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Technical means for objectification of medical treatments in the area of the deep stabilisation spinal system

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Abstract Information regarding two versions of an instrument called a muscle dynamometer, which enables detailed information about muscle activity in the deep stabilisation spinal system (DSSS), presented in this article. The MD01 (muscle dynamometer ver. 01) is a simple electromechanical instrument that allows measurement of muscle activity in two areas of the lumbar spine region. Measurements on patients have confirmed the usefulness of quantifying the initial state of a patient before rehabilitation as well as monitoring rehabilitation treatment; the MD01 is a suitable device for obtaining these measurements. However, a new and improved version of the MD01, the MD02, has been developed. The MD02 allows measurements in four different body regions and now has a PC interface, which allows achieving of patient information and data export for use with statistical software.

INTRODUCTION

Defects of the locomotor system have become one of the most common chronic diseases in adults. The causes of locomotor system disorders can often be traced back to childhood. Bonetti *et al.* (2005) reports that roughly 80% of the population has either experienced isolated pain in the lumbar spine area or experienced pain, with ischial propagation, at least once during their lives. Vertebrogenic disorders are among the most common chronic diseases. These locomotor system problems become evident with changes in body shape, which, unlike real deformities and orthopaedic defects, can be successfully treated with a suitably targeted compensation program. A detailed analysis was performed by Panjabi (1992). Spine stability is considered a prerequisite for axial skeleton stability and overload protection. Spine stabilisation refers to the ability of the spine system to function as a unit (while at rest), as determined by the shape of the vertebrae and the curvature of the spine. The deep stabilisation spine system (DSSS) is a group of muscles working together to insure stabilisation of the spine during all movements. The muscles of DSSS are activated by any static load, such as standing, sitting, etc. (Kolář, 2005). Changes in muscle activity during the stabilisation process are among the main factors that contribute to vertebrogenic disorders. Stabilisation muscle function, as it relates to vertebrogenic disorders, has a long history of research studies of Bergmark (1989), Cresswell *et al.* (1992), (1994), Deyo (2004), Gracovetsky *et al.* (1985) and many others.

The next study describe that compensatory exercise and targeted kinetic activity has favorable effects on the immune system, composition of the blood (Savas *et al.*2007), protection against diseases as well as its positive effects on quality of life. (Karacabey 2005, Karacabey *et al.*2005, Vobr 2001). Maximal aerobic exercise greatly affects the level of circulating thyroid hormones (Ciloglu *et al.* 2005, Cinar 2007). Due to the positive impact of regular physical activity on cardiovascular, metabolic, neural, and psychological changes in organism, the strengthening of muscles and compensatory exercise should be implemented into the therapeutical programs (Gaul-Aláčová *et al.*2005).

The deep stabilisation spinal system consists of the abdominal and pelvic muscles, and the diaphragm. The problem lies not in the independent function of individual muscles, but is the synergy of the muscle system as a unit; it is the synergy that plays a fundamental role in spine stability. Reduction in spine stability represents an important etiopathogenic factor causing back pain and many other back related problems. It is important to emphasise that there is no targeted limb movement that does not involve spinal stabilisation (Kolář, 2005). The ability to evaluate sagittal stabilisation is an important part of developing a targeted therapy. Until now, subjective patient evaluations by nursing staff have dominated the decision making process regarding the choice of treatment and rehabilitation in traumatogenic and degenerative cases involving the stability of muscles within the DSSS. Partial therapeutic quantification has been obtained through radiological or other standardized methods (Lewit & Liebenson 1993, Ozcelik *at al.* 2004), which, although helpful, do not give sufficiently accurate information regarding muscle strength of the DSSS. The need for this type of data has been the driving force behind the development muscle dynamometers.

Technical parameters

The muscle dynamometer MD01 is a simple electromechanical instrument that works on the principle of mechanical transmission of force from a lever system to an electronic meter, from which the measured value can be read. It lacks the ability to save or further process the recorded data. The MD01 allows for measurements of muscle activity of the DSSS only in the lumbar spine area. Subsequent measurements and their evaluation have shown the usefulness and justified the development of the MD01. Statistical evaluations at the beginning, during and after treatment have established the connection between the measurements and the progress, or lack there of, of patients (Malátová *et al.* 2007). However, the MD01 can not interface with a PC and as such is limited in its ability to perform sophisticated data evaluations or data archiving. The initial design of the MD01 only allowed measurements to be taken from two areas of the lumbar spine, which can also be considered a limitation.

However, the positive results obtained from the MD01 have prompted development of a new and improved version of the MD01, called the MD02. The MD02 allows simultaneous measurements in four areas of the DSSS and has a USB PC interface for displaying and processing measured values. Additionally, the data can be easily exported for statistical evaluation and archiving.

