EMPHASIS IN THE ECCENTRIC PHASE OF THE MUSCLE EXERCISE THROUGH THE LEG EXTENSION MACHINE ADAPTATION

Mara Nilza Estanislau Reis, mara.nilza@terra.com.br
Pontifícia Universidade Católica de Minas Gerais
Avenue Dom José Gaspar, 500 - Coração Eucarístico - Belo Horizonte - MG
Centro Federal de Educação Tecnológica de Minas Gerais
Avenida Amazonas, 5253 – Nova Suíssa - Belo Horizonte – MG

Diego Arthur, diego.miranda@br.fptpowertrain.com
Pontifícia Universidade Católica de Minas Gerais
Avenue Dom José Gaspar, 500 - Coração Eucarístico - Belo Horizonte - MG
Fpt Powertrain Technologies do Brasil
Avenida do Contorno da Fiat, 3455 – Betim – MG

Alysson Bento, alysson.bento@cnh.com
Guilherme Ferrão, guiferrao@yahoo.com.br
Pontifícia Universidade Católica de Minas Gerais
Avenue Dom José Gaspar, 500 - Coração Eucarístico - Belo Horizonte – MG

Abstract*. The muscle training that prioritizes the eccentric phase gives good results when compared to other types of strength training. The muscles exercises predominantly eccentric allow greater gain in muscle hypertrophy and strength, and contribute more effectively in the resolution and prevention of musculoskeletal tissue injury. Most sports and rehabilitation centers uses devices that offer a homogeneous load during concentric and eccentric strength exercise. So these devices reduce the chances to prioritize the eccentric phase, the main responsible for the gain in strength and muscle hypertrophy. Taking into account these factors, this work has as objective the adaptation of weight lifting equipment, Leg Extension, which emphasizes the eccentric phase in muscular exercise.*

Keywords*: leg extension machine, muscle training, eccentric phase; pneumatic system; microcontroller; musculoskeletal injuries*

1. INTRODUCTION

The skeletal muscle is capable of performing three types of contraction: isometric contraction, concentric and eccentric. The isometric contraction occurs when the muscle contracts to produce tension, but no change in its length. A considerable force can be generated against a fixed load, although there is no movement. In concentric contraction, the muscle length decreases as the tension increases in order to overcome or move the load. In eccentric contraction, the load is greater than the force produced and the muscle lengthens while produces tension (NORKIM C. C., 2001; PRENTICE W. E., 2002).

It's possible to generate greater amount of force against the resistance with eccentric contraction than concentric contraction, as the eccentric require lower activity of the motor units for given strength when compared to concentric contraction. Since fewer motor units are required to produce a specific strength, other motor units can be recruited to generate more force. Moreover, the amount of oxygen used is much lower during the eccentric exercise than concentric (PRENTICE W. E., 2002; Colliander, Tesch 1990; O'HAGAN et al. 1995; Higbie et al. 1996; Hortobágyi t. et al. 1996; Seger et al. 1998; Jonathan P. et al. 2003.; PULL M.R. et al. 2007). It is also the eccentric contractions are less influenced by fatigue when compared to other types of muscle actions (Tesch, Dudley, Duvoisin, Hather, & Harris, 1990; PULL M.R. et al 2007). In contrast to concentric contractions, rapid contraction fibers and highly resistant motor units are preferentially recruited during eccentric contractions (Nardone, Romanò, & Schieppati 1989; PULL M.R. et al 2007).

It has been shown that eccentric training produces greater muscle hypertrophy than concentric exercises (Colliander, Tesch 1990; O'HAGAN et al. 1995; Higbie et al. 1996; Hortobágyi t. et al. 1996; Seger et al. 1998; Jonathan P. et al. 2003). In addition to greater hypertrophy, eccentric training protocols result in a larger capacity in the production of force by the muscle when compared to concentric training protocols (Duncan et al. 1989; Colliander, Tesch 1990; Higbie et al. 1996; Hortobágyi t. et al. 1996, 1997; Jonathan P. et al. 2003).

