Promoting Visual Biofeedback through a Medical Device for Physical Therapy and Physical and Rehabilitative Medicine

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Abstract: The present paper synthesises the development of a medical device which promotes visual biofeedback for Physical Therapy and Physical and Rehabilitative Medicine. After the identification of a specific need, a solution extremely versatile with advantages for the patient and the health professional is presented. A brief reference to its technical development and its performance is presented, introducing the visual biofeedback interface and gathering a set of identified clinical applications. Finally, some possible further developments are listed.

1 NEEDS' IDENTIFICATION

The current models of intervention, in terms of physical therapy, focus on manual therapy, physical agents and movement therapies, usually on an outpatient basis, in which individuals are subjected to short period treatment sessions (30-60 minutes), from Monday to Friday and long periods of inactivity outside treatment. There are several health conditions with strong repercussions in terms of functionality, including changing the basic position of the body in lying down position, going from lying to sitting; maintaining balance when sitting, moving from sitting to standing and walking. (Cheng et al. 2004; Terena and Taricco, 2009).

It is also noteworthy that motor learning requires structuring activities into specific tasks with high intensity training and a strong motivation of the individual, which is not guaranteed with short and nonspecific sessions. Motor training programs, including balance and motor control should be structured in order to enable the pro-activity of the user, with or without supervision, but making a workout several times a day possible.

Thus arises the need to design specific equipment to enable individuals to train tasks/ activities included in the rehabilitation process and that simulate global patterns of activity, such as standing and sitting, which may be performed either in the clinic or at home. Such equipment should also have a low cost, be easy to understand, portable and give the individual a real-time feedback on their performance. These devices would be especially suitable for individuals with changes in terms of mobility, inability to change the basic position of the body, get up and sit down, take a standing position and walk, resulting from the aging process itself, neurological, musculoskeletal or other injuries.

Currently, there are several solutions concerning some of the features referenced. One can enumerate a set of solutions currently available on the market highlighted by some brands: platforms AMTI forces, the Tetrax of Sunlight, the Medtrack of InBalance, the product family balancing Neurocom, the Balance Check of Bertec, the Wii fit of Nintendo, the Kinectic of Xbox, among others. However the solutions listed are extremely complex in terms of interfaces, usability and interaction with the user. Their own data and information resulting from the use of such equipment are very technical, with admirable precision and not directed to the user, only the reach of scientific research centers, universities, and some hospitals and not to the reality of a clinic or a most common medical center and closer to the community. In many cases, even the setups associated with these equipments are very time consuming and require a thorough knowledge of the system. Exception is made to Wii fit of Nintendo and the Kinectic of Xbox, since they are positioned for

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the domestic segment, have capacities very interesting, very intuitive interfaces, but they are still aimed at recreational leisure time. Thus, the authors advocate the design of a device that is positioned between the more technically oriented and more recreational aspect, which is designed and the scope of everyday life in a clinic or medical center allowing these centers benefit from an important technology for your business .

Translating the need into concrete requirements, the development of a device with an automatic data acquisition was intended. This device allows the performance of several physical exercises, in which it is possible for the user to have access to real-time quantitative values about the exercises performed. It is also intended that the information provided has not only the function to re-educate the user regarding his/her posture but also to motivate the physical procedure that he/she should adopt in their daily lives, as well as encourage their awareness level of their postural control. Simultaneously it is intended that such information supports the healthcare professional attending the case, enabling him to verify the behaviour of the user during the exercise, thus being in possession of an additional tool for the evaluation plan or recovery of several users.

2 CHARACTERIZATION OF THE MEDICAL DEVICE

The developed device comprises a chair and a platform, both instrumented, and a display (Ferreira, 2012) (Figure 1).

Figure 1: Chair, platform and display.

It comprises a chair whose seat is divided into two independent and instrumented quadrants, allowing knowing the force distribution in each quadrant and differentiating the load exerted on the left or the right side. The chair also has an automatic height adjustment and the arms' position is also adjustable.

The platform is divided into four independent and instrumented quadrants, thus allowing differentiating loads exerted on each of them.

The two quadrants comprising the seat and the four quadrants that make up the platform each contain four micro load cells attached at its ends. The analogical signals from the micro load cells are then sent to a module where they are amplified and converted into digital signals and processed by a microcontroller. The communication between the application server (chair or platform) and application client (computer and display) is made over Wi-Fi.

