Diagnosis parameters used in treatment prediction of the lumbar spine

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Abstract—The paper proposes to define three parameters that can be associated with lumbar spine diagnosis. These parameters will further be used in a prediction software that aims to establish a treatment indication in the early stages of the medical exploration. These parameters quantify very different conditions of the patient: pain – a very subjective parameter; the calories consumed in one day – measurable value; biomechanical parameters like range of motion in lumbar spine and postural angle – measurable parameter. These parameters have to be interconnected and therefore recordings before and after surgery and treatment have to be made. The interconnection of those represents a challenging task that requires a large patient’s database from which the statistics can be computed. Another cornerstone in interconnection is the lack of biomechanical statistics on the lumbar spine pathologies.

Keywords: low back pain; diagnosis parameters; parameter interconnection; prediction

I. INTRODUCTION

The overall goal of this research is to implement a predictive software system necessary in early diagnosis of back pain disorders and any other conditions derived from these pathologies. For this goal, there have to be defined a series of measurable parameters that characterized a person having a lumbar spine disorder.

Back pain affects between 60-80% of the population worldwide and can be caused by several factors [1]:

- Mechanical causes. One of the most common mechanical causes is degenerative intervertebral disc disease [2]. This is not a disease itself but rather a term used to describe mechanical changes that occur in the intervertebral discs with age. Over time, the intervertebral discs deteriorate and lose their cushioning ability. Hence the back pain appears when the spine is overloaded. Other mechanical causes of back pain are muscle spasms, muscle tension and herniated disc.

- Injuries. Spine injuries such as fractures or sprains cause chronic or short term back pain. Sprains are damage ligaments and capsular structures that connect the cervical facet joints and vertebrae. Fractures are often caused by osteoporosis, a disease that causes bones to become fragile due to their demineralization. Injuries can be caused by various accidents.

- Acquired Diseases. Many medical problems can cause or aggravate back pain. They include scoliosis which causes curvature of the spine, spondylosis, various forms of arthritis including osteoarthritis, rheumatoid arthritis, ankylosing spondylitis and spinal stenosis which is a narrowing of the spinal canal pressing so the spinal cord and spinal nerves.

The difficulty of an early and safely diagnosis shows the importance of a predictive software system from both medically and in terms of ease of practical application [3].

Some of the others work in this field can be synthesized as follows:

In 2002 on a lot of seventy-one patients Timothy Flynn et all [4] identified a clinical prediction rule based on five variables. The results indicate the fact that patients that respond to the spine manipulation techniques may be accurately identified before the treatment. This prediction does not take into consideration the surgical corrections of the spine.

In 2005, Gregory E. Hick et all, develop a clinical prediction rule that predict treatment response to the stabilization exercises [5]. The study was conducted on 54 patients with nonradicular low back pain (LBP). The conclusion was that the response to the stabilization exercise in patients with LBP can be predicted from variables collected from the clinical examination.

In 2006, Joshua A. Cleland et all [6] use an alternative manipulation technique on the lumbar spine on the patients that satisfies a clinical prediction rule, evaluated by Oswestry Disability Index (ODI) score.

In 2012, Chaityuth Sutheerayongprasert et all [7] focus their study on Lumbar-disc herniation (L-DH). A group of 50 cases subjected to lumbar discectomy and a control group of 50 patients that successfully follow a conservative treatment were involved in the study. After the data processing they came to the prediction that the conservative treatment fails in L-DH patients with log duration of the symptoms, sequestered herniation and large disc fragment size.

The objective of the paper is to identify and interconnect a series of parameters that can be used in designing a prediction method for treatment indication in early investigations of patients with low back pain. The future prediction software will represent a huge benefit
for the patients in both establishing of a clear diagnostic and the orientation to the most comprehensive treatment method. As a first step, we propose three variables (parameters) that will be taken into consideration.

In order to achieve this goal, a large lot of subjects have to be involved in the study. From those, some will follow surgical corrections of the spinal disorders while others will follow only drug medication and spinal manipulation techniques.

II. MATERIAL AND METHODS

In this section of the paper an overall description of the three parameters will be done. Also, basic issues regarding the ways to determine the values of the parameters will be presented.

The parameters are: Biomechanical parameter abbreviated BP [\text{\textdegree}], Burned calories parameter BCP [kcal] and Pain parameter PP [%].

These parameters are provided by a series of investigation as it follows: results of a questionnaire are used in PP estimation; daily activity calculus is used in BCP estimation and Zebris motion analysis system for basic BP measurements. The biomechanical parameter BP is a complex one being computed from a series of basic biomechanical parameters. Those basic BP are angles [\textdegree] acquired with the system in both static and dynamic condition of the lumbar spine.

The PP is estimated based on the outcome of a questionnaire. The questionnaire is constructed to provide answers to a set of questions that are related to daily activities and life quality of the patient. This involves issues like: pain intensity, sleeping conditions, personal care, pain level in standing, sitting, walking, lifting and traveling and social life. The set of questions was built considering the [8] and [9] online resources.

