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The Highlighting of the Relationships between Biomechanical Parameters of Musculoskeletal System of the Spine Measured with Backfix Technology and its Statokinetic Functional State

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Abstract: The aim of this paper is to highlight the close relationship between mechanical work (J) values and functional status of the spine expressed by clinical signs such as regional pain and mobility. The group of participants is heterogeneous, consisting of 11 people who perform office work for 8 hours a day as employees of a software company. All are clinically healthy but experience temporary pain or discomfort during or at the end of the work schedule and during daily activities that involve low intensity physical exertion. They benefited from the 10 sessions of the program designed to measure, assess and enhance the statokinetic function of the spine for prevention purposes using BackFix technology. The research findings reveal an important connection between the evolution of test results and clinical manifestations.

Keywords: *back pain; BackFix technology; statokinetic function.*

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1. Introduction

The development trend of modern society has as a major consequence the performance of static, office activities, which are commonly associated with low back pain (Lagerveld et al., 2010) Therefore, the incidence of spinal decompensation and degeneration in adults is known to increase and affect the population in worrying percentages that range from 60% to 70% (O'Sullivan et al., 1997; Panjabi, 1992) A study focused on such a complex issue with many implications requires joining forces to conduct the research in several directions: symptoms, function, general wellbeing, work disability and satisfaction with care, meta-analyses, cost-effectiveness analyses as well as multicenter studies (Deyo et al., 1998; Pourahmadi et al., 2021) Spinal decompensation of the statokinetic function caused by a sedentary lifestyle and its late detection through the potential mechanisms for these changes in control and, secondly, the effect or outcome of changes (Hodges & Lorimer, 2003) determine the onset of various pathologies over time, which affect both the neuromusculoskeletal system and internal organs. Personal, social and economic outcomes are wide ranging and alarming. They affect human biological potential in the long run, leading to increased social costs of the health system, low potential and efficiency in the activity carried out, and extremely unpleasant consequences on quality of life and creative ability, which are diminished. Clinical practice guidelines promote the view that low back pain has a favorable prognosis, the 2000 UK Guideline stating that 90% of cases can recover within six weeks (Koes et al., 2001; Pengel et al., 2003; Waddell & Burton, 2001).

The approach with current technologies (qualitative postural analysis using the somatoscopic frame or quantitative postural analyses based on digital image) (Cordun, 1999; Pongsatorn et al., 2021; Puntumetakul et al., 2021) is tardy because it targets symptoms, therefore effects rather than causes, being related to the appearance of unaesthetic body, back pain, physical suffering, injury to the distal segments (Hodges & Lorimer, 2003; Pengel et al., 2003) or severe spinal pathology (Deyo et al., 1998;

Pourahmadi et al., 2021). Analysis of the causal chain (vicious static postures maintained for a long time, muscle imbalance, musculoskeletal biomechanical changes, hypotonia, hypertonia, muscle shortening/ lengthening, permanent postural changes, pain and the onset of severe disorders (Arab et al., 2018; Korff, 1994; Omid et al., 2011) highlights the positioning of muscle imbalance between the primary links, playing a causal or enhancing role in triggering and aggravating or, if stabilization therapy is applied in due time, counteracting, delaying and improving subsequent links (Hansen et al., 1993; Kellett et al., 1991; Koumantakis et al., 2005). On the causal chain of spinal degeneration, vicious postures are consequences of muscle imbalances and failure (Omid et al., 2020; Puntumetakul et al., 2021), followed by the onset of transient pain and contractures during or at the end of the work schedule and during daily activities that involve low intensity physical exertion (Saiklang et al., 2022). At first, pain disappears after resting but tends to persist if there is no immediate compensatory intervention (Omid et al., 2020; Saiklang et al., 2022).

2. Hypothesis

Early detection of musculoskeletal imbalances and spinal muscle failure by measuring mechanical work (J), $W = \int F\, ds$, followed by their compensation and optimising the statokinetic function of the spine through specialised intervention using BackFix technology for adults performing office activity, leads to the reduction and even disappearance of the clinical signs of regional pain and an improvement in spinal mobility.

3. Participants

The group of participants is heterogeneous, consisting of 11 people who perform office work for 8 hours a day as employees of a software company. All are clinically healthy but experience temporary pain and discomfort during or at the end of the work schedule and during daily activities that involve low-intensity physical exertion. They benefited from the 10 sessions of the program designed to measure, assess and enhance the

statokinetic function of the spine for prevention purposes using BackFix technology.