Other studies reported a reduction in the incidence of muscles injuries after a program based on eccentric strength training (Asklinh, Karlsson, & Thorstensson, 2003; Noisaka & Newton, 2002; PULL M.R. et al 2007). Similarly, it supported the use of programs of eccentric exercises in the treatment of tendinopathies (Peers & Lysens, 2005), especially the Achilles tendinopathy (Alfredson 2003; Ohberg, Lorentzon, & Alfredson. 2004; PULL M.R et al 2007).

An increase in the number of sarcomeres in series can also be observed after a period of intense eccentric training. (Butterfield, Leonrad, & Herzorg, 2005; Lynn, Talbot, & Morgan, 1998; Yu et al., 2003). This process of "sarcomerogênesis" is still little understood (Butterfield & Herzorg, 2006) but suggests that have an effect of protection the structure of the muscle-tendon unit, explained by the reduction in length of the sarcomere in a specific articulation angle. (MORGAN & PROSKE, 2004; PULL R.M. et al. 2007). This would increase the "optium angle torque", defined as the joint angle at which the maximum muscle force is produced (BROCKETT, MORGAN & PROSKE, 2000; PROSKE & MORGAN, 2001; PULL M.R et al. 2007).

Furthermore, an increase in maximum force can be achieved during maximal eccentric actions when compared with concentric or isometric actions. This can be obtained in heavy resistance training using eccentric contractions, which makes the activity more effective than strength training based on concentric or isometric contractions (Doss, W. S., and P. V. Karpovich. 1965; Elizabeth J. et al. 1996).

Due to lack of equipment used for resistance training, muscular strength or hypertrophy that prioritizes the eccentric phase of exercise, based on the related data and the evidence of the benefits to advocate the eccentric work, this research has the aim to adaptation of the adaptation of weight lifting equipment that prioritizes the eccentric muscle contraction.

The adapted apparatus will be a leg extension machine which will have a pneumatic system. Thus, it is possible that the load imposed during the eccentric phase (flexion of the knee) is greater than the resistance performed in the concentric phase (extension of the knee). As previously mentioned, the eccentric contraction can generate higher torque when compared to the concentric contraction. According to some studies, during the eccentric muscle group is capable of generating a force of 10 to 45% greater than the force generated in the concentric phase (Seger et al. 1998). However, the device will put a load in this threshold to emphasize the eccentric phase.

To switch the load during exercise, will be use a proportional pressure regulator valve, thereby enabling to vary the pressure inside the chamber of retraction, so the strength to resist the return of the rod during the eccentric phase will be greater than the force necessary to moving the rod in the concentric phase.

2. METHODOLOGY

The research: "Emphasis in the eccentric phase of the muscle exercise through the leg extension machine adaptation" involves the development of the project, the construction of the system and the adjustment of the leg extension machine.

According to the formula pressure equals force divided by transverse area, the weights will be replaced for a pneumatic cylinder that will allow through pressure variation a change in the force exercised by the user once the cylinder area keeps unchanged during the whole movement. With that a differentiated resistance during the concentric and eccentric exercises will be guaranteed.

The pressure variation will be made by the proportional pressure regulator valve that through an electric sign will allow the pressure reduction, diminishing the necessary force used to advance the cylinder, what corresponds to the concentric movement.

Sensors will be installed in the leg extension in a way that the exact moment between the concentric and eccentric movements could modify the pressure, prioritizing the concentric movement.

2.1. Calculation Memory

The cylinder that we chose is the normalized cylinder DNG-50- 700 -PPV-A – 30000 from FESTO, Fig.1, since these are normalized elements other manufacturers have the same component with the same dimensions.

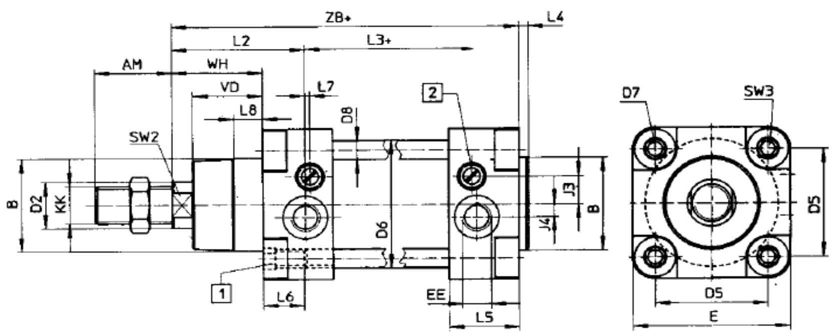

Figure 1. Cylinder dimensions and mounting style.

