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Apresentação

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[1] Editor-chefe da RPCD

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O presente número da Revista Portuguesa de Ciências do Desporto (RPCD) (i.e., o RPCD 17/S4A), bem como os anteriores (i.e., o RPCD 17/S2A e RPCD 17/S3A) e o seguinte (i.e., o RPCD 17/S5A), é constituído integralmente por comunicações submetidas e aprovadas para inclusão no programa científico do 3º Encontro Internacional de Pesquisadores em Esporte, Saúde, Psicologia e Bem-Estar (EIPSE), realizado entre os dias 12 e 15 de outubro de 2016, em Montes Claros (Minas Gerais, Brasil).

Nesse sentido, e a exemplo do verificado em relação ao número suplementar da RPCD dedicado à publicação de todos os resumos das comunicações submetidas e aprovadas para inclusão no programa científico daquele congresso (i.e., RPCD 16/S3R) entendemos ser oportuno e apropriado transcrever parte da mensagem de apresentação disponível na respectiva página electrónica, particularmente quando se refere que este Encontro:

tem por objetivo proporcionar um formato onde se discutem os mesmos problemas tal como estudados por diferentes áreas científicas. Promovendo o diálogo e a partilha de ideias, perspectivas e experiências, pretendemos que os participantes possam contribuir para o avanço da ciência identificando problemas comuns e assim construírem projetos de pesquisa em que as diferentes áreas se complementem. Desta forma os participantes darão início a um processo que tem por objetivo consolidar uma linguagem científica de forma multidisciplinar e traduzida no desenvolvimento de projetos conjuntos de pesquisa, que se pretendem de caráter internacional.

Com a realização deste evento procuramos salvaguardar o princípio de que a ciência e o saber são bens Universais. Promover a troca de experiências com o objetivo de se desenvolv-er projetos transfronteiriços é também uma forma de incentivar as boas práticas científicas tal como estas se podem corporizar na internacionalização da produtividade científica que até agora tem sido realizada em contextos isolados e em que a prioridade, graças ao isola-mento dos investigadores, tende a traduzir-se na excessiva preocupação em acrescentar linhas ao curriculum vitae de cada investigador.

Partilhamos da opinião que é urgente encontrar estratégias que permitam o desenvolvimento de uma nova cultura de prática científica, traduzida em formas de partilha diferentes daquela que atualmente dispomos e que impõe limites à operacionalização da criatividade científica. Neste sentido e certos que este é um primeiro passo na longa caminhada que se adivinha na construção de comunidades internacionais de pesquisadores em que diferentes áreas científicas se predispõem a procurar soluções para os problemas comuns e que despertam a curiosidade dos seus membros.

Complementarmente, convirá sublinhar que a RPCD tem vindo a constituir-se, desde o seu início, como um veículo privilegiado de divulgação em língua portuguesa do conhecimento gerado por académicos e investigadores da área das ciências do desporto e afins em difer-entes partes do mundo, nomeadamente nos países de expressão portuguesa.

Assim sendo, a resposta da RPCD à solicitação da Comissão Organizadora do EIPSE para publicar um determinado número de comunicações aprovadas pela respectiva comissão científica para serem apresentadas na terceira edição deste importante evento científico foi naturalmente positiva, salvaguardado que fosse um conjunto de critérios que assegurasse a qualidade e o mérito do conteúdo a publicar.

Em conformidade, e na linha do verificado em situações anteriores similares, a RPCD e a Comissão Organizadora do EIPSE definiram um conjunto de critérios a respeitar para a revisão e avaliação cegas dos trabalhos submetidos para publicação, os quais serviram de base ao trabalho posteriormente desenvolvido pelos peritos convidados para esse efeito pela Comissão Organizadora do EIPSE.

Conforme anteriormente referido, o presente número é um dos quatros números especiais que a RPCD destinou para a publicação das comunicações selecionadas para esse efeito pela Comissão Organizadora do EIPSE. Esperamos que a sua leitura se constitua como uma experiência útil e agradável para todos que a isso se decidirem...

