GAIT AND POSTURE ANALYSIS AT REHABILITATION CLINIC

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Abstract: The possibilities of human motion analysis utilisation in rehabilitation processes are described in this paper. Motion analysis is used as a routine part of patient's mobility evaluation in many medical and therapeutic centres by now. It seems to be the best tool of a special investigation as it allows performing of detailed and objective assessment of patients with different types of mobility disorders. There are several motion examination methodologies supported by the human motion analysis described in this paper. The optical motion capture system SMART, from Italian company e-Motion, was used in this project. All the analysed subjects were selected patients of the Rehabilitation clinic in Kosice – Šaca, and studies included here were performed with cooperation of rehabilitation surgeon specialists. The paper asserts that scientific video-analysis of human motion patterns can help in better understanding of different mobility disorders background by clinicians and therapists, and so consequently affects quality of patients' treatment and applied rehabilitation processes.

Introduction

Many different diseases of human motion system are being increased in the last time. These diseases with their severity, therapeutic problems and relatively frequent disablement of affected persons represent very significant medical, social and economical problem as well. On the other hand, achieved advances in orthopaedics, especially in the field of reconstructive operations, and in the field of rehabilitation, have enabled partial or complete recurrence of affected persons into the normal life.

From our point of view, it is important to evaluate the individual medical processes and classify them as accurately as possible with respect to the easy to use and especially non-expensive methods. The reason is that it should help to compare different methods used in patient's treatment and rehabilitation, and consequently to choose the most effective of them.

Human motion analysis based on optical systems is relatively a new method in the Eastern Europe countries. Department of Instrumental and Biomedical Engineering has got the 6 cameras video motion capture system SMART, from Italian company e-Motion in 2002 as a result of the international competition in human motion analysis research. Since that, there were realised three different clinical studies. Three groups of different patients were monitored and evaluated by the system SMART.

The first clinical study was dealing with patients with total hip endoprosthesis. The goal of this study was to evaluate the efficiency of pre-surgical rehabilitation process of selected patients. The quality of gait was analysed in these patients.

The second study was dealing with patients after lumbar vertebrae operation. The study was oriented on the analysis of functional blocks and hypermobility between vertebras of lumbar vertebrae during trunk bending forward.

The third study was performed to analyse human posture stability on third group of patients. Analysed patients were captured during different tests, with emphasis to catch the balance as well as possible. All the studies were performed with cooperation of rehabilitation surgeon specialists.

Materials and Methods

Optical motion capture system SMART was used to record patients' motion during individual tests. The system records motion of small „passive markers" attached to the patient's body according to the particular marker set. The markers sets vary from one study to another, and are created according to the required criteria given by the clinicians. The individual records were analysed in SMART Viewer, and in Matlab workspace.

Study of patients with spondylolisthesis.

The spondylolisthesis represents serious medical problem, in which one of the vertebras is slipped forward. Asymptomatic spondylolisthesis occurs with a small slipping. The higher slipping is followed by pain and neurological symptoms, and surgery is very often needed. There are six types of spondylolisthesis. They are as follows: dysplastic, isthmic, degenerative, traumatic, pathologic and post-surgical. The most frequent localisations of spondylolisthesis are two distal segments of vertebral column. The normal spinal unit represents stable structure, which is proved by the vertebral column ability to resist both the big acute and repetitive load. This stability is supplied by the spinal stability system, made of active and passive musculoskeletal subsystem, and CNS worked in

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interaction. The aim of surgical treatment is to stabilize, normalize and eliminate instable biomechanically unfavourable disease of individual spinal segments. The compression and/or eventually another nerve structure disability are also eliminated. Figure 1. shows two X-Rays of spondylolisthesis.

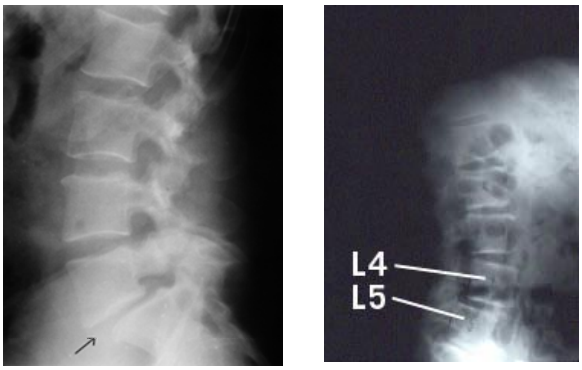

Figure 1: X-rays of spondylolisthesis.