According to the manufacturer's Tab. 1:

Table 1. Cylynder dimensions.

ø do cilindro mm	AM	B d11 ø	D2 f8 ø	D5	D6 ø	D7	D8 ø	E	EE	J3	J4	KK	L2	L3	L4	L5	L6	L7	L8	L15	SW2	SW3	VD	WH	ZB
32	22	30	12	32,5	37	M6	6	50	G 1/8	7	-	M10x1,25	35	76,5	4	26	17	9,5	10,5	146	10	6	19	26	120
40	24	35	16	38	45	M6	6	55	G1/4	9,5	2,5	M12X1,25	41	83	4	26	16,5	9	10,5	165	13	6	21,5	30	135
50	32	40	20	46,5	55	M8	8	65	G1/4	12	5,5	M16X1,5	54,5	71	4	29	17	2	12	180	17	8	28,5	37	143
63	32	45	20	56,5	68	M8	8	75	G3/8	14	6	m16x1,5	55	85	4	35	19,5	5	12,5	195	17	8	28,5	37	158
80	40	45	25	72	86	M10	10	100	G3/8	15	7	M20x1,5	63	104	4	38,5	20	8	16,5	220	22	17	34,5	46	174
100	40	55	25	89	107	M10	10	120	G1/2	13	8	M20x1,5	69	102	4	42	20	13	15,5	240	22	17	37,5	51	189
125	54	60	32	110	13	M12	12	145	G1/2	13	8	M27X2	83	124	6	48,5	25	14	20,5	290	27	19	46	65	225
160	72	65	40	140	168	M16	16	186	G3/4	22	22	M36X2	105,5	129	10	50,5	24	-	-	340	36	32	55	80	260
200	72	75	40	175	210	M16	16	230	G3/4	22	22	M36X2	118	134	12	46	24	-	-	370	36	32	65	95	275
250	sob consulta																								
320	sob consulta																								

Defining:

Shaft diameter:
Dshaft = 20 mm = 0.02m
Cylinder diameter:
Dcylinder = 50 mm = 0.05m

Calculating the gear area which is where the cylinder retraction force occurs.

$$A_{GEAR} = A_{CYLINDER} - A_{SHAFT} \tag{1}$$
$$A_{GEAR} = \frac{\pi \cdot (d_{cylinder})^2}{4} - \frac{\pi \cdot (d_{shaft})^2}{4}$$
$$A_{GEAR} = \frac{\pi \cdot (50)^2}{4} - \frac{\pi \cdot (20)^2}{4}$$
$$A_{GEAR} = 1963{,}50 - 314{,}16$$
$$A_{GEAR} = 1649{,}34 mm^2$$

$$A_{GEAR} = 1{,}649 x 10^{-3} m^2$$

Since the concentric movement forces will be the same as the conventional equipment and the eccentric movement forces are known and according to the studies made, the necessary cylinder pressure to exercise those forces can be calculated according to the Tab. 2.

Table 2. Loads applied by the equipment in the concentric movement and the respective loads in the eccentric movement.

Concentric Movement	**Eccentric Movement**	
Conventional chair	10%	45%
(N)	(N)	(N)
50	55	72,5
120	132	174
190	209	275,5
260	286	377
330	363	478,5
400	440	580
470	517	681,5

Concentric Movement	**Eccentric Movement**	
Conventional chair	10%	45%
(N)	(N)	(N)
540	594	783
610	671	884,5
680	748	986
750	825	1087,5
820	902	1189

Since the gear area is constant the necessary pressure for each load can be calculated as follows.

$$P = \frac{F}{A_{GEAR}} \tag{2}$$

$$P = \frac{F_{Minimum}}{A_{GEAR}} \qquad P = \frac{F_{Maximum}}{A_{GEAR}}$$

$$P = \frac{50}{1{,}649x10^{-3}} \qquad P = \frac{1189}{1{,}649x10^{-3}}$$

$$P = 3{,}03x10^{4}\ N/m^{2} \qquad P = 3{,}70x10^{5}\ N/m^{2}$$

Therefore the forces in Tab. 2 can be correlated with a pressure according to the Tab. 3.