01

Resistance properties of elastic tubing commonly used in rehabilitation and sports training and the effects of previous cyclic loading-unloading

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Biomechanics. Elastic resistance. Natural rubber elastic tubing. Látex elastic tubing. Sports training.

ABSTRACT

Elastic tubes have been widely used as an external variable resistance in protocols of rehabilitation and sports training. The aim of this study was to evaluate the resistance and effect of fatigue (stiffness reduction) after repeated stretching (cycling) of latex elastic tubing (LET) and natural rubber elastic tubing (NRET). The samples were submitted to axial traction tests at 0, 1000, and 3000 loading-unloading cycles. Each of the respective cycling values consisted of six samples. The loading-unloading cycle reached a 100% maximum strain from the initial length and 1800 mm/min displacement rate; after each test, the samples were loaded monotonically (500 mm/min) to 300% of strain and the force response recorded. The results obtained in this study are similar to the resistance values obtained at 0 cycles reported by the NRET manufacturer (84N vs. 80N), but they do not confirm the report that the "silver" tubing retains the ability to offer resistance after cycling of the elastic tubing for strains of 100% (p = .001), 200% (p = .021), and 250% (p = .002). The LET and NRET showed loss capacity for offering similar resistance (9.5 – 15.5% vs. 9.9 – 15.2%, respectively).

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Propriedades de resistência de tubos elásticos utilizados em reabilitação e treinamento desportivo e efeito prévio da ciclagem carga-descarga

RESUMO

Os tubos elásticos têm sido amplamente utilizados como resistência externa variável em protocolos de reabilitação e treinamento desportivo. O objetivo deste estudo foi avaliar a resistência e feito da fadiga (redução da rigidez) após estiramentos repetidos de tubos elásticos de látex (TEL) e tubos elásticos de borracha natural (TEBN). As amostras foram submetidas a testes de tração axial em 0, 1000 e 3000 ciclos de carga – descarga. Cada respectivo valor de ciclagem consistiu de 6 amostras. Os ciclos de carga – descarga alcançaram uma deformação máxima de 100% do comprimento inicial e taxa de deslocamento de 1800 mm/min; após cada teste, as amostras foram carregadas monotonicamente (500 mm/min) até 300% de deformação e registrada a resposta de força. Os resultados obtidos neste estudo são similares aos valores de resistência obtidos a 0 ciclos reportados pelo fabricante TEBN (84N vs. 80N), mas eles não confirmação a informação de que os tubos "prata" mantém a capacidade de oferecer resistência após o ciclagem dos tubos elásticos para as deformações de 100% (p = 0.001), 200% (p = 0.021), e 250% (p = 0.002) do comprimento inicial. Os TEL e TEBN mostraram uma perda da capacidade em oferecer resistência semelhante (9.5 – 15.5% vs. 9.9 – 15.2%, respectivamente).

PALAVRAS CHAVE:

Biomecânica. Resistência elástica.
Tubos elásticos de borracha natural.
Tubos elásticos de látex. Treinamento Desportivo.

INTRODUCTION

Elastic resistance (ER) has gained popularity in the last two decades and is largely used in rehabilitation programs and resistance training as a variable external load (Aboodarda, George, Mokhtar, & Thompson, 2011; Bellar et al. 2010; Hintersmeister, Bey, Lange, Steadman, & Dillman, 1998; Jakubiak & Saunders, 2008). ER can be produced using materials capable of storing elastic potential energy, such as metal springs, tubing, and rubber bands. The optimization of the use of such materials depends on the knowledge about specific mechanical requirements for the mechanical strain, dynamic in nature, of the training/ rehabilitation process (Cronin, Mcnair, & Marshall, 2003; Mcmaster, Cronin, & Mcguigan, 2010). Therefore, two characteristics of the material must be considered, force-deformation relationship and force/elastic decay (Patterson, Jansen, Hogan, & Nassif, 2001). In other words, with the cyclic loading, the material used on Variable Load (VL) loses the ability to respond with the same resistance for the same amount of deformation (Patterson et al., 2001; Simoneau, Bereda, Sobush, & Starsky, 2001).

