DEVELOPMENT OF A MECHANICAL DEVICE FOR WORKOUT EQUIPMENT OBJECTIFYING CONTROL OF MECHANICAL LOADING DURING ECCENTRIC MUSCLE ACTION

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Abstract. *Several studies have shown that the human being is capable of producing during eccentric muscle action (negative work) higher strength values than during the concentric muscle action (positive work). Most of the equipment traditionally used for training in bodybuilding, which provide a mechanical operation characterized by a system of ropes and pulleys, has the limitation of not being able to control the mechanical load imposed on the individual in a different way during the performance of different muscle actions, i.e., the mechanical load is the same for the positive and negative work. Thus, a machine used for training in the gym to provide a device capable of changing the mechanical resistance during the eccentric muscle action can bring great benefits to the practitioners of physical activity and fitness can allow a prescription for physical training most appropriate for athletes seek a maximum increase of muscular strength. Thus, the purpose of this paper is the development of a mechanical device adapted to a traditional fitness machine, which allows the increase of the mechanical load imposed during eccentric action and also permits graduating this increase in load mechanics. The development of mechanical equipment for weight training aimed at controlling the mechanical load in a way that during eccentric muscle action (negative work), there is an increased mechanical load in relation to the concentric phase. For this the original came of seated leg curl machine was replaced by a device specifically designed to attend the increased mechanical load imposed on the eccentric action of the movement performed. To verify the effect of mechanical device activation in muscle aimed at highlighting the eccentric phase, was used a repeated measures design.On the first step (two days) was performed a familiarization training protocol, followed by a pretest of one maximum repetition (1MR) in the seated leg curl machine already fitted with mechanical device developed. In the second step (two days) were carried out the training protocols, which registered the EMG activity. During the first series of the exercise, the electromyographic activity of biceps femoris was not different between protocols A and B. However, in the second and third series of exercise there was statistically significant differences in electromyographic activity of the muscle in question when the protocols A and B were compared*

Keywords*: Mechanical device, bodybuilding equipment, eccentric muscle action.*

1. INTRODUCTION

Apparatus used to measure the performance level of strength and for sports training enables the application of different forms of external resistance. Traditional equipment, commonly used in gyms, can provide a dynamic invariant resistance (without the presence of came) or dynamic variable resistance (with the presence of came).

The characteristic of these devices is the mechanical functioning through a system of cables, belts or pulleys, and sometimes with the presence of came. There are also those that works through guides and platforms. Equipment with invariable dynamic resistance are those that apply a mechanical load against the movement and this is always the same. Already the variable resistance are characterized mainly by the presence of came, which aims to vary the mechanical load during movement.

Use of these equipments, with or without the presence of came, involves making a positive work, in other words, the force generated to move the mechanical load is applied in the direction of motion, and also a negative work (force applied in opposite direction the movement), which are called respectively the concentric and eccentric muscle action. Thus, the mechanical resistance offered by the workout equipment, which do not have the presence of came, is the same for both muscle actions.

Several studies have shown that eccentric muscle action is different from the concentric muscle action both in respect to their neuromuscular responses (Nardone et. al. 1989, Abbruzzeese et. al. 1994, Enoka 1996, Higbie et al 1996, Aagaard et. al. 2000), and the adaptations induced by training (Farthing and Chilibeck 2003, Bowers et. al. 2004, Paschalis et. al. 2005, Chapaman et. al. 2006, Pincivero et. al. 2006). A important characteristic of eccentric muscle action is the mechanical load supported by the individual is always greater than that supported in concentric muscle action. This increased muscle strength during eccentric muscle action is explained by the greater involvement of passive components of muscle-tendon unit (Enoka 1996, Herzog et. al. 2005, Barroso et. al. 2005, Moragan and Proske 2006) and excitatory reflex processes (Nardone et. al. 1989, Abbruzzeese et. al. 1994, Barroso et. al. 2005). Based on this, devices that offer the same resistence in both the muscle actions, have an important mechanical limitation. The limitation of this type of equipment should be corrected, because it increases the possibilities of professional intervention in Physical Education training prescription.

Therefore, a "traditional" equipment that gives control of the magnitude of mechanical load during the eccentric muscle action can bring great benefits in developing training programs for bodybuilders, athletes and the development of research projects involving this issue.

