally on the medial knee joint line and on the medial malleoli. The standing calibration was recorded following both the stair climbing and level walking trials.

Data were collected for three trials for each of ascending, descending, and level walking conditions on three different days. The 3-D coordinate data were filtered through a fourth-order low-pass digital filter at an estimated optimum cutoff frequency of 10 Hz (Yu and Andrews, 1998). The 3-D knee joint angles were calculated as Euler angles. The knee joint resultants were estimated using an inverse dynamic procedure and were transferred to the tibia segment reference frame. The within-day and
between-day coefficients of multiple correlation (CMC) (Kadaba et al., 1991) were calculated for the kinematics and kinetics of the right knee joint during the stance phase of both stair climbing and level walking for each subject. Analyses of variance with repeated measures were conducted to compare the between-day CMC values of knee kinematics and kinetics among the three marker sets with an alpha level of 0.05 to indicate statistical significance.

**RESULTS AND DISCUSSION**

The UNC-CH marker set consisted of a standing calibration and the marker located at L4-L5, the bilateral GT, knee, tibial tuberosity, and ankles. The modified Helen-Hays and the UNC-CH marker sets had greater between-day CMC values for the knee valgus-varus angle than did the Helen-Hays marker set (p < 0.01 and p < 0.01). The UNC-CH marker set had a greater between-day CMC value for the knee valgus-varus angle than did the modified Helen-Hay’s marker set (p < 0.01). The UNC-CH marker set had a greater between-day CMC value for the knee flexion-extension angle than did the Helen-Hays marker set and the modified Helen-Hays marker set (p = 0.01 and p = 0.01). The modified Helen-Hays marker set and the UNC-CH marker set had greater between-day CMC values for the knee internal-external rotation angle when compared to the Helen-Hays marker set (p = 0.01 and p < 0.01). These results suggest that the standing calibration improved the between-day reproducibility of knee kinematics, and that placing markers on well defined bony landmarks further improved the reproducibility of knee kinematics.

The UNC-CH marker set had a greater between-day CMC value for the knee anterior-posterior shear force than did either the Helen-Hays marker set (p = 0.01) or the modified Helen-Hays marker set (p = 0.02). The modified Helen-Hays marker set and the UNC-CH marker set had greater between-day CMC values for the knee medial-lateral shear force than did the Helen-Hays marker set (p = 0.01 and p = 0.01). The modified Helen-Hays marker set and the UNC-CH marker set had greater between-day CMC values for all three components of the knee resultant moment vector on the tibia than did the Helen-Hays marker set (p = 0.01). The UNC-CH marker set had greater between-day CMC values for all three components of the knee resultant moment vector for the tibia than did the modified Helen-Hays marker set (p = 0.02). These results suggest that standing calibration and placing markers on well defined bony landmarks also improved the between-day reproducibility of measured knee kinetics.

**SUMMARY**

The addition of a static standing calibration is recommended for improving the between-day reproducibility of lower extremity kinematics and kinetics in level walking and stair climbing. New marker sets where all the markers are placed on well-defined bony landmarks may need to be considered for further improvement of the between-day reproducibility.

**REFERENCES**