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The objectification of therapeutical methods used for improvement of the deep stabilizing spinal system

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Abstract

OBJECTIVE: Despite the ever ongoing development in the examination procedures, it is still impossible to exactly diagnose a large percentage of patients with vertebral and back (low-back and neck) pains. This is due to an insufficiently clear connection between symptoms, pathological changes and results from the imaging techniques. Besides a morphological and neurological examination, a grave diagnostic attention should be given to a possible muscular dysfunction. A simple electromechanical device called muscle dynamometer (MD01) has been constructed for the purpose of enabling to effortlessly, objectively and precisely examine the muscle power-output in the lumbar spine area and reveal a possible, often found and therapeutically treated, dysfunction of the deep stabilizing spine system (DSSS).
METHODS: The six-week-rehabilitation-course, aimed at correcting the body posture and strengthening the DSSS muscles, during which two groups of healthy adolescents (girls and boys, aged 12–16) have been obtained.
RESULTS: The statistically significant change ($p<0.001$) between the values of input and output measurements of the condition of DSSS.
CONCLUSIONS: The effectiveness of therapeutical training is confirmed and the objectification of the condition of the DSSS muscles by means of the muscle dynamometer (MD01) is verified.

INTRODUCTION

The human body comprises of a system of partially and fully stabilizing locomotor organs. The least disturbance of motional stability can at various time-intervals result in symptoms and pain conditions. Statistics show that low-back pain to be one of the most frequent reasons for a medical doctor's visit. As much as 70% adults have at some point suffered from backache. Vertebrogenic disorders are among the most frequent chronic diseases in adults. Bonetti *et al.* (2005) declare, that pain in the lumbar area itself, or in the combination with sciatic propagation, affects as much as 80% of the human population at least once in their lifetime. The various causes of such disorders may originate in childhood, when muscular imbalance develops due to an incorrect load on the system, which then results in a pathological body posture. In case of such a functional disorder of the locomotor system, indicated by changes in the shape (relief) of the body, a total recovery is ensured by suitable exercise. However, the origin of a pathological body posture is composed partly from internal factors, such as congenital defects, injuries or diseases, which decrease the load endurance of the locomotor system, and by external factors (long standing periods, wrong sitting position, wrong working and relaxing positions, as well as unsuitable movements in everyday activities). The development of a poor body posture is also influenced by causes not directly related to the locomotor system, for example oculomotor system defects. Excessive increase in poor body posture in children has been lately caused by lack of activity and exercise, and the often followed obesity.

Spinal column stabilization is considered a precondition for the axial skeleton stability and for its overload protection. A more detailed analysis was carried out by Panjabi (1992). It is the ability to maintain a resting position of the whole vertebral system, given by the shape of vertebrae and curvature of the spinal column. The cooperation of paravertebral lumbar muscles called the deep stabilizing spine system (DSSS) ensures stabilization or fortification of the vertebral column during all movements. These DSSS muscles are activated during any static load, i.e. standing, sitting etc, and follow all movements of lower and upper limbs. The activation of the spine-fortificating muscles is automatic. Flexing of the hip joint, for example, results in the activation of the respective flexors, and then automatically all the muscles stabilizing the related tendon area. These are the spine extensors and abdominal pressure muscles, such as the abdominal and pelvic bottom muscles and the diaphragm, which all stabilise the frontal side of the spine. While the flexing is a targeted motion, the stabilisation of the muscle function is spontaneous and automatic (Kolář, 2005). The entire muscle network is, as a result of muscular interconnection, always completely responsible for the stabilisation process. One of the main reasons for the occurrence of vertebrogenic disorders are changes in muscle activation during this stabilisation process (Bergmark, 1989; Cresswell *et al.* 1992,1994; Deyo, 2004; Gracovetsky *et al.* 1985; Lewit, 1991, 2001).