Figure 1. Muscle dynamometer MD01

Figure 2. Muscle dynamometer MD02 components

Description and characteristics of the MD01

The construction is mechanical with levered power transmission to a digital power meter (Fig. 1 and 2). Attaching the MD01 to the body is done with a set of adjustable straps with plastic buckles. It is also possible to move the mechanical parts of the MD01 in order to adjust the touch pads of the power transmission levers to specific areas in order to compensate for torso size and shape. The MD01 allows measurements in standing, sitting and front lying positions. Fitting the MD01 is most easily done while the patient is in a standing position. Once the unit is attached to the back (and held in place with the vertical straps) the vertical cross bar can be moved so that the touch pads of the power transmission levers are in the desired positions. Thereafter the horizontal straps, around chest and pelvic areas, can be fastened. The initial power tension can now be adjusted through the movement of the cross bar lever (crude adjustment) and through the twitching screws which allow for digital movement of the power sensors (fine adjustment). The standard value of static tension is 20 Newtons (other values can also be set). After setting the static tension it is possible to reset the meters with a press of the left key, which will start measurements at zero. Actual measurements must be read and noted, as there is no system software for recording the data. In addition to measuring and reading the power, the MD01 meter also displays the time and ambient temperature.

The mechanical construction of the MD01 allows, through the use of simple movable elements, variable placement of the touch pads to accommodate different torso sizes (Malátová *et al*. 2007).

Technical parameters of the MD01:

Table 1. MD01 Parameters

Parameter	Value
Maximum measuring power	80 Newton (N)
Minimum measuring power	0.5 Newton
Accuracy	0.1 Newton
Surrounding temperature	−20 to + 40°C
Power source	3V DC, 2 x 2 pcs of type AAA batteries

Description and characteristics of the MD02

The MD02 is designed to measure the power of muscle contractions of the DSSS in the areas of the lumbar spine, abdomen and if necessary other regions. Besides the actual magnitude of muscle power, the instrument also allows for observation and measurement of dynamic muscle activity. The construction includes four-channel electronic evaluation sensors.

The MD02 consists of three main parts (Fig. 2):

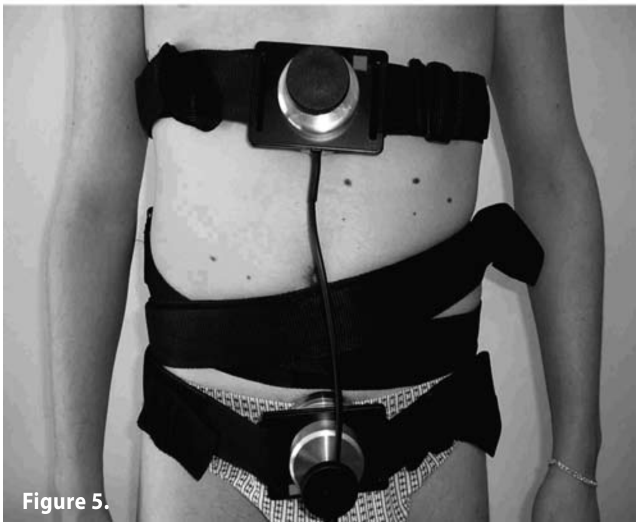
1. Four power sensors with straps
2. Evaluation unit with USB cable
3. Notebook with USB connection

The MD02 has a modular set design that enables connection of four power sensors to the evaluation unit. It is possible to adjust the unit to read one, two, three or all four sensors depending on the needs of the actual measurement. Unlike the MD01, it is possible to graph the measured data and evaluations and save all the data to a PC. File names for data can be anything that is useful; patient name, date, etc. One of the significant improvements in the MD02 is the ability to observe DSSS muscle power output as a function of time. This capability in turn allows measurement and evaluation of a num-

Figure 3. Sensor pad (internal view)

Figure 4. The placement of sensor (back view)

Figure 5. The placement of sensor (frontal view)



