STIMULON: NEW METHOD AND DEVICE IN PHYSICAL THERAPY AND REHABILITATION.

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Abstract. *Method and device for training skeletal muscles, in particular stabiliser muscles, in physiotherapy, rehabilitation, sports and space medicine. Today, most devices for training the human body work with resistance. This makes these devices rather difficult to be used under unusual circumstances and for persons of age and with disabilities. STIMULON suggests a totally novel approach: the physics behind is the Strouhal number* $S_t = A_{mplitude} \times F_{requency} / V_{elocity}$*. Recently studies have confirmed earlier studies in that the optimum Strouhal number for bird's flight and fish flexing is approximately 0,3. Looking at the Strouhal number in its fully written form, the equation describes a relationship between a potential and a movement. Furthermore, this equation has no mass involved. New requirements in space medicine and sports injury studies claim, as opposed to presently known resistance training, that certain muscle trainings do request the use of only a fraction of the muscle force but for a longer period of time. STIMULON is a method and device, where the person considered can train particularly stabiliser muscles at low efforts but over a longer period of time. The essential advantages of STIMULON are: can be used for any kind of repetitive movement (circular, elliptical, reciprocating), under most adverse conditions such as in-bed, post-surgery care, post-injury rehabilitation, for people with movement disabilities, by elderly people and in space.*

Keywords: Physical exercise without resistance, stabiliser-specific muscle training, MVC

1. Introduction - Scientific/Medical background

Conditions such as prolonged bed-rest and weightlessness cause muscle atrophy (muscle wasting) in the first instance, and subsequently a general physical deconditioning, which may include the deconditioning of the cardio-vascular and cardio-respiratory systems.

Due to their specific ways of working and muscle fibre make-up, it is possible to distinguish between two broad categories of skeletal muscle:

1) "Stabilisers", the primary function of which is to provide stability to the trunk and other body segments, and
2) "Mobilisers", the primary function of which is to move body segments

Stabilisers' muscle fiber physiology is such that it allows these muscles to work for prolonged periods of time without switching off. However, these muscles are able to produce only relatively low forces of contraction, often in the absence of movement. Stabilisers respond at 20 to 30 % of Maximum Voluntary Contraction (MVC). An example of this would be the contraction of some of the muscles along the spine to keep us upright. If these stabilizers did not work, not only would we be unable to maintain an upright posture, we would tip forwards on even slight body movements such as lifting an arm or lowering our head (Mottram and Comerford, 2001).

Mobilisers, on the other hand, fatigue quickly and are not able to work for prolonged periods of time. However, they are capable of producing great force when they contract. Mobilisers respond at 40 to 100 % MVC. An example of a mobiliser in the lower extremities would be the gastrocnemius (superficial calf muscle) which can produce great power during walking, running or even sprinting, but has to relax between contractions in order not to fatigue rapidly or go into anaerobic working mode, something that can be sustained for a matter of seconds, only.

While stabilisers are rightly associated with the human upright posture against gravity and many postural muscles are stabilisers, anti-gravity work is only part of their role. Stabilisers are responsible for maintaining a stable trunk (and, to a lesser extent stable proximal limbs) in any position. During swimming or diving, for example, the trunk is in a horizontal, or even head-down position, yet stabilisers have to work to stabilise the trunk against the vigorous movement of the limbs. The same applies to martial arts, or even to a person lying on their back or side, trying to access an awkward place and using forceful (upper extremities) limb movement at the same time (e.g. during home improvement jobs or in a work situation).

2. Discussion of current practice

Due to their differences in working stabilisers and mobilises also require different ways of training. Mobilisers are most appropriately trained by using repeated “sets” of exercises, in which the muscle contracts forcefully against resistance (at 40 to 100 % MVC) and then relaxes again. Stabilisers need to be worked at low effort (≤ 30% of MVC - maximum voluntary contraction), but sustained activity, which may be concentric or eccentric.

Traditionally, training of the musculoskeletal system (both in professional and recreational sports and rehabilitation) has focused on mobilisers, and neglected the specific training requirements of stabilisers. This has often contributed to or even caused imbalances in the musculoskeletal system.There is ample evidence in the literature on musculoskeletal rehabilitation to highlight the consequences of inadequate stabilizer recruitment and activity (Richardson and Jull, 1995). At best it results in poor motor performance, at worst in chronic pain states, such as chronic low back pain and other musculoskeletal problems.

Muscle atrophy or weakening is more problematic and disabling if it affects the body’s stabilisers, than the mobilisers. This is because if the stabilizers cannot efficiently maintain the body in any given position and during locomotion, the mobilisers have no firm base from which to work. This has an immediate knock-on effect on the mobilisers’ ability to function properly and tends to result in segmental instability (which is likely to be one of the main causes of chronic low back pain) and overuse syndromes (O’Sullivan, 2000).