The view of the etiopatogenesis of vertebrogenic disorders has in the past years undergone a steady progress. Despite the pronounced development in this area, it is still impossible to correctly diagnose a large percentage of patients, mainly due to an unclear connection between symptoms, pathological changes and results from the imaging techniques. The principal cause of this insufficiency lies in an undiagnosed disorder of the DSSS muscle function that can be found through an adequate clinical examination (Kolář, 2005).

The possibility to correctly assess the condition of the DSSS and the ability to control the sagittal stabilisation of the spine is very noteworthy as it provides an opportunity for suitably aimed therapy. There is for the time being no commercially available instrument capable of measuring or evaluating the conditions of the muscles of DSSS. That is why a simple device has been constructed which, based on mechanic transfer of force by a lever system to an electronic force measuring apparatus, enables to obtain a measured value. This muscle dynamometer is capable of obtaining objective comparable measurements of the force output of DSSS muscles in the lumbar spine area.

The working hypothesis here was that a small number of the tested individuals would be capable of a correct activation of the DSSS muscles at first, while a majority should be able to do so after a proper training and subsequent physical strengthening of the DSSS muscles.

The aim of this work was also to prove the potency of the constructed devise MD01. Further, to evaluate the initial conditions of DSSS in all tested individuals by a) palpatory examination and subsequently b) by MD01 measurements. Then to educate and instruct all the subjects on a correct body posture and introduce DSSS muscle strengthening exercises for the duration of six weeks. Thereafter to determine the condition of DSSS, and to compare and statistically evaluate the values obtained from the measuring devise MD01.

MATERIALS AND METHODS

The muscle dynamometer MD01 is designed to measure the force of DSSS contractions of muscles in the lumbar spine area. It is constructed mechanically, with a lever that transfers force to a digital force measuring device (Figure 1). There is a system of straps of adjustable length, for attaching MD01 onto the human body.

It is possible to adjust the mechanical parts of MD01 in such a way that the contact surfaces of the levers correspond to the actual body dimensions. MD01 enables measurements in standing, sitting and lying positions. The strapping of MD01 onto the body is easiest in the standing position. MD01 is placed onto the back by vertical straps (like a backpack) and then the contact surfaces of the levers are adjusted to required positions by a vertically mobile lateral truss. Then, vertical straps in the area of ribcage and pelvis are fastened.

Dynamometer function

The positioning of the contact surfaces of the muscle dynamometer is based on the fact, that the muscles of DSSS form a complex so a dysfunction of one muscle therefore results in disorder of the whole system (Figure 1). The contact surfaces are placed on the dorsal side of the lumbar vertebral area. When examined and then measured, the subject is instructed to, at expiratory position of the chest, put pressure against the given resistance (the contact surface of the dynamometer, thumbs of the hand). When this is performed correctly, all the muscles of DSSS are activated, primarily m. transversus abdominis. The arc of the lower ribs shifts in caudal direction. Activation in the contact areas arises, waist circumference increases and a pressure is evolved on the contact surfaces of the muscle dynamometer.

If the examined person suffers from a DSSS dysfunction, he or she is able to activate minimally the lumbar area and then are therefore few or no muscles activated in the investigated area.

The overall DSSS insufficiency is best demonstrated in the chosen lumbar area, where the measurement is not influenced by the activation of wrong (pathological) motion stereotypes.

Method and measurements

46 healthy adolescents (26 girls, 20 boys), aged 12 to16, were used in this study. All the individuals were without any subjective problems, feeling healthy and not taking any medications. Ten were active athletes, participating in football training sessions at least 3 times a week.

The measurements were carried out in standard conditions (same place, time and temperature), always boys and girls apart. The correct positioning of the contact surfaces of MD01 had to be first found by palpitation. The examination was carried out in standing position, with a straight spinal posture. The examination was located below the lower ribs between the lumbal and lateral regions, i.e. laterally from the outer edge of m. quadrantus lumborum. Some gentle pressure was exerted on the lateral group of abdominal muscles and the subject was subsequently instructed to meet this pressure by muscle activation when exhaled. The subjective result of activation of DSSS muscles was recorded. Then contact surfaces of the muscle dynamometer were placed onto the same, marked, by palpation examined positions on the subject and set as described above (Figure 1). The subject was then again instructed to exert counter-pressure on the contact surfaces of the muscle dynamometer. The measured values were again recorded. During the measurements the muscles of DSSS had to be kept in an upright, un-flexed position. In all further examinations the proceedings were kept exactly the same.

