**PhD course in Health & Technologies**
**Yearly PhD student report – 2018/2019**
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# Sagittal Stability: Movement Analysis before and Patient Motion after Spinal Treatments

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*Year 1 – Motion analysis of patients before and after surgery and of healthy participants*


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## Introduction:

Spinal fusion surgeries are medical procedures used to stop the movement of painful vertebrae or correct deformations at the level of the spine. The surgery entails the fusion of two or more vertebrae of the spine that they become one solid bone in order to alleviate pain or restore the stability to the spine. The vertebrae are held together by transpedicular screws and rods [1] (Fig. 1).

*Figure 1 Spinal fusion surgery showing the rods and screws fixation*

Spinal fusions are defined by the number of spinal disc levels fused. A short spinal fusion surgery corresponds to the fusion of one to a maximum of two spinal discs. While a long spinal fusion corresponds to a multilevel fusion of the spine and involves more than three spinal discs [1]. Following long spinal fusion surgeries, pathological problems have been seen to occur in the spinal segment adjacent to the instrumented vertebrae [2].

One abnormal deformity that occurs in 20 to up to 40% of cases is the proximal junctional kyphosis (PJK). PJK is a slow developing symptom showing an abnormal kyphotic or forward bending deformity occurring at the uppermost instrumented vertebrae. It could go on to be asymptomatic or develop a proximal junctional failure associated with pain, walking disturbances and a need for reoperation (Fig 2). The reasons behind developing PJK after surgery are still debated and the failure mechanism associated with it is still to be described [2].

The general aim of this project is to develop a motion analysis approach for spine motion and to provide a better understanding of the failure mechanism behind PJK. This would be achieved by describing the motion of spinal segments before and after long spinal fusion surgery and assessing the changes in the load on these spinal segments. This motion analysis technique could provide clinicians with a pre surgery tool that allows them to predict the occurrence of PJK.

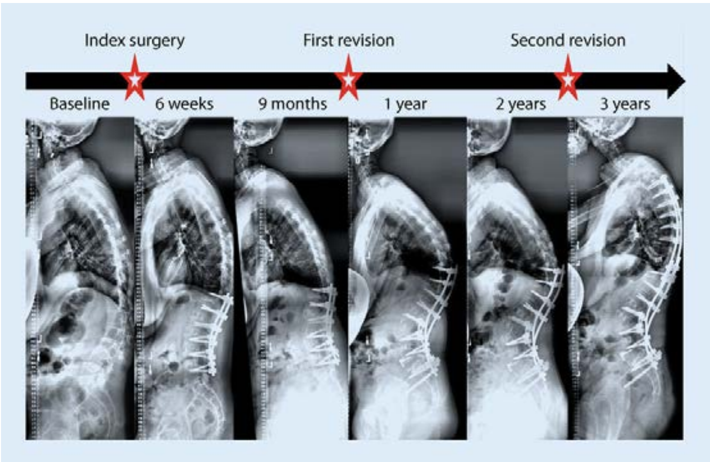


*Figure 2 Onset of PJK following spinal fusion over a 3 years period*

**Project Details and first year activities:**

As part of Spinner MSCA ITN, I have to spend 18 months in industrial secondment. I have been at the National Centre for Spinal Disorders in Budapest since March 2019 and would be staying there until August 2020. The first 4 months of the PhD were spent in Italy to start developing a motion analysis protocol and marker setup for the participant trials that are now being done in Budapest.

**Methods:**

Participants:

Participants recruited for this study could be divided into three groups. The first group is made up of healthy participants. Controls were selected to test the reliability of the motion analysis protocol developed and provide a normative dataset to compare it to spinal patients. The exclusion criteria for this group were: suffering from low back pain requiring medical attention in the last 2 years, BMI over 30kg/m$^2$, pregnancy, history of spinal surgery or spinal fracture, musculoskeletal disorders influencing the normal kinematics.
The second group of participants is made up of spinal patients undergoing short level fusions. While the third group of participants are patients undergoing long spinal fusion surgeries. Both of these patient groups attend pre surgery motion analysis while post-surgery analysis is scheduled for 6 months following the surgery.

Instrumentation:

The motion analysis protocol developed entails the use of reflective markers to be attached on the back, torso and lower limbs of participants. The marker trajectory in space would then be captured by a motion analysis system using infrared cameras. Markers are placed on the body by palpating the anatomical landmarks. The marker setup used is the VICON plug in gait model with an addition of 4 markers on anatomical landmarks of the spine. These could be seen in more detail in Fig.3. The already validated plug in gait model only uses 2 markers on the spine and regards the back as one moving segment. The marker setup proposed in this

