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Original Article

MusTone muscle analysis device. Applicability and data

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Abstract:

Considering that both in space and on earth, there is an intensive need of a complex method that can offer an objective characterization of the striated muscular tissue from the functional aspects to mechanical properties. At Institute of Space Science it was developed a device that may provide this solution. The device consists of a striker, used to apply a mechanical impulse to the muscle, up to 8 accelerometers on skin and 1 on the striker, one power supply and one data processing unit that is the data processor. The acceleration signal is recorded in the plane determined by the direction of the muscle fibre and the direction on which the mechanical excitation occurs, for both the percussion object and the 8 accelerometers placed along the fibre. At the present moment, the parameters identified that can be extracted from the raw data acquired with MusTone device are tone and muscle tension, biomechanical properties like elasticity, viscoelastic properties like the relaxation time after mechanical stress. In order to test the device applicability in different domains like space, sport performance or medical, it has to be verified in relevant environments in terms of consistency of the data. This testing campaign includes testing in Dry Immersion Facilities for space relevant conditions, testing in sport training on a group of performance athletes, testing medical suitability on patients with muscle atrophy. Considering the test already performed and the intentions in the near future, we believe that the device can possibly improve the results of training in many different domains and it has great applicability and versatility.
Key words: muscle analysis device, sport performance, muscle evaluation, microgravity

Introduction

Physical At the present moment, in space and on earth, there is an intensive need of a complex method that can offer an objective characterization of the striated muscular tissue from the functional aspects to mechanical properties. In space, because of the microgravity conditions several problems appear on the human body, and one of them is the muscle atrophy accompanied by bone loss. In this specific area, there are several aspects that need to be fulfilled in order for the device to be useful, such as small dimensions, minimum energy consume, non-invazivity and ease of use. On the other hand, on Earth, even though there are several devices that can be used because the restrictions are minimal, this type of device is needed for muscle analysis because it offers a great versatility and a lot of information with a minimum effort for the operator and discomfort for the subject.

There are many studies that describe muscle characteristics acquired with different techniques, from dynamometers (Kannus, 1994) and free oscilation technique, to more invasive methods like electromyography (EMG) (Basmajian J., 1962), magnetic resonance elastography (MRI) (Basford J., 2002) or even muscle biopsy (Morrison, 2018). All these techniques are very usefull in certain situations and they remain of great importance in muscle evaluation, but they all have major disadvatages and can not be used in space applications or in training an athlete. The main drawbacks, even though not all for every device, are related to invasivity, dimensions of device and subjectivity of data.

Inspired from a technique that earth researchers are using to detect earthquakes, based on recording the wave propagation in muscle fibre after a mechanical impuls, the device we are proposing is developed in the Space Applications for Health and Safety Laboratory, inside the Institute of Space Science. At the present moment, it is at prototype level developed in a short series.

This type of analysis is very useful both in sports and space applications mostly because it offers a powerful tool on one hand in selection of the athletes and astronauts, and on the other hand in muscle evaluation during training.

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Method

MusTone functioning principle

The device consists of a striker, used to apply a mechanical impulse to the muscle, up to 8 accelerometers on skin and 1 on the striker (configurable to meet the experiment needs), one power supply and data processsing unit, designed to send the acquired data to the computer. All the components can be observed in Figure 1.