Subsequently, two sixty-minute exercise sessions a week were carried out under the supervision of a specialist in order to achieve strengthening of the DSSS muscles. The training program lasted six weeks. The exercise routine consisted of training of correct body posture, the realization and stabilization of this posture as a starting position for further exercising, breathing and muscle conditioning exercises.

At the end, new palpatory and instrumental examinations were carried out again. Statistical evaluation was performed.

Statistical evaluation

For comparison between the values obtained before and after the training program, a statistical programme SIGMA STAT 3.1 was used and a pair t-test was applied. $p<0.05$ was considered statistically significant. The subjects were a control group for themselves.

RESULTS

Palpatory examination

At the beginning of the experiment palpatory examination of the quality of DSSS muscles in all the chosen individuals was carried out. In the initial palpatory examination 35% of the subjects were able to correctly activate their DSSS muscles against the provided resistance, while 65% subjects were unable to do so.

The results of the final palpatory examination showed a considerable improvement in the ability to activate the DSSS muscles. After the training and goal-directed

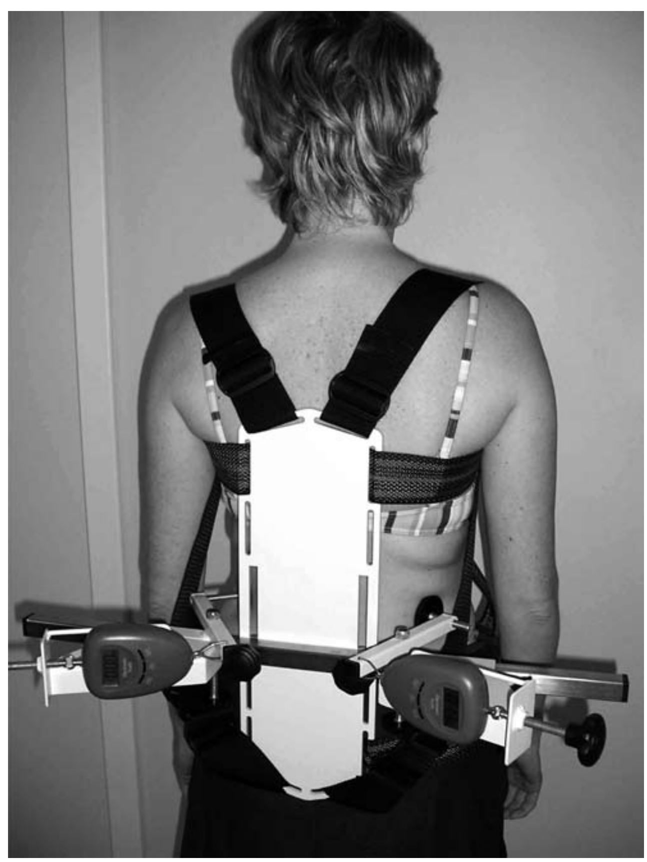

Figure 1. Illustration of strapping of the muscle dynamometer onto an examined subject

Table 1. Average values of muscle power measurements in Newtons (N) measured before the beginning of muscle training (input measurements) and after the finished six-week exercise program (output measurements).