Elastic tubing is widely used because of its versatility, practicality and lack of dependence on gravity (Ghigiarelli, Nagle, Gross, Robertson, & Irrgang, 2009; Hughes, Hurd, Jones, & Sprigle, 1999). Latex elastic tubing (LET) and natural rubber elastic tubing (NRET) can provide a considerable range of resistance and are dependent on the thickness and initial length of the material (Mcmaster et al., 2010; Santos, Tavares, Gasperi, & Bau, 2009). For example, the greater the thickness, the greater the resistance at a set initial length, and the smaller the initial length, the greater the resistance imposed on the exercise and strength required to deform the material to the same target length (Biscarini, 2012; Simoneau et al., 2001).

The use of such devices has been acclaimed for promoting increased resistance during exercise and is theoretically compared to ascending torque curve (e.g., bench press and squat exercises during the concentric action) upward trend (Rhea, Kenn, & Dermody, 2009; Wallace, Winchester, & Mcguigan, 2006). Higher resistance in the VL is observed at the end of the range of motion, next to the peak of torque curve (Anderson, Sforzo, & Sigg, 2008; Cronin et al., 2003). On the other hand, the eccentric action, as the ability to produce torque decreases, resistance is decreased too (Mcmaster et al., 2010; Rhea et al., 2009; Santos et al., 2009; Wallace et al., 2006). It is therefore presumed that the resistance applied across the range of motion is better adjusted to the force-versus-length curve than the constant load (Biscarini, 2012; Ghigiarelli et al., 2009; Kulig, Andrews, & Hay, 1984).

Surprisingly, despite the fact that ER is employed in a wide range of activities during different training/ rehabilitation phases, few studies have measured resistance under dynamic conditions and very little is known about the force response with repeated use. The change in the stress-strain relationship was investigated using only the NRET, with no consensus on the resistance loss (Patterson et al., 2001; Simoneau et al., 2001), which is unknown to the LET.

ER has been mainly quantified by static calibration tests, where the stress-strain relationship is obtained by recording the force response (weights or force transducers) associated with its displacement (deformation) from the initial length (Anderson et al., 2008; Cronin et al., 2003; Mcmaster et al., 2010; Rhea et al., 2009; Shoepe, Ramirez, & Almstedt, 2010; Thomas, Mueller, & Busse, 2005; Wallace et al., 2006). Despite the fact that the tested materials have viscoelastic properties, there is no agreement on the type of adjustment of regression models (linear, quadratic or logarithmic) provided to users (Anderson et al., 2008; Cronin et al., 2003; Mcmaster et al., 2010; Santos et al., 2009; Shoepe et al., 2010; Thomas et al., 2005). Additionally, although dynamic calibration testing demonstrates a non-linear distortion behavior, no regression models for natural rubber devices (NRET) (Patterson et al., 2001; Santos et al., 2009; Simoneau et al., 2001) and alternative synthetic rubbers have been reported (LET) (Azevedo, Benatti, Alves, & Filho, 2003).

Patterson et al. (2001) found that the response force was not significantly changed after 5000 cycles of load-unload at a constant loading rate of 1800 mm/min (0.5 Hz). Conversely, Simoneau et al. (2001) using the same tubes, observed a reduction in the force response from 4.76 – 15.36% in only 500 cycles (1080 mm/min). Considering that all of the rubber types materials exhibit some degree of fatigue (stiffness reduction) (Figliola & Beasley, 2007; Hibbeler, 2013) this phenomenon should negatively impact the average ER prescribed over chronic training protocols. Consequently, disregarding the magnitude of loads imposed on the musculoskeletal system in the VL planning and implementation may hamper a clear understanding of the adaptations (Issurin, 2010).

Accordingly, the aim of this study was to describe the force-deformation characteristics and the effect of the stiffness reduction after repeated cycling of LET and NRET. The NRET was selected because of their extensive use by therapists and coaches. Additionally, LET was tested with the empirical use of these as a cheap and easily available alternative. Thus, it was hypothesized that repeated cycling of tubes reduces the force generation over both natural rubber and latex, in the one week of use.