It is a training device for balance and motor control that enables training in the position of sitting, standing, as well as the analysis of movement get up and sit down. Allows training in the antero-posterior sagittal and rotational planes, whose operation is based on the acquisition of the mass distribution on the various support quadrants (seat and/or feet). Its ability to provide real-time, visual biofeedback directed to the user and the healthcare professional it is also shown, which allows conveying real-time visual objective data related to the exercises of clinical practice performed with the device, through software interfaces which have been specially developed for this purpose. The visual biofeedback is suggested to the patient and healthcare professional through any display as long as it has an associated processor running the same software. The health professional collects information that is sensitive in real time and can also store that information in the database associated with the software. Can even query it in the form of graphs and tables in the software itself or simply print a report.

This device allows, enhancing and intensifying the process of recovery in gym. Consequently, it stimulates the active participation of the individual, obtaining a much higher yield in terms of the recovery process, very difficult, if not impossible to achieve with current conventional programs.

The applicability of the device is directly related to its performance, which can be grouped into two distinct categories: balance category and load transfer category (Mendes, 2012). In the following subsection reference is made to each category presenting a set of specific exercises, its goals and associated visual biofeedback interface.

2.1 Balance

The balance condition assessments consist of comparing in real time the amount of force exerted on each measurement plane and verify that they are within a tolerance margin that is defined by the healthcare professional. If the individual is within the tolerance zone, the visual biofeedback indicator suggests the colour green, otherwise it suggests red. Thanks to the visual biofeedback, the user can, in real time, immediately correct the distribution of its load through a balance mobile indicator. Thus, the device allows evaluating the force distribution in several planes and hence assesses: Sagittal Balance, Antero-Posterior Balance and Global Balance.

Sagittal Balance refers to the sagittal plane that pierces the human body and comprises a left and a right side. The sagittal balance evaluation can be performed in a sitting position and in a standing position (Figure 2).

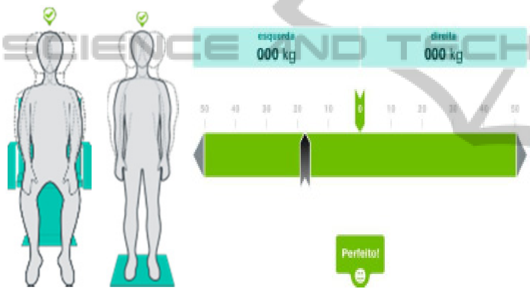

Figure 2: Exercise and visual interface representation.

Antero-Posterior Balance refers to the Antero-Posterior plan that pierces the human body and comprises the front and back side. Antero-Posterior Balance assessment is performed in the standing position (Figure 3).

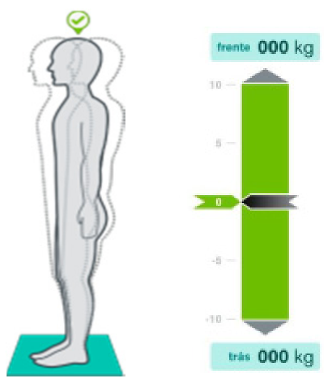

Figure 3: Exercise and visual interface representation.

The Global balance refers to the sum of the "sagital balance" and "anterior-posterior balance", where the user has to control a uniform distribution of his/her load in two different planes simultaneously and is performed in a standing position." (figure 4).

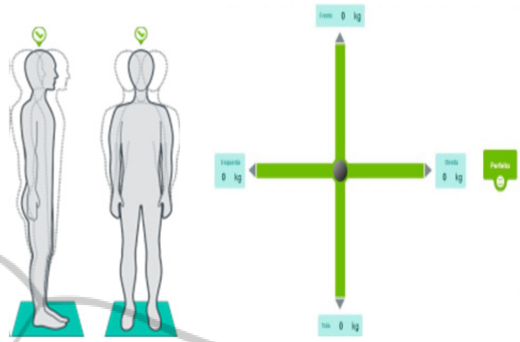

Figure 4: Exercise and visual interface representation.

