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PRIORITIZATION OF TECHNICAL CHARACTERISTICS OF A SPINE POSTURE MONITORING DEVICE

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Abstract*: The paper presents a set of technical parameters of a device used in monitoring the posture of the human spine and a prioritization of this parameters by means of competitive design. In order to achieve an optimized device, that can be used every day by any patient without special help, the parameters need to be defined and ranked by their impact over different environments. This paper focuses on this process and highlight of the most important parameters that need to be taken into consideration in designing the device.*
Keywords*: Spine posture monitoring device, technical parameters, competitive design, prioritization, spine parameterization.*

1. INTRODUCTION

The spine is the most important segment of the locomotion system [1]. It is made of 33 individual bones piled one on another. The spine provides the main support for the body, allowing to stand upright, bend, and twist, while protecting the spinal cord from injury. **A**ny of these structures affected by strain, injury or diseases can cause pain [2]. This paper accomplishes one step in the designing of a new device to help in identifying and correcting some of the spinal diseases. One important part in designing the system is to identify and define the tasks that need to be fulfilled by the device, for this part the means of competitive design are used. Competitive engineering deals with development and application of methods, instruments and specific approaches that can be developed to superior parameters in terms of technical and economic various technical systems, economic or mixed (products, processes, services) under actual working conditions (multiple constraints and requirements)[3].

2. TECHNICAL CHARACTERISTICS OF THE DEVICE

In order to be able to use the techniques of modern engineering regarding the designing of the data acquisition device, a set of technical characteristics need to be defined. These characteristics were a result of a brainstorming of the team involved in the project with respect to medical history of the devices used in human spine posture monitoring. The set of technical characteristics need to be fulfilled by the designed device as a result of a prioritization from the following chapter.

- *To not prejudice the position of the spine* - the system/device must not contain elements that through their geometry to modify the natural position of the spine;
- *To not create inconvenience for the patient*- the system /device must not contain elements that through their geometry can create inconvenience for the patient in daily activities;
- *To avoid risks of electric shock*- in designing the device for data acquisition the electric

components that can store electricity and through their unloading can create electric shocks, must be eliminated. If these components are necessary for the system they must be integrated into standard protection zone.

- *To not contain materials that can harm the patient*-the device must not contain materials that through their structure or through the variability of their structure to harm the patient (toxic substances, absorbable by the human body or materials that overheat when in function);
- *The device must be modular*-the components of the device must be designed in a such manner to assure easy portability and assembly;
- *The device must be easy to equip*- the device must be easy to integrate in a cloth piece and easy to dress by the patient;
- *The device must be easy to maintain*- the device must not contain components that need long maintenance time, or components that need special qualified personal intervention;
- *Able to function for 24 hours straight* – given the fact that the data acquisition takes place for 24 hours the device must have this autonomy.
- *To be able to communicate with PC/Tablet* - at the end of the day the data collected by the device must be downloaded in a database, this download will be made wireless or through data cable into a computer or any other device with an interface.
- *To contain a warning mechanisms for extreme positions of the spine*- in the case when the user is performing tasks that heavily load the spine (big loads, achieving positions near the limits of flexing and flexure of the spine) the device must be able to signal these positions (most plausible through an audio signal);
- *To be able to adapt to every spine* – this feature can be achieved through the modularity of the system too and need to be taken into consideration in order to use the device by any user no matter the gender, weight or the age of the user;
- *The device must be designed to fit different typologies of spines* - this feature can be achieved through the modularity of the system too and need to be taken into consideration in order to use the device by any user no matter the gender, weight or the age of the user;
- *The device must be easy to manipulate* – the transporting and storing of the device must not be a problem;
- *The device must provide essential data in useful time* – data acquisition from the device must be fast offering in the same time quick access to diagnosis methods [4].
- *The device must have a user-friendly interface* – the communication between the device and the user must be made through a user friendly interface, easy to understand and use by any user.
- *The device must be easy to control* – the control of the data acquisition device must not arise problem to the user or to the diagnose process;
- *The functioning of the device must be silent* – the noise level made by the components of the device must not interfere with daily tasks of the user;
- *The device must confer a steady running* - the running of the device must not contain errors, the functioning must not be perturbed by external factors;
- *The device must contain a sustainable battery* – the battery of the device must be able to be recharged multiple times and to discharge uniformly;
- *The device must not create allergies* – the device must not contain materials that in contact or proximity of the patient skin to emit elements that can create discomfort;
- *The device must indicate the empty battery* – the programing of the device must be designed in such manner to show the autonomy of the battery , eliminating the risk of wearing the device without collecting data;
- *The device must detect running errors* – the device must be designed to be able to supervise the state of its components

(electronic and mechanic) and to prevent the malfunction of these components;