METHODS

EXPERIMENTAL SETUP

For the present study, the force versus deformation relationship for NRET and LET has been dynamically quantified with a mechanical testing lab machine. Elastic tubes with similar cross sectional areas (CSA) were used for testing. The machine concurrently provided the force response through a load cell with an actuator and its displacement. From the displacement of the actuator, it was possible to determine the absolute (mm) and relative deformation (%) achieved by specimens. To investigate the force response on the repeated material usage, the elastic tubes were tested for cycling (load-unloading) with a constant loading rate.

The choice of the maximum number of cycles was performed by simulating a short-duration exercise protocol (one week), 7 – 8 exercises, 3 – 4 sets, frequency of 3 – 5 times/ week for 15 – 20 repetitions (945-3200 cycles). The displacement rate (loading rate) was selected so that each load-unload cycle corresponded to the repetition performed with a 4-second duration, 2 seconds for the concentric action and 2 seconds for eccentric action (American College of Sports Medicine [ACSM], 2009; Andersen, Andersen, Mortensen, Poulsen, Bjørnlund, & Zebis, 2010).

During the cycling testing, material deformation was limited to 100% (l_{final}= 60 mm) from the standard length ($l_{standard}$ = 30 mm), in accordance with the studies that investigated the force response over repeated material usage (Patterson et al., 2001; Simoneau et al., 2001). For the cycling tests was used a triangular waveform. For the monotonic loading conducted after cycling, the specimens were deformed to 300% (l_{final}= 120 mm), which was the maximum displacement allowed by the testing machine.

SAMPLES

A sample of 18 LET (“Silver”, Thera-band tubing, Hygenic Corporation Akron, Ohio, USA) and 18 NRET (“204”, Auriflex, Auriflex Industry and Commerce, São Paulo, SP, Brazil) were selected. Subsequently, samples were distributed equally and randomly into three groups, each with six elastic tubing pieces. The number of elastic tubing per treatment was determined at 95% significance (p < .05) and 90% statistical power based on the study data of Simoneau et al. (2001). To perform the sample size calculation was used the package “sample size” of the R statistical software, version 3.0. The samples were prepared from new elastic tubing obtained from sealed packages within the validity period.

INSTRUMENTS AND PROCEDURES

The determination of the length of the tubes (Total and standard length) and the diameters (External and internal diameters) was performed with a Vonder® 508045 caliper, 10 cm graduated scale and vernier .05 mm. The measurements were made on each specimen for determining the mean values of length and diameter (bellow, in approximate values). Each sample had a 100 mm total length and 30 mm standard length (section exposed and loaded during testing) (FIGURE 1). Below are the LET (1) and NRET (2) CSA equations to determine the difference between the total CSA and CSA of the materials hollow centre:

(D_{LET}) External diameter LET= 12mm;
(d_{LET}) Internal diameter LET = 6mm

$$A_{LET}=\left(\frac{\pi}{4}\right)\left(D_{LET}^{2}-d^{2}_{LET}\right)=84.78\text{mm}^{2} \quad (1)$$

(DNRET)External diameter = 11.5mm;
(dNRET) Internal diameter= 5.5mm

$$A_{NRET}=\left(\frac{\pi}{4}\right)\left(D_{NRET}^{2}-d^{2}_{NRET}\right)=80.07\text{mm}^{2} \quad (2)$$

It were inserted carbon steel pins were inserted into the internal diameters at both ends of the samples and technyl bushings over the external diameters to increase the rigidity and facilitate the attachment of samples (FIGURE 1).