4. Technology and method

The technology and method that has brought quantitative measurement solutions for the most commonly affected part of the human body – the spine – is called BackFix, which is developed in Romania, is a registered trademark in Europe, has two basic patents (Schor et al. 1993; 2015), and benefits from a lot of studies and research, scientific papers, bachelor's (Schor, 1997; 1998) and doctoral theses (Schor, 2001; 2012). BackFix technology has resulted from the need to develop a standardized system for the diagnosis and computerized optimization of the statokinetic function of the spine, which allows preventing and treating orthopedic conditions specific to the period of child and adolescent growth and development (postural changes, spinal deviations and deformities) as well as arthritic-type degenerative diseases that occur either due to a sedentary lifestyle or intense and repeated demands (discopathy, herniated disc, protrusion, etc.) (Panjabi, 1992; Pongsatorn et al., 2021; Puntumetakul et al., 2021). The novelty brought by BackFix technology consists in the possibility of measuring the values of musculoskeletal function (force - N), amplitude (cm) and mechanical work (J) in the spine and finding a mathematical expression that can both numerically characterize the state of balance in the muscular support of the trunk and allow a direct association with correct posture.

Thus, as regards the computerized measurement and musculoskeletal assessment of the spine using BackFix technology, we are interested in two categories of indicators: mechanical work (J) (as an expression of strength and mobility) and coefficients of musculoskeletal functional balance of the spine (CETAP and CETOLO).

In order to highlight the close relationship between mechanical work (J) values and functional status of the spine, Tables 1 and 2 provide information about the clinical signs of pain and regional mobility obtained through the initial and final assessments. Table 3 shows the mechanical work

(J) values measured initially and finally (after 10 sessions) as well as the parameters of musculoskeletal balance of the antero-posterior thoracic and thoracolumbar spine (CETAP and CETOLO) for the mechanical work (J) values measured initially and finally.

BackFix technology was used to measure and assess the spine, being possible to interpret the results according to value ranges for the following selected indicators: antero-posterior thoracic musculoskeletal balance coefficient (CETAP) and thoracolumbar musculoskeletal balance coefficient (CETOLO). These ratios faithfully characterize the functional proportionality between agonist and antagonist muscles, between agonist and antagonist muscle chains as a numerical expression of the individual posture, the values of 0.80-0.90 representing the correct, optimal posture of the spine (Schor, 2012).

The value domains (zones) for the CETAP and CETOLO indicators are:

A. Functional optimum zone – 0.80-0.90 – characterized by good health, lack of pain, optimal mobility, correct posture in static and dynamic conditions, spine with proper level of balanced muscle support; staying in this zone requires maintenance gymnastics with compensatory efforts for the effects of office work.

B. Zone of medium risk for pathology and overload – 0.60-0.79 – characterized by physical fatigue, posture with negative attitudinal changes in static and dynamic conditions, spine with moderate musculoskeletal imbalances, lack of pain; it can be considered as a "transition zone" from where one can either access the upper "functional optimum zone" through computerized physiotherapy or relapse into the "major risk zone" by ignoring maintenance gymnastics and compensatory efforts.

C. Zone of major risk for pathology and overload – 0.30-0.59 – characterized by incorrect posture with pronounced physiological curvatures, local or global pain in the spine that occurs during physical exertion (transient pain) or has become permanent, low mobility, discopathy, disc degeneration, protrusion or even herniated disc in adults).

The computerized individual kinetic program designed to enhance the statokinetic function of the spine was based on measurement results. Computerized kinesiotherapy was performed using BackFix technology.

The measurement, assessment and computerized kinetic program were carried out within Medisport using the own BackFix equipment, and physical therapists were part of the Medisport team.

5. Results

Table 1. Clinical signs at the initial assessment.