2.2 Load Transfer

The information of the force distribution by the several plans can be used in a different perspective other that maintaining balance. It is very interesting in a clinical practice to ask the user to transfer all his/her load to one side, especially in cases of recovery from a stroke and promote the load transfer to the most affected side. In this perspective, visual biofeedback suggests the use of a "filling bar" effect as the load exerts on the measuring plane.

Following, an exercise is presented in which the individual is asked to transfer their load to one side. The exercise can be performed in a sitting or standing position in the sagittal plane, i.e., between the left and the right side (Figure 5).

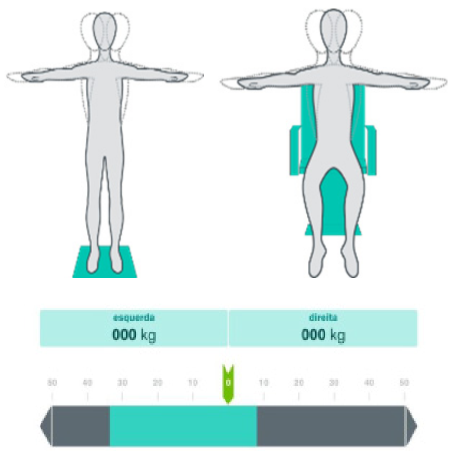

Figure 5: Exercise and visual interface representation.

Another interesting way to promote load transfer, regarding the lower limbs, is an exercise in which the individual in the seated position is requested to transfer his/her load exerted on the chair to the lower limbs (based on the platform), without getting up. This exercise is particularly interesting for enhancing muscle strength in the lower limbs (Figure 6).

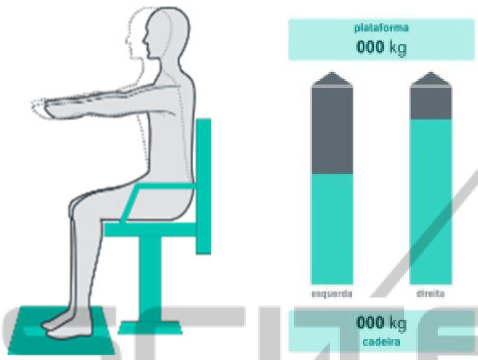

Figure 6: Exercise and visual interface representation.

The device also allows quantifying load distributions in the sitting-standing and standing-sitting movement in the sagittal plane, i.e., it is possible to quantify the force that the user makes in his left and right leg during the described movement and also to know which limb he/she uses more frequently. This information is graphically presented and in this specific case is directed to the healthcare professional (Figure 7).

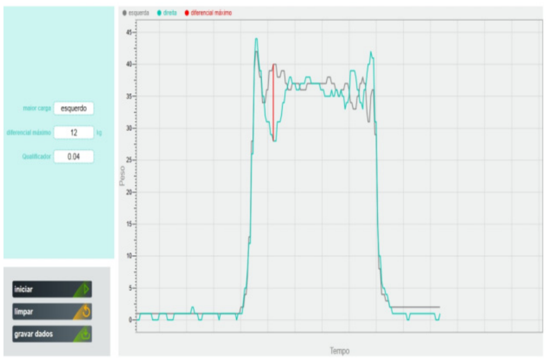

Figure 7: Visual interface representation.

3 ADVANTAGES OF THE MEDICAL DEVICE

The medical device described presents the following advantages:

- Chair and platform set

The set of chair and platform forces allows working several movements and positions and obtaining objective data of various nature. The chair also plays a key role for users with a more limited degree of mobility and allows starting the process of their recovery while still in the sitting position, as is the case of strokes' recovery. The chair may also play a role of support and security to the user in their recovery process as it allows situations of rest if the patient needs it.

- Versatility

Although the greatest potential of the device is in the joint operation between chair and platform, you can use the equipment separately, by only using the platform or chair, changing into a modular concept.

- Functionality

The device is designed to be easy to handle, and is not demanding in terms of settings, so that its potentials are always available in a functional, fast and convenient way, referring to the reality of a physiotherapy clinic or a physical rehabilitation centre.

- Low learning curve

Handling the device, by health professionals, does not require specific training or waste of time. It should also be highlighted that it was developed with healthcare professionals using as a preferential factor for its development methodologies defined by therapists and users. Result of several tests, it can be seen that learning to handle the equipment is significantly fifteen minutes.