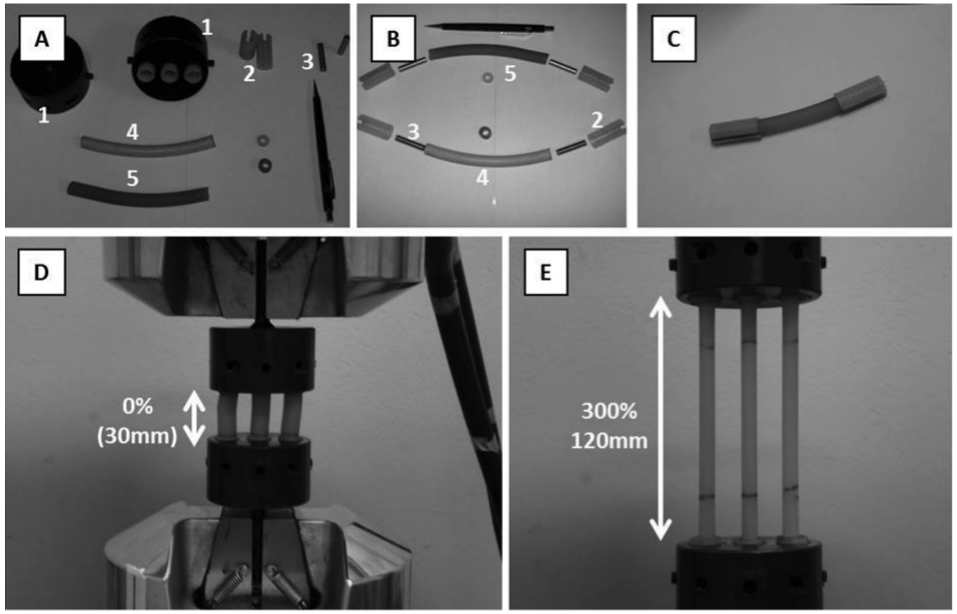

FIGURE 1. (A) Attachment device: 1 – Attachment device, 2 – Bushings, 3 – Pins, 4 – Elastic tubing Thera-band silver®; 5 – Elastic tubing Auriflex 204®, (B) Sample Assembly; (C) Sample; Mechanical evaluation of elastic resistance after cyclic loading – unloading of 0 (D) at 300% (E) deformation of the initial length.

Before the trials, each elastic tubing was manually elongated 20 times, as recommended by the study of Patterson et al. (2001). An attachment device for sample attachment in the testing machine was designed and built. Such a device enables the attachment of up to 3 samples, tensioned by screws, to evaluate the ER (FIGURE 1).

For analysis of the ER and stiffness reduction of samples, a testing machine MTS® 810 (Material Test System Corporation, Minneapolis, Minnesota, USA) was interfaced with a computer through the Multi Purpose Tortwore® (MPT) application. The testing machine had a load cell with 250KN capacity, which was previously calibrated for this study (Figure 1).

The elastic tubes were tested with a random distribution, without replenishment, in the following three treatments: 0 (Control, no cycling), 1000 (Treat1000), and 3000 (Treat3000) load-unload cycles. During experiment cycling at 1000 and 3000 cycles, the prescribed deformation was 0-100% ($l_{standard}$ = 30 mm; l_{final} = 60 mm) of the sample's initial length, at a displacement rate of 0.5 Hz (1800 mm / min) (FIGURE 2).

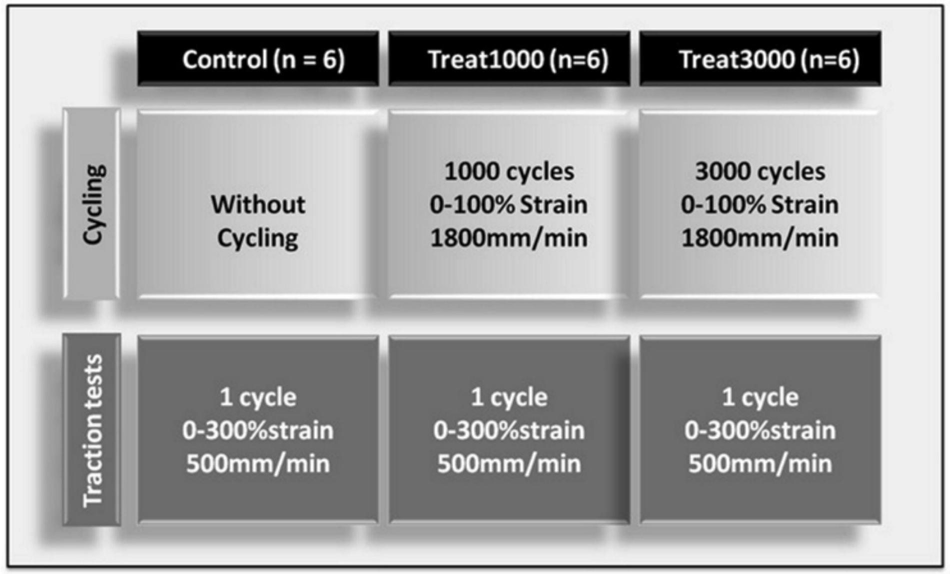

FIGURE 2. Experimental Design.