	GIRLS					BOYS			
	INPUT		OUTPUT			INPUT		OUTPUT	
	Left	Right	Left	Right		Left	Right	Left	Right
Subject	(N)	(N)	(N)	(N)	Subject	(N)	(N)	(N)	(N)
1	4.2	4.3	9.4	8.1	**1**	5.6	2.3	15.7	24.9
2	7.5	6	9.1	6.8	**2**	2.6	7.6	21.1	23.3
3	7.1	5.1	11.6	11	**3**	2.3	2	15.9	20.5
4	10	10.9	25.8	23.2	**4**	3.1	3.5	16.5	17.4
5	8.4	5.1	33.3	24.3	**5**	5.8	4.1	17.8	23.1
6	1.4	2.1	14.7	8.1	**6**	6.4	5.1	21.1	30.7
7	4	4.3	20.1	14	**7**	3.6	4.4	19.2	29
8	1.7	0.8	24.5	20.8	**8**	2.6	2.6	12.7	20.4
9	6.4	10.4	13.2	15.5	**9**	5.2	5.2	23	29.5
10	4.4	5.4	12.6	14.1	**10**	8.1	3.1	31.1	23.7
11	0.7	0.5	13.8	9.2	**11**	5.9	7.8	26	32.5
12	6.1	0.5	22.5	17.3	**12**	2	2.3	15.6	4.3
13	2.4	4.1	11.6	11.8	**13**	1.9	11.5	17.7	22.4
14	11	8.2	14.8	9.6	**14**	5.2	3.4	46	50.1
15	15.2	14.3	8.5	9.7	**15**	10.3	9.9	32.1	39.2
16	11.9	7.4	8.7	4.1	**16**	2.2	1	24.2	28
17	5.1	9	3.9	5.2	**17**	6.9	8.3	26.9	32
18	10.8	2.3	10.8	11.2	**18**	15.4	8.9	38.4	24.7
19	9	7.1	7.1	7.4	**19**	5.8	6.8	18.1	30.3
20	9.4	7.3	15.3	13.1	**20**	7.6	10.3	24.2	10.4
21	2.7	2	39.9	31.6					
22	10.4	1.8	21.3	21.2					
23	12.7	12	12	10					
24	11.4	7.8	24.4	19.7					
25	1.8	2.1	14.1	8.6					
26	5.7	7.5	18.3	10.2					

muscle conditioning of the DSSS, a total of 89% of the subjects were able to activate these muscles correctly. There was no improvement in 11% of the subjects.

Measurements of DSSS muscle activation by the muscle dynamometer

Subsequently, the muscle power measurements of the DSSS were carried out with the muscle dynamometer MD01 according to the above mentioned instructions. A total of 552 measurements were performed during the course of the experiment. 6 input and 6 output measurements were performed on each of the individuals. Each measurement consisted of two values, one each from the right and the left side of the body. Average values (input and output) were calculated from the obtained ones (Table 2).

The aim of the chosen exercise program was to achieve that the individuals get the right stabilization muscle coordination under his or her volitional control and can start using it in his or her regular daily activities. The prerequisite of a successful therapy was the necessity of the subject's active attendance, which for the girls was not always hundred percent (Table 1). Demonstrating this are results from the following subjects – girls Nos. 2, 15, 16, 17, 19, 23 (Table 1), in whom no positive effects of training could be noticed and for most (except no. 2) the output values were in fact lower than the input ones. In Table 1 the difference between right and left side values measured in the lumbar spinal area is shown. This is connected with a greater load being put on one of the upper extremities.

Both groups, boys and girls, exhibit a statistically significant change ($p<0.001$) between the values of the two measurements. For the output measurements there is a statistical difference between the two groups, where boys show a more significant improvement after the six-week training programme than the girls. The boy group consisted to 50% of active athletes (footballers, with training sessions three times a week), who very quickly mastered the training of correct body posture and corrected the initial positions for exercises and muscle strengthening. The overall approach of the boys toward exercising and muscle strengthening was more active and responsible.

Comparison of palpation and dynamometer methods

It is significant to examine the results obtained from the two experimental methods used in this study. While the palpatory examination is highly subjective, based on the experience of the examiner, the results received from measurements performed with the measuring devise are precise and objective. Especially relevant to compare are the two output values, received from one individual, from each one the two methods used. According to the output palpatory examination, 89% of the subjects were able to correctly activate the DSSS muscles, while 11% were not capable to do so.