The BCP is calculated using a well-known daily activity formula agreed by the World Health Organization (WHO). This parameter takes into consideration the gender and age of the subject and also its weight P [kg] and height T [m]. The tabular formula is presented in the Table 1 [10].

### TABLE 1. DAILY ACTIVITY FORMULA

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Men (cal./day)</th>
<th>Women (cal./day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-18</td>
<td>(16,6xP)+(77xT)+572</td>
<td>(7,4xP)+(482xT)+217</td>
</tr>
<tr>
<td>18-30</td>
<td>(15,4xP)+(27xT)+717</td>
<td>(13,3xP)+(334xT)+35</td>
</tr>
<tr>
<td>30-60</td>
<td>(11,3xP)+(16xT)+901</td>
<td>(8,7xP)+(25xT)+865</td>
</tr>
<tr>
<td>After60</td>
<td>(8,8xP)+(1128xT)-1071</td>
<td>(9,2xP)+(637xT)-321</td>
</tr>
</tbody>
</table>

After calculating calories /day using the mathematical formula presented in Table 1, we ask the patient what activities takes place during the day for him. Depending on the patient’s response the number of calories obtained is multiplied by the appropriate activity factor. These values are presented in Table 2 in concordance to the physical activity. Also, a rank is associated for further data interconnection.

At the investigation time, the patients will be asked to fill the questionnaire. The answers to the ten questions are used in scoring the degree of incapacity of the patient. The questionnaire will be applied every time the patient will be investigated: before surgery/treatment, at 2 weeks, 6 months and 1 year.

### TABLE 1. CLASSIFICATION VALUES FOR DAILY ACTIVITIES

<table>
<thead>
<tr>
<th>Activity level</th>
<th>Daily calories [kcal]</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced physical activity</td>
<td>1.56</td>
<td>1.56</td>
</tr>
<tr>
<td>Medium physical activity</td>
<td>1.78</td>
<td>1.64</td>
</tr>
<tr>
<td>High physical activity</td>
<td>2.1</td>
<td>1.82</td>
</tr>
</tbody>
</table>

The basic biomechanical parameters are acquired using an ultrasound system. It measures the range of motion of the lumbar spine in all anatomical planes. Also, the system provides information on the alignment of the spine in the sagittal, frontal and horizontal planes and pelvic position in three-dimensional space. Typologies of mobility can be determined in flexion-extension, rotation and laterality movements.

The system relay on ultrasound emission and reception between two components: the emitter and the microphones. The microphones are arranged in special configurations according to the investigation site. One arrangement is called marker, and is being attached to the subject by Velcro strips. The data resulted after the measurements are stored in a database for a further processing. The basic data processing required to be done are averages and standard deviations. Also, for comparing the results of a large lot of patients, the time series has to be normalized. Also, if the lot is not homogenous enough, the data can be normalized taking into account the anthropometric data of the patients.

During the patient’s recovery we target to monitor the parameters initially, at 2 weeks, 6 months and 1 year after initial diagnosis. The patients involved in the study suffer from low back pain and are divided into 2 groups:
- Operated patients lot;
- Non-operated patients lot;
Each patient belonging to a lot will follow the same recovery program and the same medication. Patients will be monitored by measuring all the parameters.

The lumbar spine disorders that may lead to low back pain are very various. From this variety, the patients involved in the study have the following diagnostics: lumbar stenosis, spondylitis, spondylolisthesis, disc herniation at one or multiple vertebral levels.

The resulted of the study will help us in early diagnosing and orientation for the best therapeutic measures, on a large variety of disorders.

III. BIOMECHANICAL PARAMETER DEFINITION

A. Basic biomechanical parameters definition

Basic biomechanical parameters refer to a set of measurable data that can be objectively acquired for any
subject. In this project they are represented by angles measured on the human spine, in each anatomical plane. We took into consideration a number of five independent parameters noted $\beta_f$, $\beta_e$, $\beta_r$, $\beta_l$ and $\alpha$ [°], according to the figure 1.

![Figure 1. Range of motion of the lumbar spine and postural angle of the whole spine.](image)

All five angles can be measured either before or after the surgery/treatment and therefore they are stick to the labels (init), (postop) or (postmed). The meanings of the basic parameters are:

- $\overline{\beta_f}(\text{init})$ – The average flexion angle of the lumbar spine measured in the sagittal plane, before surgery/medication
- $\overline{\beta_e}(\text{init})$ – The average extension angle of the lumbar spine measured in the sagittal plane, before surgery/medication.
- $\overline{\beta_r}(\text{init})$ - The average lateral angle of the lumbar spine measured in the frontal plane, before surgery/medication.
- $\overline{\beta_l}(\text{init})$ - The average rotation angle of the lumbar spine measured in transverse plane, before surgery/medication.
- $\alpha(\text{init})$ - The postural angle of the spine measured in the sagittal plane on a subject being in orthostatic position, before surgery/medication.