While the deconditioning of the body’s stabiliser muscle system as a result of prolonged bed-rest is undesirable and detrimental, it is equally, or even more problematic in relation to weightlessness. During bed-rest and under weightlessness conditions all the stabilisers which normally work at a low grade but constantly to keep the body upright against gravity do not have to fulfill this function any more. As a result they become de-conditioned very rapidly. However, the stabilisers do not only have an important anti-gravity role. As already mentioned, they also need to stabilize the trunk and parts of limbs while limbs or other parts of the same limb move. Unless they can do this effectively, limb movement will result in overall body movement. This is detrimental under the influence of gravity, where a weakened muscular-skeletal system is likely to prolong patients’ stays in hospital and may even contribute to falls and further problems on discharge from the hospital. It is equally problematic in space, where it causes other challenges. There, a simple movement such as operating a lever or using a screwdriver may result in the whole body moving. This, clearly, not only poses a risk of injury to the person’s musculoskeletal system, but may also adversely affect the operation itself (Jemmett *et al*., 2004). In addition, persons exposed to prolonged weightlessness in space tend to experience significant problems with their musculoskeletal system on their return to Earth, while their system has to readjust to the effects of gravity.

Clearly, both people on prolonged bed-rest and people experiencing prolonged weightlessness would have less musculoskeletal problems in their transition to normal activities, if their stabilising muscle system was not allowed to weaken.

3. Innovation

Interestingly, nature itself provides a model that can be used to counteract these effects and train stabilisers effectively. Migratory birds and other animals, including fish, cover long distances while making optimum use of their resources and minimizing fatigue.

The physicist V. Strouhal came up with an equation (1878), which expresses an ideal relation between performance/potential and movement:

$$S_t \times V_{(Velocity)} = A_{(Amplitude)} \times F_{(Frequency)} \quad \textbf{(1)}$$

Better known as the dimensionless Strouhal number:

$$S_t = fA / V \quad \textbf{(2)}$$

Note the absence of mass in this formula, which equates to an absence of resistance and load. Taylor *et al. (2003)* have confirmed that in migratory birds and fish the Strouhal Number is ~ 0.3 .

Based on this equation we have developed a training method and device, STIMULON, which allows for stabiliser-specific training, by facilitating exercise

- at ≤ 30% MVC
- over prolonged periods of time
- at low frequencies (0,1 to 4 Hz)
- without working against resistance or load.

Inspired by these physiological and natural principles, we specifically aim at exercising stabilisers. Due to the principles governing the training of stabilisers, it is not desirable to work against resistance, or to do forceful movements such as in weight training and with other gym equipment such as steppers or static bikes.

On the contrary, relatively small movement at very low force (up to 30% MVC) is required to ensure that

a) stabilisers *are* recruited
b) mobilisers *are not* recruited
c) stabilisers remain recruited throughout the movement.

STIMULON's way of functioning may be based on a simple crank mechanism. Depending on the specific training requirements, the crank lever can be operated in a circular, elliptical or linear manner. With reference to Strouhal's equation: A = a variable lever arm or the amplitude of the movement (length, height or circular movement), F = frequency of the movement, V = a target/mean speed, and $S_t \leq 0.3$, which is equivalent to ≤ 30% of MVC for stabiliser muscles. It should be reminded that human physiology is organised for low frequency movements.

STIMULON thus defines a specific movement in its movement pattern and speed and furthermore controls it over an adequate time. The work to perform the movement is done by the person exercising. This work can be done by moving upper or lower limbs or by stretching movements like in rowing, whatever is adequate to recruit stabiliser muscles associated with the movement.

STIMULON can be connected to a computer, which not only calculates the optimum parameters, but also provides an objective and reproducible way of assessing and reassessing stabilizer performance. Both the computer and a display panel on the device itself also allow immediate auditory and visual feedback on operator performance against a set target, making it easy for operators to exercise consistently at the optimum setting.

The STIMULON method and device has multiple applications:

- in rehabilitation,
- in post-surgery care, including with patients on prolonged bed-rest
- in physiotherapy
- for people with movement deficits (for e.g. orthopedic or neurological reasons)
- in recreational and elite sports.

STIMULON does not work with resistance. So it can be built extremely lightweight, which makes it equally suitable for operation in space and from a hospital bed. Its use is easy and very motivating for two main reasons:

a) it allows constant comparison of one's performance against the target performance,
b) due to the absence of resisted muscle work even very weak or frail individuals are able to exercise effectively and successfully.

The evolutionary idea of STIMULON is that it can be used equally well on earth as in space. The key to this is the absence of mass / resistance in the Strouhal equation. The dimensionless Strouhal number has been found to be ~ 0,3 for energy optimum. $S_t \sim 0,3$ seems to be a universally valid evolutionary optimum for any continuous movement, that can be assimilated to wavy movements.

Within the scope of a doctorate thesis, clinical studies are presently undertaken at UFMG, Belo Horizonte, to

- help define a set of specific exercises for relevant stabiliser muscles to be trained
- refine the device for the exercises so defined
- evaluate the therapeutic effects of STIMULON exercises in a clinical environment

Furthermore, the STIMULON method and device participate in a bed-rest study organised by ESA (European Space Agency) for evaluating STIMULON exercises under space conditions

Besides training posture musculature, STIMULON helps mobilizing joints and articulations, activating the cardio-vascular system and enhancing body proprioception. It is lightweight and easy and safe to be used. STIMULON is totally objective, reproducible and controls movements at optimum energy input.

4. References

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5. Responsibility notice

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