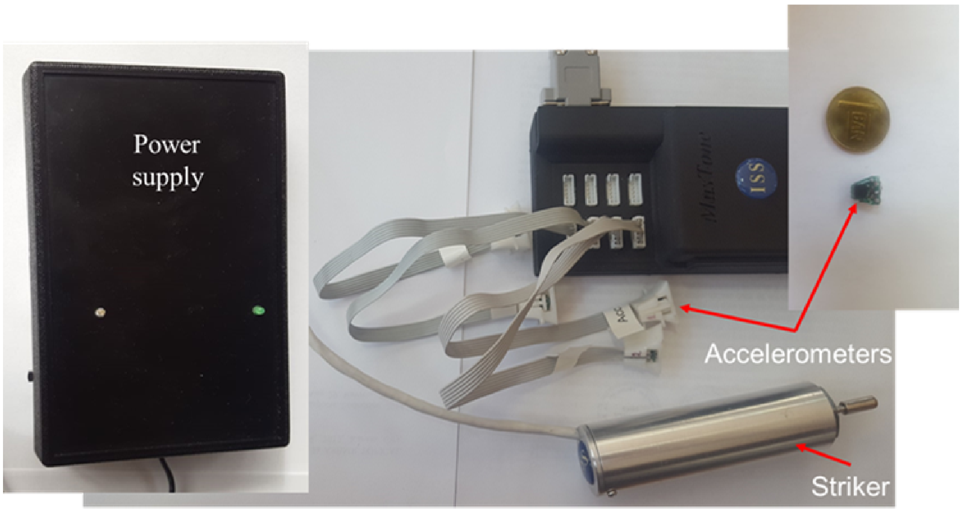

Fig. 1. MusTone device components

Using the striker, the muscular tissue is mechanically excited through a controllable percussion in terms of shape and duration, perpendicular to the direction of the muscle fibre. The acceleration signal is collected from the accelerometer associated with the striker as well as the measurement accelerometers placed along the muscle fibre. The collected signals give information on how the mechanical perturbation propagates along the muscle fibre.

The acceleration signal is recorded in the plane determined by the direction of the muscle fibre and the direction on which the mechanical excitation occurs, for both the percussion object and the 8 accelerometers placed along the fibre

All the acquisitions are performed through a dedicated computer software that gives the operator the possibility to control the parameters (e.g. acquisition tact, stimulus action time, acquisition time) to be used for experiment and to visualise a plot of the recorded data. This step is useful for the operator to select and eliminate the data marked by artefacts.

The measuring method per subject includes all the steps in the methodology, from area preparation, placement of acceleration sensors and data acquisition. For each muscle there are performed several percussion cycles in order to have a possibility to eliminate the errors. One percussion cycle lasts around 10 seconds.

The data is exported for each percussion cycle as a *.csv file with the raw data and the application also displays a graph of acceleration in relation to time as shown in Figure 2. The data can be furthere analysed in order to extract parameters of interest.

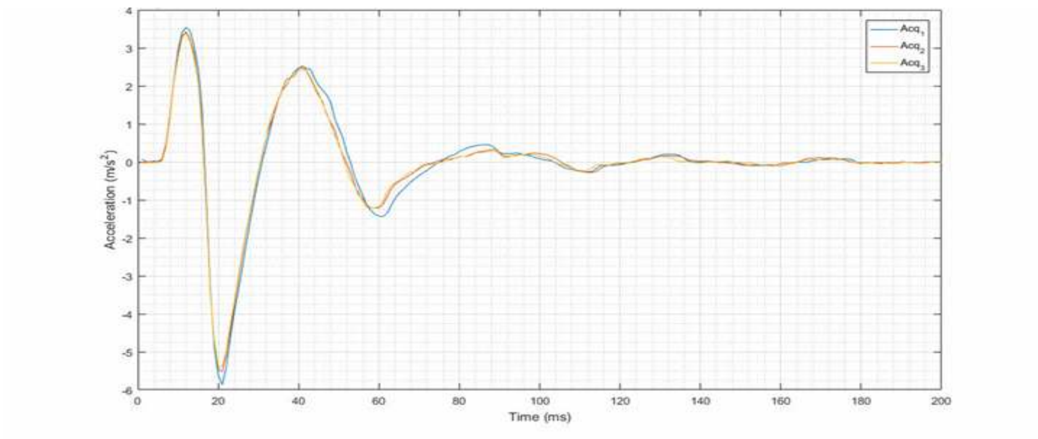

Fig. 2. Data acquired on three different percussions cycles on one accelerometer

Results and discussions

1. Muscle mechanical characteristics extracted with MusTone device

Muscle mechanical properties are defined in the literature as mechanical manifestations of the muscular contraction and are the most obvious and easy to observe (YMED, 2018). The mechanical properties of the scheletic muscle are (Dragulin, 2018):

- Contractility – the capability of the muscle to develop tension between its ends;
- Excitability – the property to elongate passively under exterior force;
- Elasticity – the capability to recover after a force was applied to it;
- Muscle tone – the permanent tension in the muscle;
- Rigidity – the property to resist to an external force.