Initials	Status of the spine – Clinical signs
P.A.	Reduced mobility of the shoulder girdle and pain in the thoracic area, mild cervicothoracic pain
N. B.	Low back pain when walking more than 30 minutes
O. R.	Pain in the thoracic area when sitting on a chair for more than 2 hours
V.V.	Cervical pain in the evening, low back pain when walking
I.I.	Low back pain after cycling
E. P.	Low back pain, contractures in the cervical area when sitting on a chair for more than 2 hours
A.N.	Reduced mobility of the shoulder girdle and pain in the cervicothoracic and lumbar areas
V.P.	Cervicothoracic and low back pain when standing for an extended period of time
K.C.	Cervical and low back pain
K.L.	Low back pain at the end of the day
A.S.	Low back pain when getting up from the chair

Source: Authors' own conception

After performing 10 computerized kinesiotherapy sessions using BackFix technology, patients reported an improved status of the spine at the final assessment, the clinical signs being presented in Table 2:

Table 2. Clinical signs at the final assessment.

Initials	Status of the spine
P.A.	No pain, improved mobility
N. B.	No pain, improved mobility
O. R.	No pain, improved mobility
V.V.	No pain, improved mobility
I.I.	No pain, improved mobility
E. P.	No pain, improved mobility
A.N.	Cervicothoracic discomfort when sitting on a chair more than 2 hours, improved mobility
V.P.	No pain, improved mobility
K.C.	No pain, improved mobility
K.L	No pain, improved mobility
A.S.	No pain, improved mobility

Source: Authors' own conception

Table 3 shows the mechanical work (J) values measured initially and finally (after 10 sessions) as well as the parameters of musculoskeletal balance of the antero-posterior thoracic and thoracolumbar spine (CETAP and CETOLO) for the mechanical work (J) values measured initially and finally.

Table 3. Test parameters – initial and final measurements

	TRB RS I	TRB RS F	TRB RF I	TRB RF F	TRGN IL I	TRGN IL F	CET AP I	CET AP F	CETO LO I	CETO LO F
PANB	121	136	154	165	46	98	0.79	0.82	0.3	0.61
OR V	64	105	144	167	40	124	0.45	0.63	0.28	0.74
V	43	87	76	110	39	81	0.57	0.79	0.52	0.73
II	116	159	169	190	35	90	0.69	0.83	0.21	0.47
EPAN	122	194	215	220	37	87	0.57	0.88	0.18	0.99
	31	80	115	166	43	108	0.27	0.65	0.37	0.48
	53	60	123	166	40	86	0.43	0.52	0.32	0.35

VPK	66	130	90	158	44	80	0.73	0.82	0.49	0.50
CKK	33	57	75	91	25	47	0.44	0.62	0.33	0.51
LA	70	119	153	161	57	104	0.46	0.74	0.37	0.64
S	110	137	187	204	55	135	0.59	0.67	0.29	0.67

LEGEND

TRBRFI - front pull ups - initial

TRBRFF - front pull ups - final

TRBRSI - pull ups to the back - initial

TRBRSF - pull ups to the back - final

TRGNILI - knee-to-chest pull ups - initial

TRGNILF - knee-to-chest pull ups - final

CETAPI - antero-posterior thoracic balance coefficient - initial

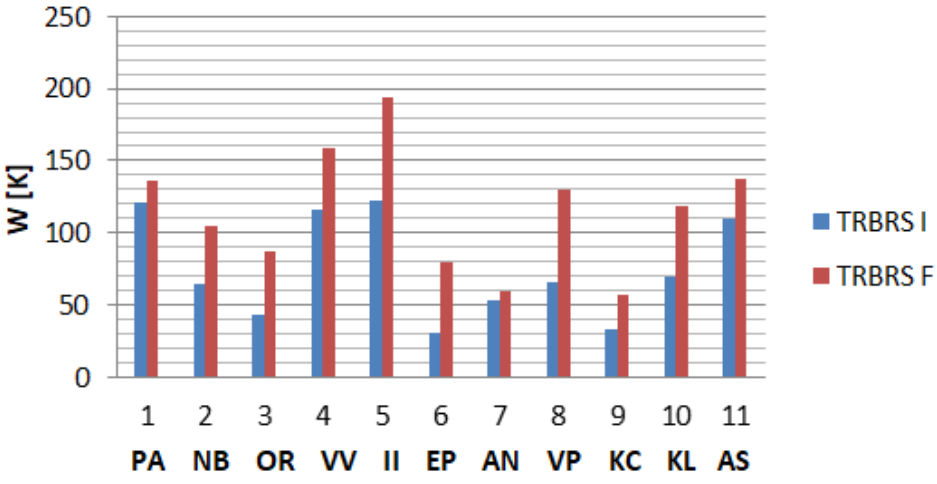
CETAPF - antero-posterior thoracic balance coefficient - final

CETOLOI - thoracolumbar balance coefficient - initial

CETOLOF - thoracolumbar balance coefficient – final.