Table 3. Correspondent pressures.

Concentric Movement		*Eccentric Movement*			
Conventional Chair		10%		45%	
Force	*Pressure*	*Force*	*Pressure*	*Force*	*Pressure*
(N)	(N/m^2)	(N)	(N/m^2)	(N)	(N/m^2)
50	3,03E+04	55	3,33E+04	72,5	4,40E+04
120	7,28E+04	132	8,00E+04	174	1,05E+05
190	1,15E+05	209	1,27E+05	275,5	1,67E+05
260	1,58E+05	286	1,73E+05	377	2,29E+05
330	2,00E+05	363	2,20E+05	478,5	2,90E+05
400	2,43E+05	440	2,67E+05	580	3,52E+05
470	2,85E+05	517	3,13E+05	681,5	4,13E+05
540	3,27E+05	594	3,60E+05	783	4,75E+05
610	3,70E+05	671	4,07E+05	884,5	5,36E+05
680	4,12E+05	748	4,54E+05	986	5,98E+05
750	4,55E+05	825	5,00E+05	1087,5	6,59E+05
820	4,97E+05	902	5,47E+05	1189	7,21E+05

The Fig. 2 shows in a more clear way the evolution of the pressure in relation to the forces.

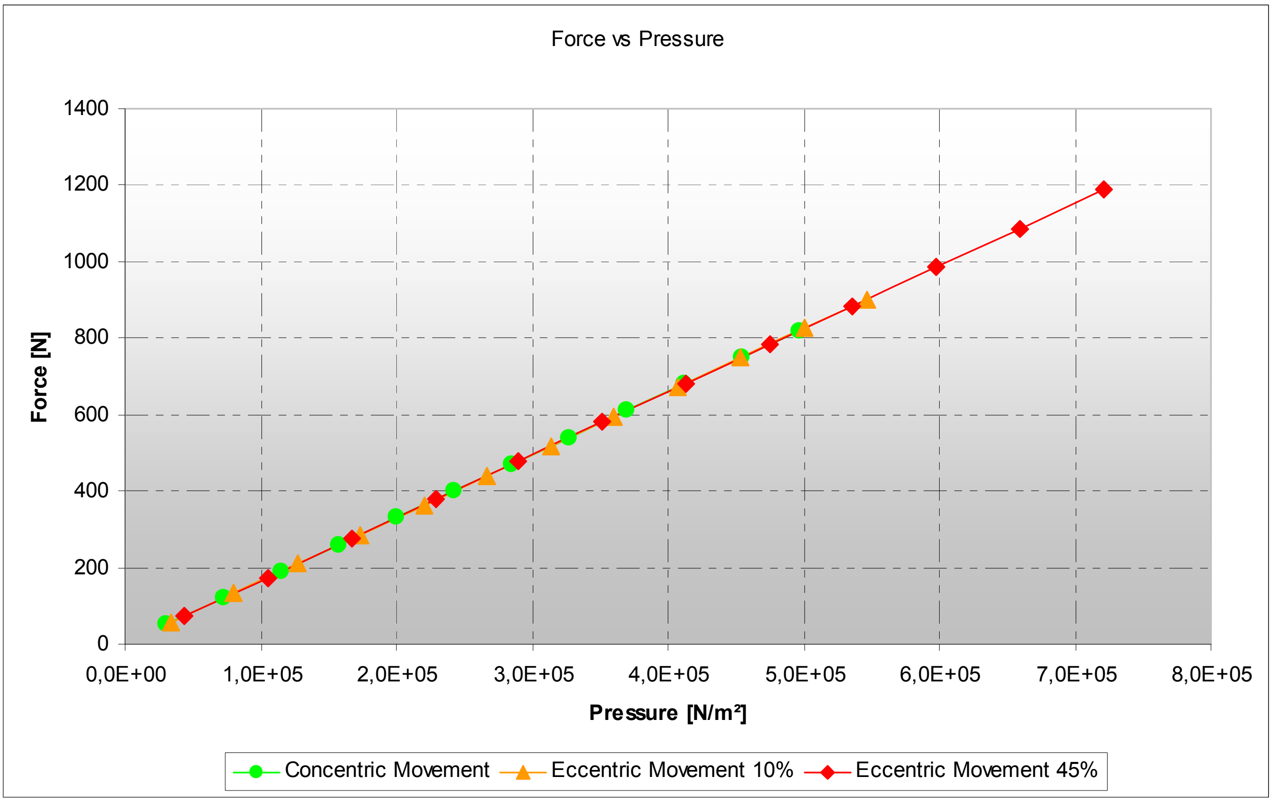

Figure 2. Force versus Pressure.