After each experimental condition was completed, the tubes were tested to 0-300% strain ($l_{standard}$ = 30 mm; l_{final}= 120 mm) in a single monotonic loading, at a displacement rate of 500 mm / min to determine the force –deformation relationship. Three samples were tested simultaneously (during cycling and post-treatment testing) by mounting them together in the same fixtures as shown in Figure 1. Thus, it was possible to save time in the implementation of the experimental design, without bias in to the tests on the force response.

The MPT software was used to acquire the signals of the force and displacement. From the data of the absolute displacement (mm) and relative deformation (%) was determined by initial length of the tubes. Data on force and strain during cycling to 100% strain and elongation to 300% strain were obtained from a sampling rate of 60Hz and 2Hz, respectively.

The total force data obtained after each treatment at 300% strain were filtered with a low-pass Butterworth filter (low-pass) of 20Hz, first order and then divided by the number of samples per test (3) to obtain the force for each sample. For each sample in each treatment was obtained a third-degree polynomial function of the force response according to the percentage deformation for the brands of elastic tubing tested. Equations were used to obtain the force response for percentages of 100%, 200% and 250% deformation, which was followed by the mean values of force. It was also plotted the mean force versus deformation (all specimens) for each treatment (FIGURES 2A E 2B). The data processing was performed with Matlab®, version 7.9 (Mathworks, Natick, USA).

STATISTICAL ANALYSIS

The force data for both types of elastic tubing tested were described with the mean and standard deviation for 100%, 200% and 250% deformations. A regression equation (force vs. deformation) was developed for each brand at 0 cycles and the coefficient of determination (R^2) of the models obtained. To determine the testing reliability, the coefficient of variation (CV% = mean/standard deviation x 100) was calculated for each type of tube and for force responses at 100%, 200% and 250% of deformation.

Previously the assumptions of data normality and homoscedasticity were verified. The normality of all data was verified with the Shapiro-Wilk test. The homoscedasticity was verified through the Bartlett's test. If any of the assumptions were violated, a logarithmic transformation was carried out and again performed the tests for normality and homoscedasticity of transformed data (Hopkins, Marshall, Batterham, & Hanin, 2008). As the normality assumption was violated, again a nonparametric Kruskal-Wallis test was used to compare treatments. To identify the differences between the treatments, were employed a test for multiple comparisons of Nemenyi. For all the procedures, was considered the significance of *p* <.05 and used the R® statistical software, version 3.0.

RESULTS

The LET tubing subjected to treatments of 1000 and 3000 load-unload cycles in this study showed significant reduction for force response to deformation of 100% (*p* = .003 for both treatments), 200% (*p* =.002 and *p* =.002, respectively) and 250% (*p* =.002 and *p* =.002, respectively) compared to the control treatment (0 cycles) for the respective strains. However, there was no significant change in the force response between the treatments of 1000 and 3000 cycles for deformations of 100% (*p* = .985), 200% (*p* = .983), and 250% (*p* = .985) (FIGURE 3 AND TABLE 1).

TABLE 1. Force response (mean ± standard deviation in Newtons – N) to deformation (%) obtained after treatments (0, 1000, and 3000 cycles) for latex elastic tubing and natural rubber elastic tubing (six samples for each treatment).

BRAND	LET			NRET		
	DEFORMATION (%)					
Treatments	100%	200%	250%	100%	200%	250%
0 cycles	43.99±0.04	61.65±0.19	67.87±0.12	50.61±4.23	72.25±4.24	80.26±3.87
1000 cycles	37.04±3.36*	55.31±4.71*	60.80±4.78*	42.69±1.02*	65.50±3.25	72.86±3.33*
3000 cycles	37.33±0.07*	55.79±0.55*	62.05±0.75*	43.11±0.05*	64.71±0.2*	71.77±0.05*

Note. * p <.05; indicates significant differences compared to control treatment.