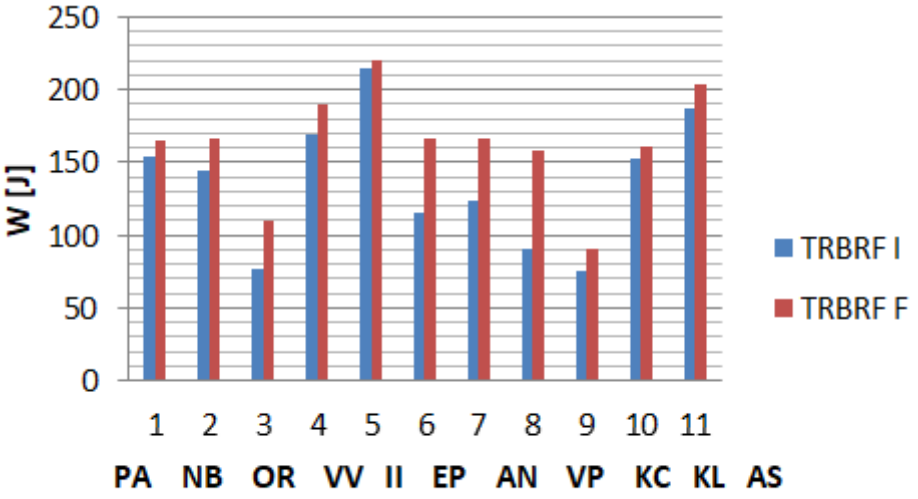
Source: Authors' own conception

The increase of mechanical work (J) values is noticed in all participants for all measured regions. For the posterior half of the thoracic area, patient AN has obtained the smallest increases, being the only one who still experiences discomfort in the cervicothoracic area when maintaining the sitting position for more than 2 hours (fig 1). Mechanical work (J) measurements for the 1/1 anterior cervicothoracic area show sufficient increases for all patients (fig 2), this being the region that reveals each person's potential to develop mechanical work (J). The increases of mechanical work (J) in the lumbar area are very large, highlighting that the main deficit of each patient was in the lumbar-abdominal area (fig 3). As a result, low back pain disappeared in all patients.



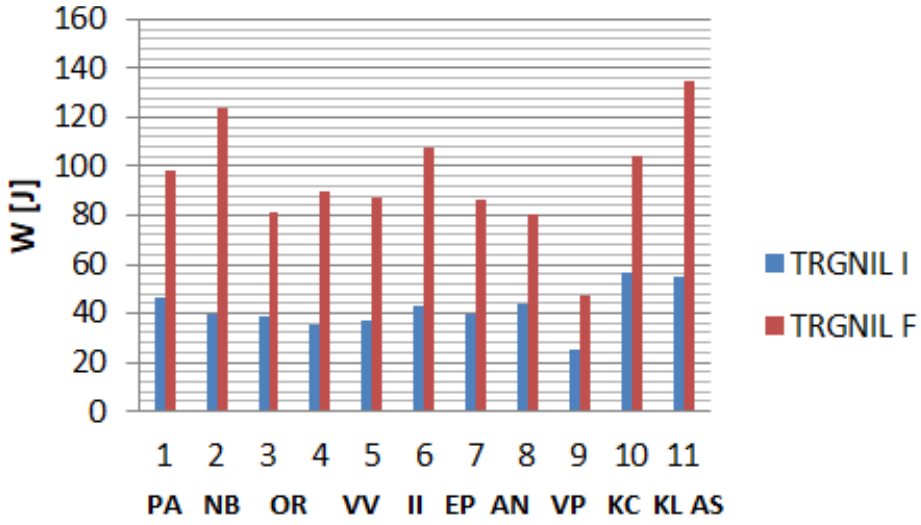
Source: Authors' own conception

Figure 1. Evolution of mechanical work (J) values for the posterior half of the cervicothoracic area – initial measurement (blue), final measurement (red).