- *The device must not generate radiations* – the device must not contain components that can emit radiations (mostly thermic)

3. PRIORITIZATION OF THE TECHNICAL CHARACTERISTICS OF THE DEVICE

In order to prioritize the technical characteristics of the device one of the methods of competitive design will be used, namely AHP (Analytic Hierarchy Process) method. The AHP method is a structured technique for organizing and analyzing complex decisions. The method is based on math and psychology, and it has been developed by Thomas L. Saaty in the '70 [5]. AHP method does not prescribe a correct decision rather it helps the decision makers to find the solution that fits best their purpose. The method provides a comprehensive and rational environment for structuring a decision problem, for representing and quantifying the elements of the problem, for linking these elements with the general purpose and for evaluating the alternative solutions to the problem.

The AHP users divide first the problem into a hierarchy of easier problems that can be analyzed individually. The ranking elements can relay to any aspect of the decision factor. At the end of the ranking, a systematic evaluation of the elements is made, by comparing elements two by two, with respect to the impact of the analyzed element on the element above him in the hierarchy. In the algorithm of creating the comparing factor, specific data can be used, but in the same time the importance and the signification of the analyzed factor has a big decisional impact.

The AHP method converts these evaluations in numeric values that can be processed and compared throughout the expansion of the problem. A priority of the each element results at the end of this ranking allowing that diverse and unmeasurable elements to be compared with other elements in a rational and consistent way. In the final stage of the process a numeric priority of each element is computed for each alternative decision. These numbers represent the relative ability of ranked elements to fulfil the optimization objective of the process.

In Fig.1 is represented the first step of the AHP method using the software Qualica QFD. As it can be seen a matrix has been build containing both on rows and columns the previous defined set of characteristics. For comparing this elements the degrees of comparison from Table 1 have been used.

As a result of the previous step is the chart in fig.2, representing the importance of each technical characteristic linked to the other technical characteristic.

As it can be seen the most important element is 13.7 times more important than the least important element.

Table 1 Degrees of comparison

DoC	Meaning
9	An order of magnitude more important
8	Absolutely more important(8 x important)
7	Demonstrated more important
6	Demonstrated more important (6 x important)
5	Essentially more important
4	Essentially more important (4 x important)
3	Considerably more important
2	Twice as important
+	Somewhat more important
0	Equally important
-	Somewhat more important
1/2	Half as important
1/3	Clearly less important
1/4	Essentially less important (4x less important)
1/5	Essentially less important
1/6	Demonstrated less important(6x less important)
1/7	Demonstrated less important
1/8	Absolutely less important(8x less important)
1/9	An order of magnitude less important

How Important is the Left Item (Row) as Compared to the Top Item (C...

Group: **Top Level ITEMS** — Output — Completed: ☑

AHP Toplevel Matrix

9	9,00 an order of ...	⅙	0,17 demonstrat...
8	8,00 absolutely ...	⅐	0,14 demonstrat...
7	7,00 demonstrat...	⅛	0,13 absolutely l...
6	6,00 demonstrat...	⅑	0,11 an order of ...
5	5,00 essentially ...		
4	4,00 essentially ...		
3	3,00 considerabl...		
2	2,00 twice as im...		
+	1,50 somewhat ...		
○	1,00 Equally imp...		
-	0,67 somewhat l...		
½	0,50 half as imp...		
⅓	0,33 clearly less...		
¼	0,25 essentially l...		
⅕	0,20 essentially l...		