This article focuses on the development of a mechanical device, adapted to a traditional gym equipment that will enable the control on the increased mechanical load imposed on the eccentric action of the movement held.

2. METHODOLOGY

2.1 Mechanical device

The development of mechanical equipment for weight training aimed at controlling the mechanical load in a way that during eccentric muscle action (negative work), there is an increased mechanical load in relation to the concentric phase.

To reach the objective was performed an adaptation of a device called seated leg curl machine where hamstrings muscles are activated by the knees flexion as shown in Fig. 1.

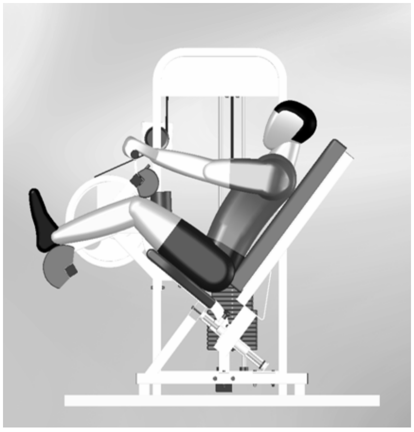

Figure 1. Schematic representation of seated leg curl machine.

The original bank came of seated leg curl machine was replaced by a device specifically designed to attend the increased mechanical load imposed on the eccentric action of the movement performed.

The seated leg curl consists with a backrest to support the trunk of the volunteer. In this seat is fixed a mechanical arm with a padded bar at its end, which will be supported in the distal part of the lower limbs. This equipment also contains a latch that is positioned above the supra-patellar edges, which ensures greater stability of the lower limbs (Fig. 1). Some adjustments are possible to be made in this device, such as determining the angle at which the motion occurs and regulation of anteroposterior back to the trunk. In this equipment the volunteer is seated and with his back against a backrest that forms an angle of 94 degrees with the seat. The knee joint at the beginning of the movement, is positioned approximately 180° of extension. The volunteer has his lateral epicondyle aligned with the axis of rotation of the lever of seated leg curl machine. From this measure, the backrest is positioned to keep the volunteer as firmly as possible, along with the lock that will hold two legs. Aiming to minimize any compensatory movement at the hip, the volunteer is fixed by a tape positioned on the anterior superior iliac spine, and another tape will be strung on the distal thigh and along the seat.

The kinematic chain for the functioning of traditional seated leg curl is shown schematically in Fig. 2. It is possible to determine the Eq. (1) that, from the lever principle, relates the force applied by the volunteer to keep in balance the load established in the mechanical device.

In the seated leg curl, the came allows the variation of the radius (a) throughout the movement, changing the value of the force (F) being applied by the volunteer, however such a change happens in the concentric action and in the eccentric action. The mechanical device designed to replace traditional came, has a mechanical expander that increases the value of the measure (a) in a pre-established along the eccentric action, allowing the force (F) by the voluntary action is greater in this than that made during the concentric action. The switching values of the measure (a) in the mechanical system expander can be done manually through a handle or automatically by a slave motor at the end of each movement of concentric and eccentric action. Figure 3 illustrates the above.

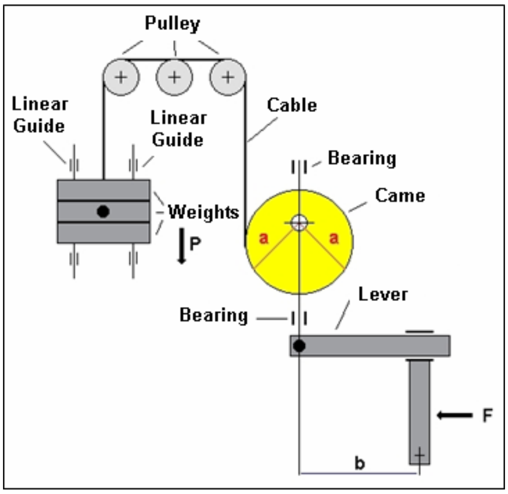

Figure 2. Scheme of the kinematic chain of traditional seated leg curl machine

$$F \bullet b = P \bullet a \quad (1)$$

Where:

F – force to be applied by the volunteer (N)
b – distance between support point and the point of force application F (mm)
P – load set on the unit considering the weight (N)
a – radius of the came (mm)