There were included five patients after operation of degenerative spondylolisthesis, hospitalised at the Rehabilitation clinic in Kosice-Saca, in this study. Four of them were the patients with spondylolisthesis of L5 and one with listhesis of L4. All the patients underwent ambulance rehabilitation in the following years with average 3,5 times per year, because of chronic intermittent course of troubles, especially pain emphasizing at lumbar vertebrae with irradiation into the lower limb, paresis and the weakness of lower limb and the pain at the other parts of the vertebral column. The small passive markers were placed on the anatomically important points on patients' bodies. In this case, the markers were attached on both right and left shoulder, cervical spine C7, lumbar spine L1, L2, L3, L4, L5, right and left PSIS, right and left ASIS, right and left greater trochanter, and right and left femur epicondyle. Patients were captured during walking forward and backward, and during trunk bending forward. Trunk bending forward requires making the biggest motion in vertebra column and therefore it was the most important examination.

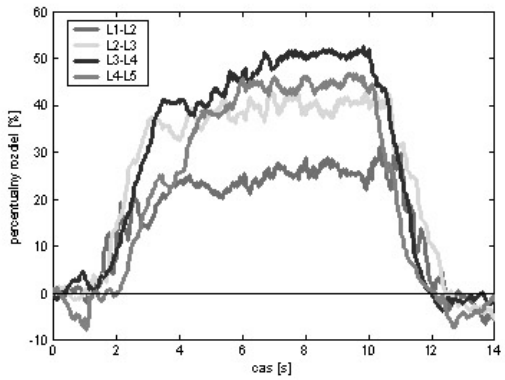

Figure 2: Distance between vertebras of lumbar column expressed in percentage.

The graph no the figure 2 documents the hypermobility in the segment L4-L5 during trunk bending forward by the 46 years old patient. The fusion was made in segment L5-S1. Even bigger hypermobility is in L3-L4, changed by the hypomobility in the higher segments. Similar results were obtained in other subjects of the group.

Study in the rehabilitation of total hip endoprostheses patients.

Hip problems can affect anyone at any stage of life. A baby may be born with the thighbone (femur) sitting loosely in the hip socket or completely outside of it. A growing child may develop a disease in the upper thighbone, or suffer slippage in the joint. An adult may be troubled by damaging arthritis in the hip, or develop osteoporosis that weakens the bones and leaves the hip vulnerable to a fracture from a fall. The main reason for surgical operation is coxarthrosis as a kind of osteoarthritis. It is chronicle multifactorial disease of hip joints with degenerative changes in the joint, connected with many other physical disorders. The treatment for that multifactorial disease is usually based on the complex plan, which includes proper diet and movement activity, physical therapy, physical exercise programme, rehabilitation aids and prosthetics tools and medical treatment. Figure 3 shows x-ray of affected hip joint and x-ray of total hip endoprosthesis.

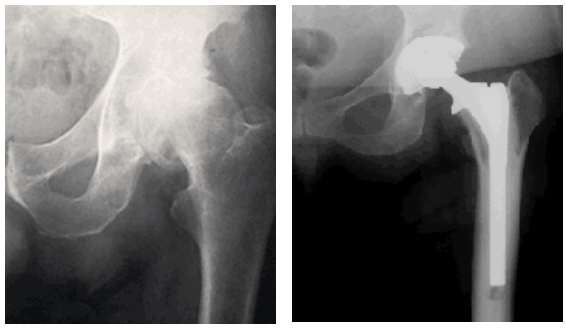

Figure 3: X-rays of affected hip joint and its replacement.