Source: Authors' own conception

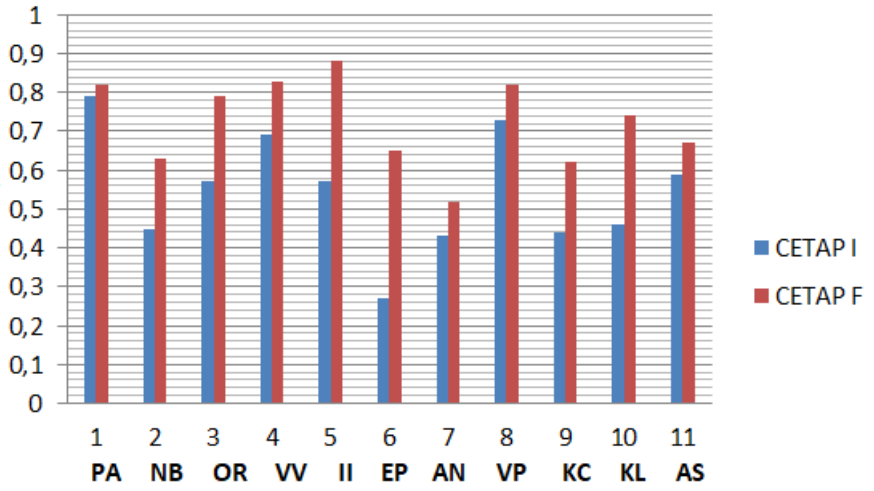
Figure 2. Evolution of mechanical work (J) values for the anterior half of the cervicothoracic area – initial measurement (blue), final measurement (red)



Source: Authors' own conception

Figure 3. Evolution of mechanical work (J) values for the lumbar-abdominal area – initial measurement (blue), final measurement (red).

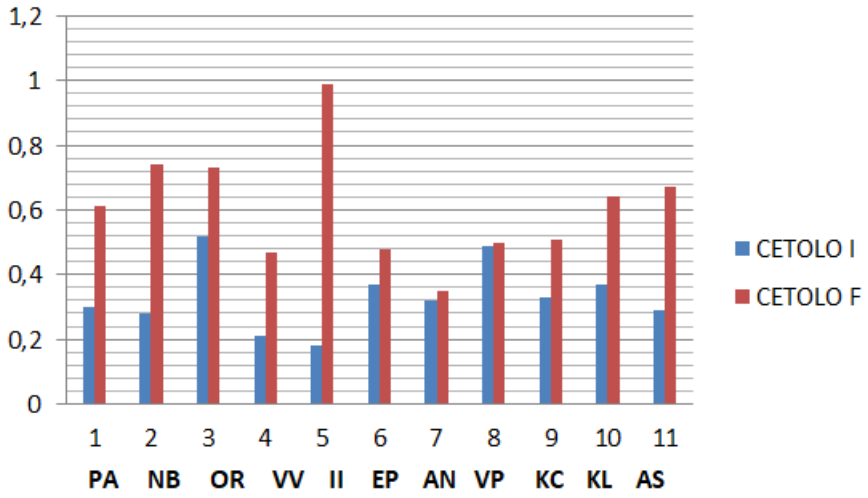
For the antero-posterior thoracic musculoskeletal balance coefficient (CETAP) defined as a ratio between W_{TRBRS}/ W_{TRBRF}, the progress is obvious. In the initial test, 4 patients were in the "transition zone" of the musculoskeletal functional balance diagram (0.60-0.79), and 7 were in the "major-risk zone" (0.30-0.59). After 10 sessions, in the final test, the antero-posterior thoracic musculoskeletal balance coefficient (CETAP) has increased for all participants, 5 of them being in the "functional optimum zone" (0.80-0.90), and 6, in the "transition zone" (0.60-0.79). All participants have exceeded the "major-risk zone" (0.30-0.59) (fig 4).



Source: Authors' own conception

Figure 4. Evolution of antero-posterior thoracic balance values – CETAP – initial measurement (blue), final measurement (red)

For the thoracolumbar musculoskeletal balance coefficient (CETOLO) defined as a ratio W_{TRGNIL}/ W_{TRBRF}, the increases are also high. In the initial test, all participants were in the "major-risk zone" (0.30-0.59). After 10 sessions, in the final test, the thoracolumbar musculoskeletal balance coefficient (CETOLO) has increased for all participants, 1 of them being in the "functional optimum zone" (0.80-0.90), 5 in the "transition zone" (0.60-0.79), and 5, still in the "major-risk zone" (0.15-0.59).