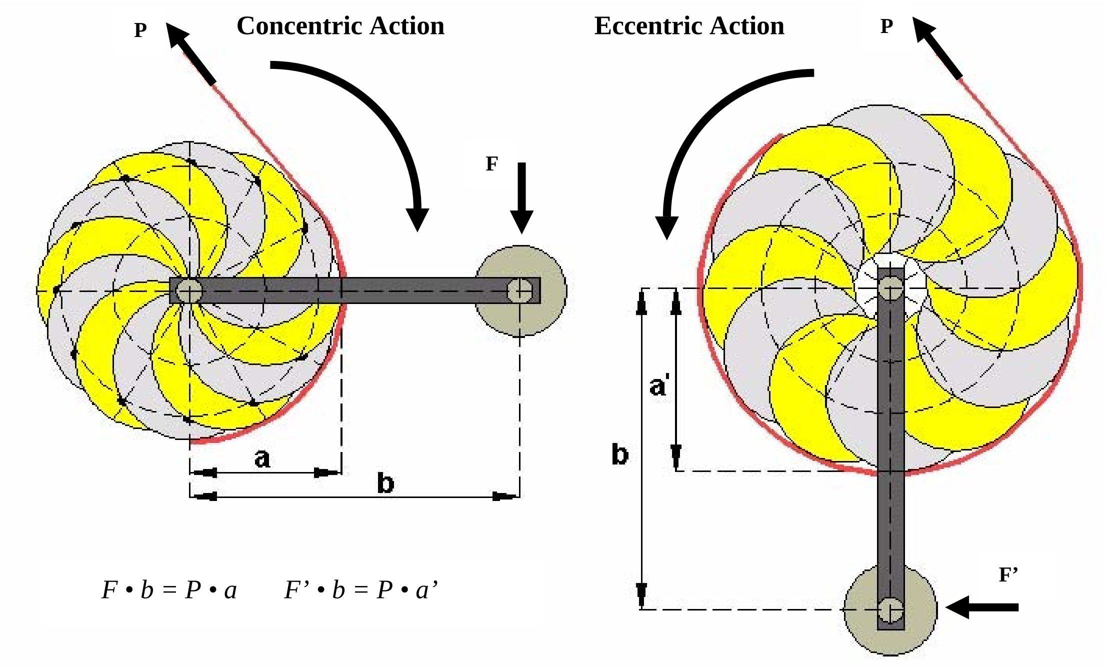

Figure 3. Switching values of measured (a) in the mechanical system expander during concentric and eccentric phases.

The mechanical device was developed and based on the principle of levers, which is a force multiplier system, which indicates logical validity, understood as evidence argued on the basis of theoretical reasoning. (Thomas and Nelson, 2002).

2.2 Verification test of the effect of device on muscle activation

To verify the effect of mechanical device activation in muscle aimed at highlighting the eccentric phase, was used a repeated measures design. Each volunteer came to the Laboratory of Training in Bodybuilding (LAMUSC) four times.

These sessions should be separated by at least 48 hours intervals. On the first training session was performed a familiarization training protocol, which was used as a warm up, followed by a pretest of one maximum repetition (1MR) in the seated leg curl machine already fitted with mechanical device developed. In the second training session was performed the anthropometric part, which consisted of measures of height, weight and skin folds, followed by familiarization protocol and then the 1MR. In sessions 3 and 4 were carried out the training protocols, which registered the EMG activity. In all four sessions the attendance of the volunteer was always at same time with minor variations being about an hour more or less. This small difference occurred because the availability of voluntary, which could not always attend every time at the same time. Table 1 shows training protocols used to determine the effect of the device at the level of EMG activity.

The first protocol (protocol A), consists of three series of 8 repetitions with 60% of 1MR concentric and eccentric, with 3 minutes break between series, with a repetition length of 6 seconds (2 concentric followed by a isometric and 2 eccentric followed by a isometric) and the second protocol, protocol B, consisting of 3 series of 8 repetitions with 60% of concentric 1MR, and a value that is greater than 60% for the eccentric action, with 3 minutes break between series, with a duration equal to that of protocol B as shown in Tab. 1. The exercise was performed with only one lower limb (unilateral).