- Use philosophies

The use of the device can be viewed in the perspective of assessment, diagnosis and training. Thus it can be used to evaluate, to define an intervention plan, train and continually re-evaluate. The device is currently undergoing certification under ISO 13485 relating to medical devices.

- Patient's autonomy

Another advantage lies in the fact that the individual, in some training situations already defined, have the ability to can use the equipment alone or with the supervision of a family member, not requiring the presence of a healthcare professional.

- Freedom of exercises

Several categories of exercises are available and their use is not static, since the healthcare professional has the freedom to choose the movements he/she deems relevant, i.e. the exercises in the software interface do not limit the activity of the healthcare professional. The healthcare professional can still have free force measurements, without being associated with a protocol or pre-defined exercises. The measurement of forces and weighing free refers to the sensitive areas of the machine, unlike the exercises which interfaces signals from the six sensitive areas are processed.

- Management of exercises

A set of features that enable the exercises' management is available: time, results, objectives, difficulty regulation and recording data.

- Pro-active Rehabilitation Process

The Visual Biofeedback promoter interface is designed to be very simple, intuitive, attractive and easy to understand. Thus it promotes the user to have a more active role as they are encouraged to achieve goals for which they will strive to achieve, perceiving them as a challenge.

4 APPLICATIONS AND CLINICAL INDICATIONS

The fact that it is a device that aims to prevent the dysfunction and/or enhance the ability of the individual in performing specific tasks, such as maintaining balance in a sitting position, get up and down, and maintain balance while standing, allows its applicability in all situations where these tasks are compromised and/or are essential to perform others. To sit and rise from a chair is one of the most common activities of daily living, vital for assuming and maintaining a standing position, to walk and thus maintain the ability to perform day-to-day activities, personal hygiene, and mobility, among others. However, the ability to assume and maintain a balanced sitting position is essential, without which the other are compromised. This situation is often compromised by a variety of pathologies, or even by the aging process.

This equipment makes it possible to improve the capacity of intervention by exercising a set of neuromusculoskeletal functions such as:

- Function proprioceptive
- Functions of mobility and stability of joints
- Functions of strength and muscle tone
- Functions of muscular endurance
- Functions motor reflexes
- Functions of voluntary movement control
- Functions related to gait pattern
- Sensations related to muscles and movement functions

In mobility stands out:

- Changing the basic position of the body
- body position maintenance
- Auto transfers
- Balance sitting
- Walk

Thus, this device allows a wide applicability enhancing rehabilitation of functional disorders caused by neurological pathologies, musculoskeletal, motion diseases and/or loss linked to aging.

The improvement found in the individual's performance of the tasks may still be considered extremely important in the prevention of falls in an elderly age, strongly associated to tasks like sitting, standing and walking. The gains in terms of balance and motor control may also be relevant in the recovery or sports performance.

It is also noteworthy that the improvement in terms of the tasks listed, is important in reducing the difficulties that the individual may have in executing activities, as well as the problems that an individual may face when involved in real-life situations.

The training methodology and the active participation of individuals in the program may also, in an indirect way, enhance the improvement of other functions, such as cardio respiratory functions and mental functions such as improving levels of attention, concentration and memory.

5 FURTHER DEVELOPMENTS

The versatility of the described device opens a huge window for future developments at various levels, either in its improvement and performance, or as complement to other clinical techniques. A set of plans in the medium short to medium term for the device are presented:

- Forecast of falling risk

The fact that the device allows to quantify a number of objective data, lead to its use in a pilot study that relates the data from the device with the Berg and Tinetti balance scale through multiple linear regressions and artificial neural networks. The results were very satisfactory and indicate a strong relationship. The data, methodology and results can be found at "*Modelação Numérica do Índice de Tinetti e de Berg"* (Mendes,2012). It is expected that in the near future the device may have an application that provides the fall risk of the individual. There is an ongoing larger study to investigate this trend in more detail.

- Sound Feedback

At the moment, the only form of feedback focuses on vision. In the future we intend to extend the feedback to the hearing ability, allowing blind or individuals with some degree of vision impairment to benefit from the device potential.

- Association image capture

Since kinematic consists in measuring motion without considering the forces involved thereby serving to calculate displacements, velocities and linear and angular accelerations present in the observed motion, its association with the referenced device will allow a better understanding of the errors in movement patterns and the definition of an intervention program.

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