Source: Authors' own conception

Figure 5. Evolution of thoracolumbar balance values – CETOLO – initial measurement (blue), final measurement (red)

4. Conclusion and discussion

The research findings reveal an important connection between the evolution of test results and clinical manifestations.

The use of mechanical work (J) measured with the help of BackFix technology has proven to be effective in assessing muscle failure and musculoskeletal imbalances of the spine for adults performing office activity, and the improvement of mechanical work (J) values and musculoskeletal functional balance has resulted in the disappearance of spinal pain in all participants after 10 computerized kinesiotherapy sessions. Measuring the mechanical work (J) of the spine and using its musculoskeletal functional balance coefficients (CETAP and CETOLO) allowed prioritization in the personalization of programs designed to enhance the statokinetic function of the spine according to their values. The value domains (zones) for the CETAP and CETOLO indicators show that patients have reached a statokinetic functional status of the spine that allows:

- making the transition to the next (upper) stage of balancing and increasing mechanical work (J) for patients in the "transition zone" or the "major risk zone";

- maintaining long term health through minimal maintenance gymnastics and preventive annual measurements for patients in the "functional optimum zone".

Therefore, we propose the following practical prevention solutions:

- continuation of computerized kinesiotherapy until reaching the "functional optimum zone" for all patients in the other two zones;

- biannual preventive tests for the entire staff;

- personalized adjustment of the workspace and position in relation to the components of office work (chair, desk, monitor, keyboard);

- calculation of losses that result from neglecting issues related to the musculoskeletal functional balance of the spine starting from the days of sick leave for back pain per year.

5. Discussion

A relationship was observed between the low values of mechanical work (J) in the muscle chains and muscle groups of the trunk and the low functional status characterized by the emergence of pain. Also, a relationship was noticed between the improved personal values of mechanical work (J) and the achievement of wellbeing accompanied by the disappearance of pain.

The physiological explanation for the disappearance of pain with the increase of mechanical work (J) is related to the fact that, among the elements that participate in generating mechanical work (J) (muscles, joints and bone levers), muscles are the most intensely vascularized structures, and blood supply to the muscles is dependent on and directly proportional to their ability to produce mechanical work (J), the intake of nutrients being also directly proportional to it. The nutrition of periarticular and articular structures thus depends on the functional level of the muscles, on their ability to develop mechanical work (J).

A low functional musculoskeletal level, translated by a weak ability to develop mechanical work (J), explains the onset over time of arthritic-type degenerative diseases at the intervertebral and disc joints.

Author Contributions

Conceptualization, D.S. and V.S.; methodology, D.S. and V.S.; software, D.S. and V.S.; validation, D.S. and V.S.; formal analysis, A.G., F.B. and C.P.; investigation, A.G., F.B. and C.P.; resources, D.S. and V.S; data curation, A.G., F.B. and C.P.; writing—original draft preparation, D.S. and V.S.; writing—review and editing, A.G., F.B. and C.P.; visualization, A.G., F.B. and C.P.; supervision, D.S; project administration, D.S. and V.S; funding acquisition, D.S. and V.S. All authors have equally quoted and read and agreed to the published version of the manuscript.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

BackFix technology has two categories of tests: the preliminary ones and standard tests (Schor, 2012). Regardless of the type of test it is very important to make a very clear instruction for the patient, so that he understands how to collaborate, the test position and the correct execution of movements, and if a painful threshold test is done it is important to communicate properly to accurately determination of the level of the pain threshold.

A. Preliminary tests (pain threshold test, antagonist test and bilateral 10RM) - include a category of measurements that allow us to determine the load and range of motion in the exercises necessary to eliminate pain and achieve the appropriate level of improvement in order to perform tests standard (10RM).

1) Pain threshold test - this test is particularly valuable and is used in all situations where pain is present on movement, the analgesic blocking reflex being present and directly proportional to the intensity of pain. It is the test by which we establish 3 parameters of execution of the movement:

a) the level of movement length at which the patient can work without feeling pain.

b) the level of the brake at which the patient can work without pain.

c) the level of force with which the patient can work without pain.

Depending on these parameters we establish the working model / graph at the painful threshold.

2) Antagonist test - with the help of this test we establish that working model for antagonists that would allow the painless stretching of the agonists. When active movement is possible on agonists, we do the painful threshold test and establish the range of painlessness. We work with this model until the maximum painless contraction is possible.