Table 1. Setting the training protocol to be performed in seated leg curl machine (with (B) and without (A) of the mechanical device action)

Protocols	Series	Repetitions	% of Concentric 1MR	% of Eccentric 1MR	Duration of the repetition (seconds)	Interval (minutes)
A	3	8	60	60	6	3
B	3	8	60	84	6	3

The definition of the training load is carried out according to previous studies, so that the expectation is that all volunteers complete the training protocol. The difference between the protocols will be an increased mechanical load during the eccentric muscle action. The increase in the eccentric action was 40% of the concentric performed. Thus, to perform the comparison between the training protocols, all volunteers must be able to perform both training protocols.

The volunteer began to perform the movement at full extension of knees, and a screen located at the base of the unit indicated the range of motion necessary and was the reference to consider a valid repetition. An examiner dictated the rhythm with a metronome to help the volunteer to perform each repetition at the appointed time and also gave verbal reinforcement to encourage voluntary. An electronic goniometer was used to monitor the range of motion in the knee joint and to control the actual duration of each muscle action (concentric and eccentric) and therefore the repetition.

To check whether there is a greater activation during the eccentric action was used during the test the capture of electromyographic signals. To capture the EMG signals were used active surface electrodes (Silver / Silver Chloride - Midi-Trace ® Foam 2000, Graphic Controls Corporation - Canada) with amplifiers (up to 5000 x) and bipolar configuration. These electrodes are self adhesive and are placed parallel to the muscular fibers. Electrodes were positioned on the back of the thigh and the reference electrode was placed over the lateral malleolus in accordance with the norms of SENIAM.

The sites of attachment of the electrodes will first be shaved and sanitized with alcohol and marked with black marker, so that the second day of the protocol electrodes were positioned in place. The distance between the electrodes used in the experiment will be about 2 cm. This spacing is used for no overlap of the electrodes, due to the perimeter of their adherents parts.

The signal acquisition system will consist of a portable microcomputer, with the program DASYLab 11.1 (Dasytech Laboratories, 32 bits). The variables analyzed were the integral of the electromyographic signal (iEMG) of the biceps femoris. For the analysis of signals was used the average iEMG series of Protocol A and the average iEMG series of protocol B and analyzed using a paired t test and adopted a significance level of $p < 0.05$.

2.3 Results of muscular activity

During the first series of the exercise, the electromyographic activity of biceps femoris was not different between protocols A and B ($p = 0.07$). However, in the second and third series of exercise there was statistically significant differences in electromyographic activity of the muscle in question when the protocols A and B were compared (Series 2: $p = 0.042$ and Series 3: $p = 0.036$) as illustrated in Fig. 4.

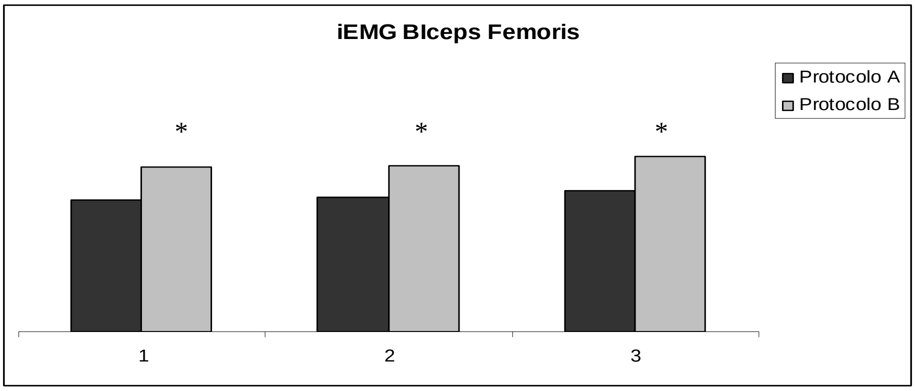

Figure 4. Activity of the biceps femoris muscle in series 1 (p = 0.07), Series 2 (p = 0.042) and Series 3 (p = 0.036).

3 CONCLUSION

The results in relation to the development of mechanical device were satisfactory, because during testing of the level of muscle activation was found that during protocol that used the increased load, through equipment, in the eccentric action, muscle activation was greater than in Protocol had not load increased. Thus it can be concluded that the device developed reached satisfactorily the objective of regulating the intensity during the eccentric action and still shows positive results in muscle activation.

4. ACKNOWLEDGEMENTS

The authors thank the Graduate Programs in Mechanical Engineering and Physics Education from UFMG, the Research Support Foundation of Minas Gerais (FAPEMIG) and all those who directly or indirectly contribute to this work.

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