It is not common method to prepare patients by pre-surgical rehabilitation before implementation of total hip endoprothesis. TEP is indicated only in some cases without dedicated clinical parameters and there are only a few sources that concentrate on importance of this rehabilitation or about influence on post surgical results. There were two groups of patients with indication of total hip replacement in this study. It was patients with intensive pre-surgical rehabilitation and patients without this rehabilitation. In the first group of patients the gait analysis was made before pre-surgical rehabilitation, after pre-surgical rehabilitation and after operation. The patients of the second group were analysed before operation and after operation. To increase the objectivity of the study the gait analysis is also made in the same time period after operation. The 17-marker set was designed for gait analysis in this study. The markers ware placed at the S2, ASIS, greater trochanters, lateral

ISSN: 1727-1983

and medial epicondyles, tibial tuberositas, lateral malleolus, heels and fifth heads of metatharsals. The additional markers were placed on the crutches if the patients use them.

The walking velocity, speed, stride length, stride time, strides per minute, step length, step time and cadence, all for right and left leg, and stance and swing phase were calculated and compared for all the subjects. All these parameters are compared and saved for further analysis. Individual joint angles versus gait cycle percentage were plotted and analysed as well. The figure 4 shows these angles in the same patient before operation. The biggest deviations from normal gait data were detected in the sagittal plane.

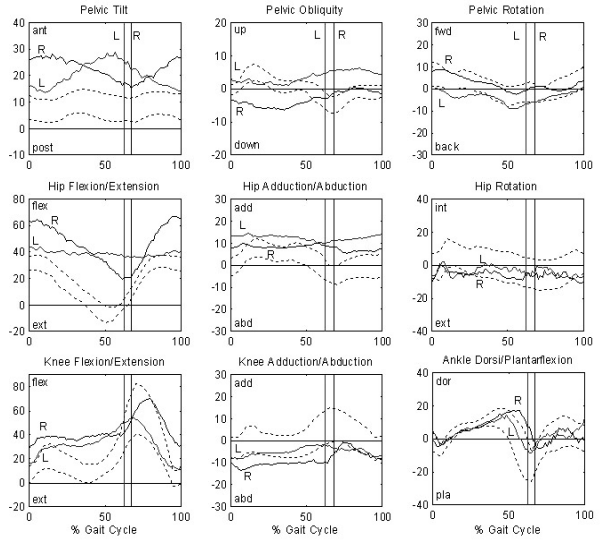

Figure 4: Anatomical joint angles of the patient before TEP.

We compared parameters collected from patients with intensive pre-surgical redresion rehabilitation technique with data obtained from patients without this pre-surgical rehabilitation. Although, the walking velocity wasn't changed too much, the symmetry of gait was gradually achieved. The highest differences were observed in hip flexion/extension angles and pelvic position.

Study of the patients with posture disorders.

This study is oriented on problems of human posture stability, which can be affected by many factors. One could deal with diagnostics process in the fields of ORL, orthopaedics, rehabilitation, neurology and so on. Posture stability is a complex process, incorporated the coordinated activity of many sensory systems, motor and biomechanical components. To maintain the stability of human body in vertical position over the surface of contact the body with the ground it is necessary to control the centre of mass (COM) and to retain it in the stability area. The stability boundary is a plane defined by the angle of maximal allowed COM deviation from the central position. For the study of the maintenance of erecting posture is very important to consider the visual, proprioception and vestibular system. The majority of the clinical workplace uses the stabilometrical methods with the investigation of the body centre stability for the evaluation of the posture stability. Stabilometrical diagnostics evaluates the posture as a complex without distinction of body segments on the maintenance of the erecting posture.

In contrary of these studies we tried to use the video-analysis and adopt the currently used methods to the easiest and faster method. The really important was to follow the trajectories of individual body parts and especially the point of centre of mass. As we know that this is placed in the middle of body, we derived it from S2 and ASIS points. The first task was to design the appropriate model of markers placement. With cooperation with clinicians we settle the 17-marker set. Markers were placed at the forehead, C7, shoulders, wrists, ASIS, S2, lateral epicondyles, lateral maleollus, heels and the fifths metatarsal heads. Using this model we prepare four types of tests at all. The posture analysis was our first study. Each subject was recorded during 20s standing on the same place with opened and 20s with closed eyes. Through the marker placed on S2 we have observed the oscillations of centre of mass trajectory and its length during the experiment.