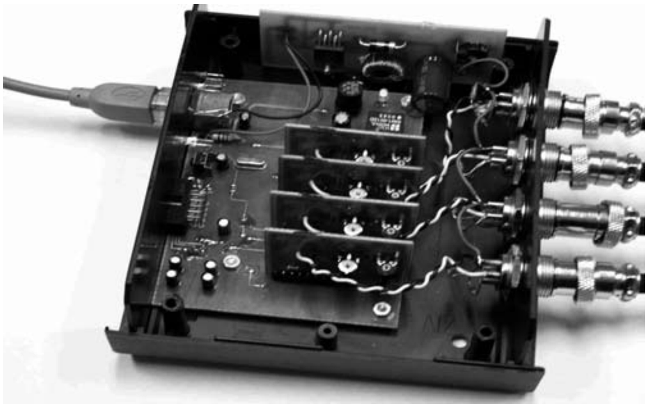
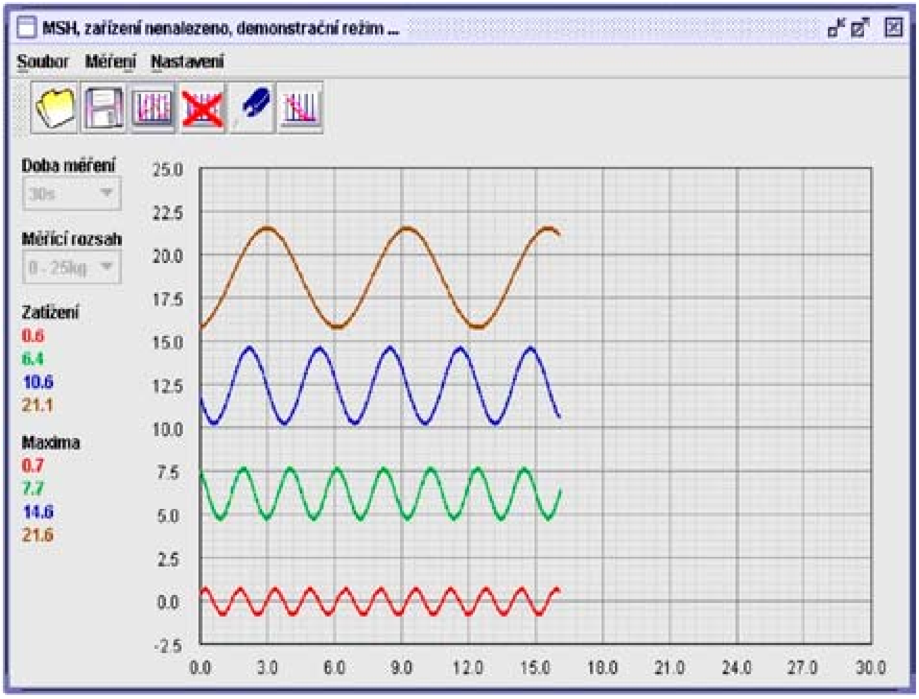


Figure 6. Evaluation Unit (internal view)



MSH, zařízení nenalezeno, demonstrační režim ...

Doba měření
30s

Měřicí rozsah
0 - 25kg

Zatížení
0.6
6.4
10.6
21.1

Maxima
0.7
7.7
14.6
21.6

Figure 7. MD02 Main (start-up) screen

Table 2. Software and Hardware requirements

PC Software and Hardware requirements	
Programming language	Java
System requirements (minimum)	CPU 500MHz, 128MB RAM, 50 MB free HDD space, USB 1.1, OS: Windows 98, 2000, XP, JRE 1.4.2 and higher
System requirements (recommended)	CPU 1GHz or faster, 256MB RAM, 50MB free HDD space, USB 1.1, OS: Windows 98, 2000, XP, JRE 1.4.2. and higher
Used libraries	Java Comm API, Swing

ber of parameters not possible with the MD01. Thanks to the transfer speed of the sensors used it is possible to observe, without any value distortion, the onset of muscular load and the subsequent load discharge. A set of adjustable fastening straps with adjustable plastic buckles allow the sensors to be placed in a variety of positions. It is also possible to adjust the mechanical parts of the MD02 in order to secure the touch pads to the required part of the body, independent of body size or shape (Fig. 4 and 5).

Muscle output values can have both positive and negative muscle power values, depending to the initial settings of the muscle preload. The power sensors, which are placed on a metallic base, are integral with the belt straps. The touch pads of the sensors are replaceable, and easily cleaned and disinfected. It is also possible to use pads of various sizes and shapes. Figure 3 shows a disassembled power sensor. The basis of the power measurement is the deflexion of a steel bar. The magnitude of the deflexion, and as such the power, is read by a tensiometer. The tensiomenter is connected to a strain-gauge bridge, where another tensiometer is placed, away from the measuring bar, providing compensation for changes in temperature. The output from the strain-gauge bridge is reinforced by an amplifier, located on the printed circuit board under the bar. The amplified and impedance adjusted signal is then fed into the evaluation unit (EU). This evaluation unit, which can be seen opened in Fig. 6, further reinforces the signal and converts it into a digital signal.