The results obtained from the measuring device show a distinct positive change between the input and output values for 87% of the subjects (correct activation of the DSSS muscles), while minimal or negative change was recorded for 13% of the tested individuals.

Table 2. The results from statistical comparison between the input and output values of muscle power. The values are recorded in the table as the average (X) ± standard deviation (SD).

	INPUT measurement		OUTPUT measurement		p-value
	X	SD	X	SD	
Boys	5.6	±3.2	24.4	±9.0	<0.001
Girls	6.3	±3.9	14.7	±7.5	<0.001

DISCUSSION

The muscle dynamometer MD01 has been confirmed to objectively and precisely diagnose the state of the muscles in the DSSS region, through measurements of their degree of activation. Especially clearly shown are the relative changes between the initial condition of the muscles and the state of these after a suitable exercise programme or physiotherapy. Also the effectivity of a given exercise, respectively its incorrect performance, is recognized directly by repetitive measurements throughout the physiotherapy programme. The program can then be effectively adjusted to suit individual requirements. Furthermore, repetitive measurements can be used to encourage the patient in question. From the improving numbers a correct approach to the program and a progressing amendment of the DSSS muscle area is inferred, which in its turn further motivates to rigorous exercising.

Repetitive measurements and further collaboration is also necessary in case of a revealed imbalance between the left and right sides of the lumbar area. This imbalance, when present, is clearly indicated by the DM01 results and can thus be effectively reduced or even removed by suitable physiotherapy.

As mentioned above, when performing physiotherapeutic or conditioning exercises a correct starting position is vital. Therefore, it is necessary for the patient to go through a certain instruction and/or training course aimed at correcting the initial body posture. The person should feel the difference between his/her initial posture and the newly trained way of the correct axial organ position. This posture has to be fixed, strengthened and transferred into everyday motions and activities (Kolář, 2005). Active participation of the trained person here is absolutely necessary and crucial. In this study, some of the girls were clearly less active and their approach to the exercising was at times irresponsible. This fact is then mirrored in the much less encouraging results of their group. For these girls there is no visible change between the input and output values from the MD01 measurements, for some there is even a noticeable impairment of the muscular imbalances due to an incorrect performance of the given exercises, where the correct body posture and initial position was not applied and muscles in the DSSS area were incorrectly and unevenly strained.

The difference between the two methods, though shown statistically to be minor, is also demonstrated. Whereas the subjective palpatory examination does not show any changes, the negative numbers of the DM01 measurements can objectively show a worsening of the situation. The objectivity of the measuring devise is also important in case of a partially correct activation of the DSSS muscles of a subject. Subjective conclusion of the palpatory examination can be positive in both the initial and final stages of the experiment. The precise measurements of the DM01 will by a comparison of the input and output numbers clearly indicate an improved state of the muscle area or the lack thereof.

The power and usability of the constructed device has been sufficiently proven in this study. It can find use in many areas, for one example, it can be found very valuable in fitness centres, where a measurement would show whether a visitor uses correct initial positions for his/her exercises. If a person does not perform strengthening exercises in the correct initial position, then repeated exercising only aggravate the misbalanced DSSS muscles, which will eventually cause unspecified lower back pain. One possible outcome is then a subconscious shift of the body to an antalgic position, typical and clearly recognizable in acute pain conditions. This postural change may be less apparent, but all the more dangerous, in chronic stages of the pain syndromes (Rokyta, 2000). As an incorrect initial position is easily revealed by the measuring devise, these complications can be successfully avoided by its precautionary use.

CONCLUSION

With the help of the muscle dynamometer MD01 it is possible to objectively evaluate the condition of DSSS muscles and the effectivity of the selected physiotherapy. Based on the positive results from the application of this devise, an assignment and stimulus for the project of muscle dynamometer MD02 has been initiated. This more advanced dynamometer should make it possible to monitor up to 4 DSSS muscle groups separately. Besides the static measurements of the muscle power, it will also provide measurements of muscle dynamics.

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