Input	1 To not prejudice the position of the spine	2 To not create inconvenience for the patient	3 To avoid risks of electric shock	4 To not contain materials that can harm th...	5 The device must be modular	6 The device must be easy to equip	7 The device must be easy to maintain	8 Able to function for 24 hours straight	9 To be able to communicate with PC/Tablet	10 To contain a warning mechanisms for e...	11 To be able to adapt to every spine	12 The device must be designed to fit diffe...	13 The device must be easy to manipulate	14 The device must provide essential data ...	15 The device must have a user-friendly int...	16 The device must be easy to control	17 The functioning of the device must be si...	18 The device must confer a steady running	19 The device must contain a sustainable ...	20 The device must not create allergies	21 The device must indicate the empty bat...	22 The device must detect running errors	23 The device must not generate radiations	Importance in group
1 To not prejudice the position of the spine		○	+	○	9	9	9	5	5	4	+	+	3	5	9	3	9	5	9	2	9	5	5	13,7%
2 To not create inconvenience for the pati...			+	○	9	9	9	5	5	4	+	+	3	5	9	3	9	5	9	2	9	5	5	13,7%
3 To avoid risks of electric shock				○	5	4	9	8	8	8	+	+	3	4	5	2	7	3	6	2	5	4	4	11,3%
4 To not contain materials that can harm ...					+	2	2	3	3	3	2	+	+	+	+	○	2	○	5	○	2	2	○	6,0%
5 The device must be modular						○	○	+	○	○	○	+	○	○	○	-	+	○	○	-	2	○	-	2,7%
6 The device must be easy to equip							○	○	○	3	○	+	○	3	+	○	○	○	2	○	+	2	○	3,4%
7 The device must be easy to maintain								○	○	+	○	-	○	+	+	○	+	○	○	-	2	○	-	2,7%
8 Able to function for 24 hours straight									○	○	○	-	-	○	○	-	○	○	○	½	○	○	-	2,2%
9 To be able to communicate with PC/Ta...										○	-	-	○	○	○	+	+	○	○	-	○	○	-	2,5%
10 To contain a warning mechanisms for ...											+	+	+	+	+	+	+	+	+	○	+	2	○	3,2%
11 To be able to adapt to every spine												○	+	○	○	○	2	2	5	○	4	3	○	4,5%
12 The device must be designed to fit diff...													+	○	+	+	2	○	+	○	3	2	○	4,0%
13 The device must be easy to manipulate														○	○	○	+	○	○	-	○	○	-	2,8%
14 The device must provide essential data...															○	○	+	○	○	○	+	○	-	2,6%
15 The device must have a user-friendly in...																○	+	○	○	-	+	3	½	2,6%
16 The device must be easy to control																	2	○	○	-	○	○	-	3,0%
17 The functioning of the device must be ...																		⅓	○	⅓	○	○	⅓	1,8%
18 The device must confer a steady runni...																			○	○	○	○	-	2,8%
19 The device must contain a sustainable...																				-	○	○	½	2,1%
20 The device must not create allergies																					6	7	○	4,7%
21 The device must indicate the empty ba...																						○	-	1,9%
22 The device must detect running errors																							½	2,1%
23 The device must not generate radiations																								3,7%

Fig.1. Comparison matrix

Importances / ITEMS	Calculated Importa...	Final Importance %
1 To not prejudice the position of the...	13,7%	11.8%
2 To not create inconvenience for th...	13,7%	11.8%
3 To avoid risks of electric shock	11,3%	9.9%
4 To not contain materials that can ...	6,0%	5.7%
5 The device must be modular	2,7%	3.1%
6 The device must be easy to equip	3,4%	3.6%
7 The device must be easy to maintain	2,7%	3.0%
8 Able to function for 24 hours straig...	2,2%	2.7%
9 To be able to communicate with P...	2,5%	2.9%
10 To contain a warning mechanism...	3,2%	3.4%
11 To be able to adapt to every spine	4,5%	4.4%
12 The device must be designed to fi...	4,0%	4.1%
13 The device must be easy to mani...	2,8%	3.1%
14 The device must provide essentia...	2,6%	3.0%
15 The device must have a user-frien...	2,6%	2.9%
16 The device must be easy to control	3,0%	3.3%
17 The functioning of the device mus...	1,8%	2.4%
18 The device must confer a steady ...	2,8%	3.1%
19 The device must contain a sustai...	2,1%	2.5%
20 The device must not create allerg...	4,7%	4.6%
21 The device must indicate the em...	1,9%	2.4%
22 The device must detect running e...	2,1%	2.5%
23 The device must not generate rad...	3,7%	3.8%
Most important item:	13,7%	
Least important item:	1,8%	