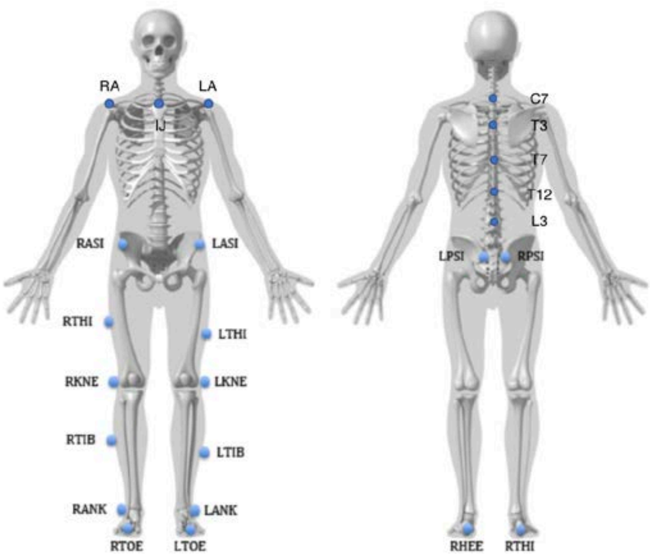


*Figure 3 Marker setup on anatomical landmarks*

project allows for the division of the spine into 4 motion segments. Studies have shown that the segments of the spine move differently to achieve a motion task thus regarding it as one rigid segment would hide vital motion data [3,4]. The spine was divided into upper thoracic, lower thoracic, upper lumbar and lower lumbar. The markers on the spine were used to define each of these segments.

The marker setup proposed aims at providing a multi segment model of the spine for the plug-in-gait model while also being easy and fast to attach. A total of 24 reflective markers are used on the whole body. The kinematic and kinetic data of the subject are collected using a 6-camera motion analysis system (VICON MXT40) at 100Hz and one force plate (AMTI OR6).

Experimental Procedure:

The three participant groups were asked to carry out a number of functional tasks to assess the range of motion of the spine. The tasks were: sit to stand transitions, lifting an object and walking trials.

The healthy participant cohort was asked to carry out 3 further tasks and these were full flexion forward, thoracic flexion forward and lateral bending. These tasks were added in order to evaluate the accuracy of the marker setup and provide a basis to validate the marker setup protocol. One static standing trial was also recorded for all the participants.

All the tasks conducted were within the capture zone of the 6 cameras. All the motions except for the walking trial were conducted while the participant was standing over the force plate. For the walking trials, participants were walking along a 6-meter room with the force plate in the middle to get only one clear step on the plate.

Data Processing:

Marker labelling and model creation is completed in VICON NEXUS. The data is then exported and analysed using a custom MATLAB code. The trajectories of the markers are first imported into MATLAB. The static standing trial is used to create a reference frame and local coordinate system. The motion capture lab is considered to be the global coordinate system. The marker position in the global coordinate system is then transformed into the reference frame using the singular value decomposition (SVD) method. This method gives the rotation matrix from the global to the local coordinate system [5]. After getting the marker location in the local coordinate system, the four segments of the spine are defined. The joint coordinate system described by Grood and Suntay [6] is then used to calculate the three-dimensional joint angles (flexion extension, lateral bending and axial rotation) between the segments and between each of the segments and the pelvis. The data processed from the marker trajectories generates 24 joint angles describing the motion at the segments of the spine in the three anatomical planes (sagittal, coronal and transverse). The 3 trials of each motion conducted by each participant are superimposed on one plot. The inclination angle between the segments is also calculated, this calculation gives the kyphosis and lordosis angles of the spine at the level of the thoracic and lumbar segments. A gait analysis of the walking trials of patients is done to calculate the angular kinematics of the lower limbs in addition to the moments and power in the hip, knee and ankle joints.

**Expected Results:**

The data collected generates 24 joint angles describing the motion at the segments in the three anatomical planes (sagittal, coronal and transverse). The 3 trials of each motion conducted by each participant are superimposed on one plot. This is done to see the repetitiveness of the motion and to calculate the normal range of motion of participants. This data is especially important currently for the healthy participant cohort as it could generate a normative database of how each spinal segment moves during a certain task.

The data generated from the healthy participants is then used as a reference band for the patient cohort. This reference band would then be compared with the bands generated from patients before and after their surgery.

From initial results, it could be seen that the patient cohort group have very different changes in their motion before and after the surgery and this is due to the extent of pain and instability of the spine present before the surgery. We have seen that these patients could not complete the tasks put in front of them comfortably. As such the reliability of the motion analysis setup is not assured. For those reasons, patients with shorter fusion surgeries were recruited. These patients would help us show that the marker setup is able to show the motion of the spine in pathological cases and the differences present in the data are not only due to the limitations of the participant. The patients with shorter fusion have a better motion of the spine and are able to carry out the tasks set out more easily.

By analysing the data from the healthy participants cohort, a power analysis of the data would be generated. This power analysis would give us an idea of the optimal healthy participant cohort needed to get statistically significant data. Healthy participant recruitment would restart after finalising the power analysis. A larger healthy participant cohort would also be used to validate the marker setup and protocol in the next year.

The three dimensional data collected from the participants and the patients would then be used as input to create a musculoskeletal model of the multisegmented spine.

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