3) The 10 RM bilateral test is used for the alternative work of the lower or upper limbs and allows the establishment of the initial level of asymmetry between the 2 limbs on the tested movements, the final objective being to symmetry them.

B. Standard tests - allow us to measure values of force (N), amplitude (cm) and mechanical work (j) at the trunk, the type of test used to be 10RM (RM = maximum repetitions). In the case of standard tests, we always measure in advance the amplitude potential on the test movement, from the test position 0 to the maximum possible amplitude level.

I. Simultaneous traction of the knees to the chest - (ILIO)

Test position:

In Figure 6. D.D. with the knees bent at 90 degrees, the hip 90 degrees, the arms close to the body.

For the application of the socket we have two situations:

- ankle socket.

- grip above the knee, in the lower third of the thigh (for patients with knee problems).

1. The instruction is made very clear so that the patient understands how to collaborate.

2. Passively measure the amplitude potential of the motion from the zero-test position to the maximum possible amplitude on the tested motion.

3. Perform 10 traction movements of the knees to the chest in a regime of 10 RM (maximum repetitions), starting from zero position to maximum active amplitude, the patient ensures the fixation of his position with his hands.



Figure 6. Simultaneous traction of the knees to the chest - (ILIO). Initial and final positions.

Source: Authors' own conception

II. Stick chest expander traction - TRBRF

Test position – In figure 7. D.V. with legs apart, chin at the edge of the table, arms outstretched diagonally-forward-up, elevation under the abdomen to dilute the lumbar area.

- Hands on the cane to set the grip depending on the length of the patient's arm. It is considered that the angle formed between the vertical line

of the head and the line of the arm stretched diagonally-forward-up to 45 degrees. (respectively at 10:00 and 14:00).

1. The instruction is made very clear so that the patient understands how to collaborate and what to do.

2. Passively measure the potential amplitude of the motion from the zero-test position to the maximum possible amplitude on the tested motion.

3. Perform 10 traction movements of the cane up to the level of the intermammary line.

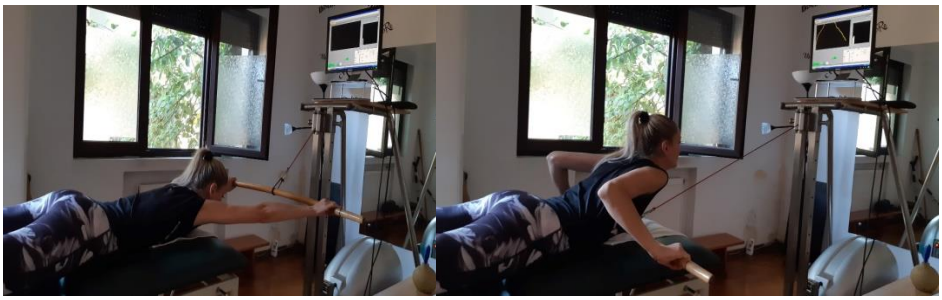


Figure 7. Stick chest expander traction – TRBRF. Initial and final positions.

Source: Authors' own conception

III. Stick traction to the blades - TRBRS

Test position

In the figure 8. D.V. with legs apart, chin at the edge of the table, arms outstretched diagonally-forward-up, elevation under the abdomen to dilute the lumbar area.

- Hands on the cane and set the grip depending on the length of the patient's arm. It is considered that the angle formed between the vertical line of the head and the line of the arm stretched diagonally-forward-up to 45 degrees. (respectively at 10:00 and 14:00).

1. The instruction is made very clear so that the patient understands how to collaborate and what to do.

2. Passively measure the potential amplitude of the motion from the zero-test position to the maximum possible amplitude on the tested motion.

3. Perform 10 traction movements of the cane to the level of the shoulder blades.

If it is not possible to test the movement up to the level of the shoulder blades, then it is necessary to determine the cause:

- if there is only a deficit of muscular strength on the muscles of the scapular belt and the posterior half, then from the seated position, the patient can wear the cane with wear through the back of the head up to the level of the shoulder blades;
- if there is a deficit of mobility in the scapular belts then the patient cannot pass over the shoulders.

The cause of impossibility to perform the movement tested according to the formulated requirement becomes, in this case, an intermediate objective to recovery.



Figure 8. Stick traction to the blades – TRBRS. Initial and final positions.

Source: Authors' own conception

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