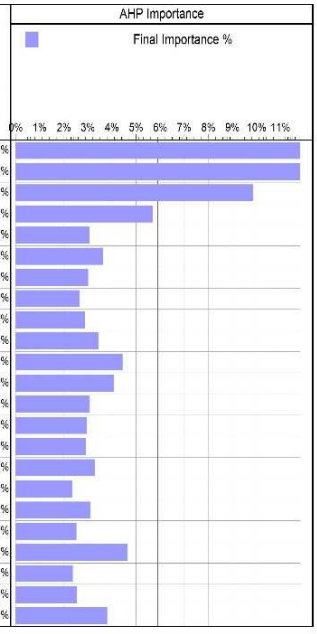

Fig.2. Computed importance

Importances / Sorted ITEMS 1	Calculated Importa...	Final Importance %
1 To not prejudice the position of the spine	13,7%	11,8%
2 To not create inconvenience for the patient	13,7%	11,8%
3 To avoid risks of electric shock	11,3%	9,9%
4 To not contain materials that can harm the patient	6,0%	5,7%
20 The device must not create allergies	4,7%	4,6%
11 To be able to adapt to every spine	4,5%	4,4%
12 The device must be designed to fit different typologies of spi	4,0%	4,1%
23 The device must not generate radiations	3,7%	3,8%
6 The device must be easy to equip	3,4%	3,6%
10 To contain a warning mechanisms for extreme positions of the spine	3,2%	3,4%
16 The device must be easy to control	3,0%	3,3%
18 The device must confer a steady running	2,8%	3,1%
13 The device must be easy to manipulate	2,8%	3,1%
5 The device must be modular	2,7%	3,1%
7 The device must be easy to maintain	2,7%	3,0%
14 The device must provide essential data in useful time	2,6%	3,0%
15 The device must have a user-friendly interface	2,6%	2,9%
9 To be able to communicate with PC/Tablet	2,5%	2,9%
8 Able to function for 24 hours straight	2,2%	2,7%
22 The device must detect running errors	2,1%	2,5%
19 The device must contain a sustainable battery	2,1%	2,5%
21 The device must indicate the empty battery	1,9%	2,4%
17 The functioning of the device must be silent	1,8%	2,4%
Most important item:	13,7%	
Least important item:	1,8%	

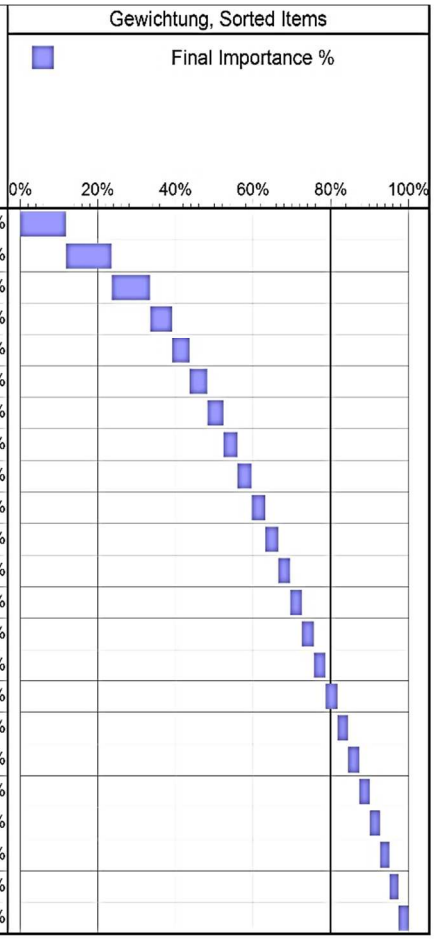

Fig.3.Final importance

In Figure 3. a final sort of the technical characteristics is presented by their importance. As a result of the ranking most important characteristic from the set was to not prejudice the position of the spine, while the less important feature seemed to be that the functioning of the device must be silent. As it can be seen the highest on the ranking are the characteristics that define the health and the safety of the user followed by characteristics that, if taken into consideration will lead to a more liable product. Given the fact that the device would accompany a human being during a whole day, the technical characteristic ranked on the highest positions are all regarding the safety of the daily user, and this result would be incorporated into device's design in following possible ways:

- in order for the device to not prejudice the position of the spine, the elements of the device will be produced from a flexible material (plastic), applicable on a cloth in constant touch with the patient skin on the spine path;
- the flexibility of the material used in producing the device will accomplish also the second ranked characteristic;
- in order to avoid the risk of electric shock the device will be designed in concordance with the European laws regarding safety in working with electric equipment ;
- all the components will be designed in concordance with European regulation regarding health, to avoid the inconveniences that can cause allergies;
- In order to assure the modularity of the device each, component will be designed to be easy to replace, easy to detach from the device and the number of components of the

device should be easy to modify in order to fit different typologies of human spine.

4. CONCLUSIONS

A set of 23 technical characteristics of a human spine monitoring device has been presented in the paper, followed by a prioritization of these characteristics in order to rank them by their importance, using one of the competitive design method, namely AHP method. As a result of the prioritization most important characteristics seemed to be the components regarding the health and the safety of the user, a way of incorporating these features in the device has been presented in the last part of the paper.

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Ierarhizarea caracteristicilor tehnice a unui dispozitiv de monitorizare a pozitiei coloanei vertebrale

Abstract: Lucrarea prezinta un sete parametrii tehnici puntru un dispozitiv folosit in inbunatatirea pozitiei coloanei vertebrale umane si o ierarhizare a acestor parametrii folosind mediul ingineriei competitive. Pentru a obtine un dispozitiv optimizat, care sa poata fi utilizat zilnic de catre orice pacient fara a avea nevoie de ajutor special, parametrii vor fi definiti si ierarhizati in functie de impactul lor asupa diferitelor medii in care este folosit dispozitivul. Aceasta lucrare se concentreaza pe acest proces si pe sublinierea celor mai importante caracteristici tehnice care trebui luate in considerare in proietarea dispozitivului.

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