The term (init) stance for initial recordings of a patient, (postop) is associated with the parameters recoded after the surgery while (postmed) is associated with the parameters recorded after medication.

For each angle type the average is computed from the maximum values recorded for one patient in 10 movement trials.

Because the final purpose of the research is to create a prediction rule that can indicate a treatment method of a patient with lumbar disorders, the biomechanical parameters that we need to manage are the (init) ones. But, since there are no statistical references of these parameters associated to the pathology in the literature, we are looking to obtaining them by recurring measurements.

In order to achieve this, a large lot of subjects that will either follow surgery or medication have to be investigated. Their initial results have to be compared with the normal statistic ones, and also the performances after surgery or medication have to be compared with statistic. The differences between the performance before and after the surgery/medication will indicate if we got an enhancement of the movement or not. Also, we expect that patients with very low range of motion in lumbar spine can improve their mobility only by surgery. On the other hand, the patients with moderate mobility (but out of the statistical range) will improve their mobility by medication and rehabilitation exercises.

In these conditions, we reduce this problem to experimentally find a critical value for each of the five angles. A patient who’s placing below the critical values it will require surgery while patients with mobility over the critical values will improve the performances by medication. For example, if we consider the average flexion mobility of a patient $\beta_f$ before the surgery/medication, than we have to find a $u[°]$ value for which:

- $\overline{\beta_f}(\text{preop}) \in [0, u]$ - “surgery will improve the mobility”
- $\overline{\beta_f}(\text{preop}) > u$ “non-surgical treatment will improve the mobility”

B. Obtaining the critical values of the parameters

A way to determine the critical values of the biomechanical parameters is to find a pattern in the measurements when comparing to the statistical reference [11] for a person at the same age and the same gender as the patient.

An early stage in this pattern finding is to compare the initial measurements with a statistical average ($V_{\text{stat}}$) and also the postop and postmed results with this statistical average (1). In the figure 2 is presented an example for the $\beta_f$ angle post surgery measured. The $\text{def}_{\text{postop}}$ term refers to the post-surgery deflection of the $\beta_f$ parameter determined as a difference from $V_{\text{stat}}$ (2).

![Figure 2. Framing the $\beta_f$ parameter](image)
The paper proposes a series of quantifiable parameters that can be used in development of a prediction software. Because the prediction software has to provide medical solutions for patients in early stages of investigation, the parameters that have to be used are the initial parameters.

The major challenge is to associate the initial parameters with the medical condition that the patient can develop. These associations can only be made by methodically studying the initial parameters and the parameters after the surgery/medication, and all of these for a large and homogenous lot of patients.

The parameter definition and their interconnection are in early stage of development (assumed for a lot of 20 patients) and they may be subjected to change when the statistic evidence will requested.

### References


### IV. Conclusions

The basic biomechanical parameters will further be integrated in a superior parameter called BP [°]. This parameter will integrate all the basic parameters as a summation of the individual parameters βi and α (5).

A threshold value of this parameter will be found, based on the critical values of the individual parameters.

For a BP value under the threshold value the level associated will be 1 while BP values over the threshold value will have level 2.

\[
BP = \sum_{i=1}^{5} \bar{\beta}_i
\]  
(5)

C. Parameter interconnection

For the biomechanical parameter BP, the level 1 lead patient to non-surgical treatment methods and level 2 lead him to surgery.

Another parameter involve in the prediction in the pain parameter. Pain parameter PP [%] defined on the Quebec scale is a subjective parameter and it has five levels. The levels 1 and 2 correspond to non-surgical treatments while 3 to 5 levels correspond to surgical treatments. From the physiological point of view, the levels 1 and 2 range from 0 to 40% motion incapacity. The levels 3 to 4 range from 41 to 100% motion incapacity.

Burned calories parameter BCP [kcal] has three levels, according to the table 2. The levels 1 and 2 are leading us to a non-surgical treatment while level 3 is associated with surgical methods.

The three parameters were interconnected as in the table 2, using the level combinations.

### Table 3. Treatment prediction based on the three parameters

<table>
<thead>
<tr>
<th>BP [°]</th>
<th>BCP [kcal]</th>
<th>PP [%]</th>
<th>Treatment to follow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lev.1</td>
<td>Lev.1,2 or Lev.3</td>
<td>Lev.1,2</td>
<td>Non-surgical</td>
</tr>
<tr>
<td>Lev.1</td>
<td>Lev.3</td>
<td>Lev.3</td>
<td>Surgical</td>
</tr>
<tr>
<td>Lev.2</td>
<td>Lev.1,2 or Lev.3</td>
<td>Lev.3</td>
<td>Surgical</td>
</tr>
<tr>
<td>Lev.2</td>
<td>Lev.3</td>
<td>Lev.1,2</td>
<td>Non-surgical</td>
</tr>
<tr>
<td>Lev.2</td>
<td>Lev.3</td>
<td>Lev.1,2</td>
<td>Surgical</td>
</tr>
</tbody>
</table>