Signals from all four power sensors are transferred to the PC through a USB port. The whole unit is small and light-weight. The MD02, compared to the MD01, has a reduced number of mechanical parts and greater emphasis has been placed on expanded electronic evaluation and imaging. The MD02 is equipped with four independent power sensors. Each sensor is connected to its own input unit with its own amplifier and zero load setting; both are controlled by the microprocessor which processes the measurements from the individual sensors. The measured data is digitally filtered to remove noise generated during measurements. This is done with an algorithm that evaluates the floating average for a certain number of measurements. The measured data is transferred through the USB port to the PC for further evaluation. The measuring system and the probes get their electric power through the USB port. There is an electric potential of 5V for a maximum load of 500mA (per USB port without external power). The potential needed for the input units (± 12V) is achieved with the use of a DC/DC converter. The measuring unit is an Atmel, AVR 8-bit microprocessor. The program in the microprocessor is written in C and the complier was AVR-GCC.

When started the program searches for the measuring system, if not found, the program starts in demonstration mode which allows viewing of previously measured data.

An integral part of the MD02's PC software is the calibration program. Calibration in this case means a linearization process and calibration between the load on the sensors and the displayed load on the screen, expressed as kilograms dependent on time. True calibration is started from "calibration.exe" which is located in the "bin" directory. It is necessary to enter, into the power sensor, the exact weight, in grams. After opening the "calibration.exe" file, the calibration program control panel will appear on screen. Then, by clicking "START" the program is ready to receive input data. First, it is important to identify each of the power sensors which will be visually represented on screen by different colours (red, blue, green and brown). The choice is made by clicking "PROBE". The colour differentiation also corresponds with the markings on the input connectors on the evaluation unit, and with the colour traces on the PC screen. After choosing the appropriate sensors, their outputs must be reset. This is done by clicking "RESET" which displays the message "*reset finished*" in the right field of the screen. Next, after clicking and placing the cursor in the "real power" box and entering "0"; click on the "ADD CORRECTION" button. This action sets the output of the power sensor to zero. The load on the power sensor is then increased stepwise and the values read on the scales are entered in the "actual power" box, followed by clicking "ADD CORRECTION." This is repeated for each weight, the transferring characteristics for the whole setting is adjusted and the power values on the vertical scale on the PC screen (Fig. 7) corresponds to the load applied onto the power sensor. These steps are followed for the entire 10 kg range. When calibration is finished for all four probes, the calibration mode is ended by clicking the "CREATE AND SAVE THE CALIBRATION TABLE". This will save four calibration files, one for each sensor, into the "cal" directory. The next time the MD02 program is started, it will automatically use these calibration files and the values shown on the screen will, with maximum accuracy, correspond to the loads on the sensors.

The user package contains a set of four power sensors with corresponding cables, an evaluation unit and a CD-ROM containing a zipped "md02-install"-file. Opening and unzipping this file results in the installation of the MD02 program on the PC. Java Runtime Environment must be installed on the PC prior to unzipping the MD02 software. A driver, allowing for immediate communication with the program, is also on the installation CD. This driver is installed through the Windows "Control panel",/ "Add hardware" function. Following a successful installation, the MD02 icon will appear on the Windows desktop. The program is started by clicking the icon which will display the MD02 start-up screen (Fig. 7).

Explanations

The PC program is written in Java and requires installation of Java Runtime Environment, version 1.4.2 or higher. This program enables programming of measuring time and the span of the power load on the measuring probes. It is also possible to set the preload on the probes. In Fig. 7, the PC program screen is shown, which can, after appropriate setting changes, show the measured values, including the maximum values, show elapsed time and save all data. It is also possible to choose between two different types of visual display; (i) showing four individual graphs or (ii) one joint graph, as shown in Fig. 7. It is possible to preset, using the program menu, the measurement time and the load range put on the power sensors.

The measured values can be saved in files with unique names, such as patient name, date, etc. These files can also be exported to EXCEL or other statistical evaluation programs. Regarding the time dependent data entries, programs for frequency analysis can also be used.

CONCLUSIONS

Back pain can have a wide range of causes. One of the main etiopathogenic factors that cause back pain are problems associated with spine stabilisation muscles. The DSSS muscles need to work together as a single unit and are mutually linked through tendinous connective tissue. Attenuation or functional superiority of one muscle is never isolated, and is projected through the whole complex, resulting in the statics and dynamics of the spine always being perturbed. The result is non-specific pain in the lumbar region. Patients try to alleviate the pain by subconsciously assuming an antalgic posture that is typical and easily observed in back pain sufferers. Less obvious, and therefore more dangerous, is the change in posture associated with chronic pain syndromes (Rokyta, 2000). These problems can be diagnosed through the use of muscle dynamometers. Measurements obtained from these devices can reveal problems with the DSSS. Muscle dynamometers can then be used to monitor the progress, and adjust as necessary, the chosen therapy, in order to achieve optimal results. Examinations and measurements have confirmed the ability to quantify and the value of quantifying DSSS muscle strength using the MD01 (Malátová *et al.* 2007). We expect the MD02 to further extend this ability and value.

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