At the present moment, the parameters identified that can be extracted from the raw data acquired with MusTone device are:

- Tone and muscle tension, by analysing natural oscilation frequency;
- Biomechanical properties like elasticity, by analysing the decay of logarithmic oscilations;
- Viscoelastic properties like the relaxation time after mechanical stress.

Considering that the device was built in a configuration that allows to record the mechanical wave propagation along the muscle fibre, our goal is to identify and extract other muscle characteristics (e.g delay time, damping rate etc.). The team at Institute of Space Science is developing a complex device for an extensive muscle analysis that is able to outperform the devices already on the market on certain levels, satisfying different needs.

In order to test the device applicability in different domains like space, sport performance or medical area, it has to be tested in relevant environment with respect to the consistency of the data it provides and also to experiment reproductibility. The testing program includes:

- Testing in Dry Immersion Experiment for space relevant conditions;
- Testing in sport training on a group of performance athletes;
- Testing in medical field on patients with muscle atrophy.

2. MusTone applicability fields testing and device importance

Exceeding the article preparation phase, the device and methodology is already in use in a dry immersion experiment in a collaboration with the Institute of Biomedical Problems of the Russian Academy and all the data presented in this article are from the experiment preparatory phase.

Dry immersion (DI) is a procedure that involves the immersing of the human body in water while covering with a waterproof cloth to keep the subject dry (L. Treffel, 2017) as shown in Figure 3. This type of experiment is useful in simulating microgravity conditions.

Fig. 3. Dry immersion model (MEDES, 2018)

In DI the whole body is affected by physiological changes similar to the ones that appear in real microgravity. This exposure eliminates gravitational loads on the spine and, therefore, results in vertebral deconditioning which is characterized by a lengthening of the spine, **muscular atrophy**, back pain, and herniated discs (L. Treffel, 2017).

In space applications the MusTone device is useful in evaluation before, during and after spaceflight, considering that in microgravity conditions the muscle loss is between 2% to 5% on lower limbs and postural muscles.

The necessity of a device capable to evaluate and give objective information on the muscle health is well known in **sports performance area**. For this particular area we chose for the first part of the experiment to evaluate a sports team (e.g. rugby team, football team) in order to have mostly the same type of muscular training for each subject. For this specific experiment the muscles/muscles investigated will be chosen with the help of the team physical trainer and it will be performed at the beginning and the end of a specific workout and also at different times (beginning, middle and end) of their training period in order to see both the evolution inside one training, but also the evolution in time.

In sports the device is useful for maintaining an optimal physiological state and for training costumization for each subject, as well as in monitoring the subject after an injury.

The medical area investigations we believe that there are very important from two perspectives: first and the most important for the patient, in order to observe the evolution and adapt the recovery in order to have the best results and secondly for the space-like type of affections that can be used to some extent as microgravity analogs. For this part of evaluations the department from Institute of Space Science already started some "case study" experiments on patients after stroke with one side hemiparesis and on patients that are recovering after injury (e.g. broken leg).

Conclusions

Using the device developed at Institute of Space Science can possibly improve the results of training in many different domains and it has great applicability and versatility.

The proposed device, in its current state at prototype level, can give enough information on the muscle to observe the changes in muscle properties. The studies that we are intending to develop in the near future can be of utmost importance in device stability and future evolutions and can offer valuable information both for us and for the trainers and doctors.

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