Analysis of body motions based on optical markers

Accuracy, error analysis and clinical applications

Akademisk avhandling

som för avläggande av medicine doktorsexamen vid Sahlgrenska akademin vid Göteborgs universitet kommer att offentligen försvaras i Mölndalsaulan, Sahlgrenska universitetssjukhuset, Mölndal fredagen den 19 november 2010, kl 09.00

av

Roy Tranberg
Leg. Ortopedingenjör

Fakultetsopponent
Universitetslektor Nerrolyn Ramstrand
Avdelningen för rehabilitering,
Hälsohögskolan, Jönköping

Avhandlingen baseras på följande delarbeten:

I. **The relative skin movement of the foot: a 2-D roentgen photogrammetry study.**
Tranberg R, Karlsson D.
Clinical Biomechanics, 1998, 13, 1998, 71-76

II. **On skin movement artefact-resonant frequencies of skin markers attached to the leg.**
Karlsson D, Tranberg R.
Human Movement Science, 1999, 18, 627-635

III. **Simultaneous measurements of knee motion using optical tracking system and Roentgen stereo photogrammetric analysis (RSA).**
Tranberg R, Saari T, Zügner R, Kärrholm. J
Conditionally accepted

IV. **Muscle strength and kinetic gait pattern in children with bilateral spastic CP.**
Nyström Eek M, Tranberg R, Beckung E.
Conditionally accepted

V. **Improvements in Hip- and Pelvic motion for patients with Osseo-Integrated trans-femoral prostheses.**
Tranberg R, Zügner R, Kärrholm J.
Conditionally accepted

Göteborg 2010

UNIVERSITY OF GOTHENBURG

Analysis of body motions based on optical markers

Accuracy, error analysis and clinical applications

Roy Tranberg

Department of Orthopaedics, Institute of Clinical Sciences
Sahlgrenska Academy at University of Gothenburg, Göteborg, Sweden 2010

This thesis aims to evaluate the influence of soft-tissue artefacts on analyses of body motions based on optical markers. A second aim is to apply instrumented gait analysis in clinical situations.

Introduction: Instrumented gait analysis has been used since 1960 as a clinical evaluation/investigative tool at orthopaedic clinics. The technique is based on a number of reflective spherical markers attached to the skin. The position of the skin markers is recorded as the subject walks through the measurement volume. Recorded data form the basis when monitoring movements of body segments. The crucial and still not completely explored issue is to what extent these systems are able to reproduce the movement of the body segment that is being studied.
Material and methods: In *Study I*, the skin movement at the foot was studied using skin markers and radiographs. The subjects stood on one foot in three positions, 20° dorsal flexion, a neutral position and 30° plantar flexion, while radiographs were exposed. In *Study II*, the aim was to study problems with soft-tissue movement along the lower extremity. Skin and underlying structures were provoked partly by anterior-posterior and longitudinal strain and partly by being put into vibration to investigate their stiffness and damping characteristics. The aim of *Study III* was to examine the accuracy of the optical tracking system used throughout *Studies IV-V* by simultaneous recording using skeletal markers and radiostereometry (RSA). Nine patients with a total knee arthroplasty (2 males/7 females, median age: 63.1 years; range 59-72) were included in *Study III*. In *Study IV*, 20 patients with bilateral spastic cerebral palsy (15 males/5 females median age: 12.9 years, range 9.4-15.3) and 20 controls (13 males/7 females, median age: 13.0 years; range 10.2-15.7) were included. For *Study V*, nineteen unilateral transfemoral amputee patients (9 males/10 females, median age: 46.5 years; range 19.9-62.3) and fifty-seven matched controls were included.
Results: Studies of soft tissue motions on the foot revealed marker movement in relation to the bone up to 4.3 mm at the ankle, which decreased gradually to 1.8 mm at the first inter-phalangeal joint. Soft-tissue movements mainly occurred in the anterior-posterior direction of the leg and pronounced self-oscillations were recorded when markers were placed on wands. The results from comparisons between RSA and OTS showed good agreement regarding extension/flexion motions. For abduction/adduction and in-/external rotation, significant differences between the two systems were observed. The group with cerebral palsy was weaker in all muscle groups in the lower limbs and they walked at a slower speed. A significant relationship between plantar flexing torque and the strength of six of the eight investigated muscle groups could be detected in patients with cerebral palsy. An even stronger relationship (rho=0.58-0.76) was found between generating power and muscle strength in all eight muscle groups. Two years after conversion from a conventional to bony anchored leg prosthesis, femoral amputees improved their hip extension and reduced their anterior pelvic tilt.
Conclusion: Instrumented gait analysis is a non-invasive and valuable tool to study body motions. Knee motions in the sagittal plane (flexion/extension) are close to data obtained from RSA based on skeletal markers, whereas the resolution of rotations in the two other planes is poorer, probably due to soft tissue motions and geometrical reasons. Further comparative studies with simultaneous use of skeletal and superficial skin markers are needed to explore this issue further; not least concerning the hip and ankle joint.
Keywords: Instrumented gait analysis, Motion analysis, Skin markers, Optical tracking system

ISBN: 978-91-628-8047-7
Correspondence to: roy.tranberg@gu.se