According to these pressures the components that are part of the equipment can be dimensioned.

2.2. Pneumatic circuit description - Working principle

Before starting the user have to regulate the pressure in the air service unit and the intensity/tension that will be available to the proportional pressure regulator valve, this pressure must correspond to the eccentric movement which is the greater pressure in the system.

In the first movement, the extension of the knee, the compressed air located in the tank passes through the air service unit where it is filtrated, pressure regulated and lubricated. Then it goes to the general valve, the air passes from 1 to 2 going to the 5/2-way stack valve. After that the air passes from 1 to 2 going to the proportional pressure regulator valve, the pressure is reduced and passes through the logic element that is connected to the cylinder retraction chamber. During the concentric movement the user will have to pull the steel cable, exceeding the resistance imposed by the pressure inside the cylinder retraction chamber.

Since the final and initial position in both the concentric and eccentric movements can't be determined due to the biotype of each user and in situations of hypertrophy and lack of adequate physical condition, a sensor was installed in the lever arm of the chair which will activate the stack valve when a inversion of the direct of rotation is detected. Once activated the stack valve will change the direction of the air flux, so the air that comes through the stack valve will change from 1 to 4 and pass through the logic element raising the internal pressure of the cylinder retraction chamber and raising the necessary force that the user will have to make to resist the cylinder retraction movement. This movement corresponds to the knee flexion movement or eccentric movement. In the same way, when the sensor detects a different rotation direction the pressure regulator valve is toggled once again, starting a new concentric movement which will be pressure regulated by the proportional pressure regulator valve, according to Fig. 3 and Tab. 4:

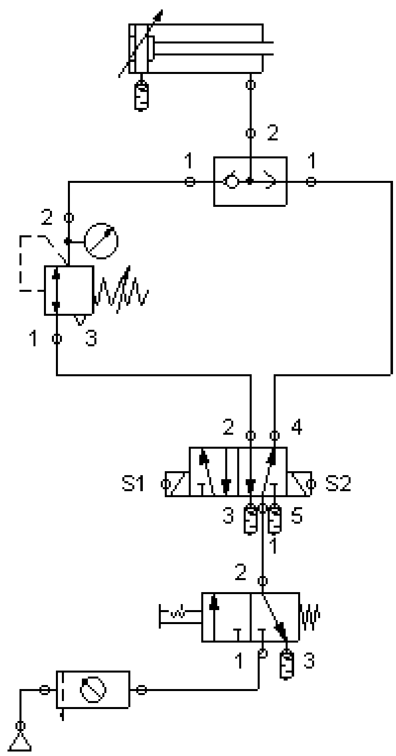

Figure 3. Pneumatic Scheme.

Table 4. Materials list.

1	Air treatment unit AS2
1	Interligation element AS-2
1	Slide valves 3/2 - 1/4"
1	Stack Valve 5/2-way double solenoid
1	Shuffle Valve
1	Proportional pressure regulated valve
1	Cylinder PRA diameter 50mm x 750 course
2	Magnetic sensor ST6 Reed w/ led, cable 3m, 10-30
1	Flange fixation MF1/MF2 for cylinder ISO diameter 50
14	Connection 1/4" for 10mm tubes
~	Hose 10mm

2.4 Conclusion

In most sports centers such as academies, clubs and even rehabilitation centers, the equipment used for muscle training, is east of hypertrophy, maximal strength or power, proposing a uniform resistance during concentric and eccentric phases. The way that these devices are produced decreases the possibility of any benefit that may be achieved through an emphasis on one stage of exercise.

The leg extension machine adaptation with a pneumatic system, still in progress, will be of considerable importance in order that will be possible emphasize the main phase of the muscle strength, as required protocols for training of strength, resistance or muscle hypertrophy and rehabilitation of various diseases such as tendinopathy and arthrosis.

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