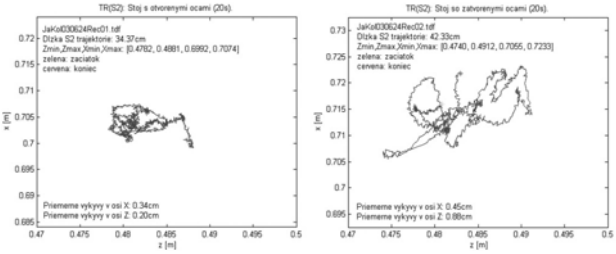

Figure 5: COM trajectory in standing during 20s tests with opened and closed eyes.

Figure 5 shows the difference between the two tests in standing. As it can be seen from the left picture, the patient was quite stable in standing with opened eyes. On the other hand the right picture shows the biggest oscillations especially in the medial-lateral direction. The patients with closed eyes declined to the left side and slightly forward. Naturally, also the length of trajectory is longer. While in opened eyes it was 34.37cm, during the standing with closed eyes it was 42.39cm. Also other parameters were compared and analysed.

The second test in this study was oriented on COM trajectory analysis during stepping. Investigated parameters were the length passed no intentionally, oscillations of the subject centre of gravity and the rotation angle while the subject was stepping with the opened eyed and consequently with closed eyes. The aim of the third test was to analyse the posture stability in standing on an unstable platform. The subject was placed first on Anterior/Posterior platform during 20s and then on medial/lateral platform during the 20s, both with opened and closed eyes. Different positions were analysed in situations when the patient was disposed forth, back and left side, right side, when he was in the balance. The last test was concentrated on gait analysis

ISSN: 1727-1983

with orientation on stability during turning round several times. This test was made with opened and closed eyes as well. Each subject of the group (patient) undergoes each examination.

Results

In the study of spondylplisthesis, we have analysed the lumbar vertebrae dynamics, flexion and lateral flexion by the SMART system, in an effort to make the hyper-mobility in the segments above the fusion objective. The following functional disorders were recognized: recidivous dysfunctions in the key points of the vertebra column, segmental dynamics disorder of lumbar vertebrae, middle thoracic vertebrae and ribs, absence of pelvic rotary synkinesis, as well as irritable symptoms L4, L5 and S1. The permanent muscular dysbalance was recognized in the pelvic, neck and shoulder. Achieved results have documented hypermobility of the L4-5 of the patients, who have instrumental fusion L5-S1. Even bigger hyper-mobility was detected in the segment L3-L4. This hyper-mobility was changed by the hypo-mobility in upper segment of lumbar vertebrae. The smallest mobility was detected just above the segment with the biggest hyper-mobility that is in segment L2-L3.

We supposed that intensive pre-surgical rehabilitation could influence significantly recovery of patients after the surgery in positive way and the first results of the study indicated the positive effect of pre-surgical rehabilitation. As for the changes in insurance legislation there was no consensus between the insurance companies and Rehabilitation clinics, and no insurance company was disposed to cover the pre-surgical rehabilitation process. Therefore we have a small group of patients, and we have to change our study a bit. In general, the patients with intensive pre-surgical rehabilitation were able to stand up and walk earlier and more independently as the patients without pre-surgical rehabilitation.

The maintaining of the erecting posture is the complex process which makes use the central processing of the proprioception visual and vestibular system. This methodology allows evaluation of various strategies for the maintaining of the balance and the differentiation between the motion in the ankle, the hip joint and the motion in the segments. The clinicians are able to choose the optimal methodology of the vestibular training for the patients with the disorders of the balance through the evaluation of this methodology.

Discussion

The presented methods represent one of the possibilities how to diagnose and analyse the segmental mobility of the vertebral column, different rehabilitation process of patients with total hip endoprostheses, and how to evaluate the patient's posture stability. Of course, these are only a part of wide range of areas, where the motion analysis can be utilised. We have been motivated by this method for its further usage of patient's evaluation with different diseases of motion system, as there do not exist many objectives diagnostic methods in our field of the study.

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