At 3000 load-unload cycles, the NRET showed a significant reduction in the force response to 100% (*p* = .001), 200% (*p* = .021), and 250% (*p* = .002) strains compared to the control treatment. At 1000 cycles there was significant reduction in the force for 100% (*p* = .001) and 250% (*p* = .002) deformations without significant changes for 200% (*p* = .093). However, there were no significant changes in the force response between treatments of 1000 and 3000 cycles for 100% (*p* = .987) 200% (*p* = .84), and 250% (*p* = .986) strains (FIGURE 3 AND TABLE 1).

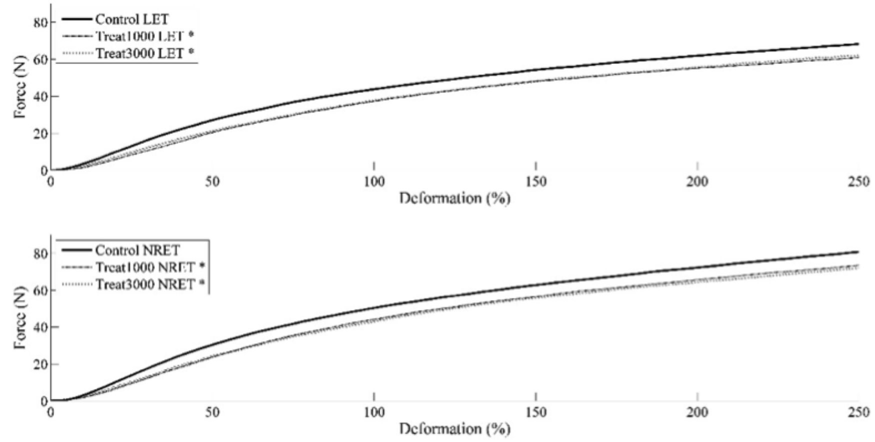

FIGURE 3. Force (N) – Deformation (%) ratio for the treatments (0, 1000, 3000 cycles) of Auriflex® (204) tubing (Upper graph – LET) and Thera-Tubing® tubing (Lower graph – NRET).

Additionally, the regression polynomial equations for LET and NRET showed high coefficients of determination for 0 cycles (TABLE 2).The relative instability (CV%) observed in the trials ranged from 0.1% – 9.1% for LET and from 0.1% – 8.4% for NRET (TABLE 3).

TABLE 2. Polynomial regression equation and coefficient of determination for latex elastic tubing and natural rubber elastic tubing (six samples for each brand).

TYPE	POLYNOMIAL REGRESSION EQUATION	COEFFICIENT OF DETERMINATION (R^2)
LET	*f = 0.000004x3– 0.0026x2+ 0.6403x + 5.7284†*	0.9963
NRET	*f = 0.000004x3– 0.0024x2 + 0.6421x + 6.9495†*	0.9975

Note. f = Force (Newtons – N), x = deformation (%).

TABLE 3. Reliability of tests (CV%) obtained after treatments (0, 1000, and 3000 cycles) for latex elastic tubing and natural rubber elastic tubing (six samples for each treatment).

BRAND	LET			NRET		
	DEFORMATION (%)					
Treatments	100%	200%	250%	100%	200%	250%
0 cycles	0.09	0.30	0.17	8.35	5.86	4.82
1000 cycles	9.07	8.51	7.86	2.38	4.96	4.57
3000 cycles	0.18	0.98	1.20	0.11	0.31	0.06

DISCUSSION

The aim of this study was to evaluate the force-deformation response of two different brands of tubes. The other major goal was to evaluate the effects of previous cyclic loading on the force-deformation response, for synthetic and natural rubber tubes. Table 1 provides information about the force response with respect to the percentage of deformation of elastic tubing tested. The regression equations provide useful information for quantifying the resistance and initial length at 0 cycles (TABLE 2). Low values on relative instability (CV < 10%) denoted a high reliability of the trials for LET and NRET, over the force response (TABLE 3).

It should first be noted that no studies were found that evaluated the resistance and stiffness reduction of LET tubing with the same experimental design. With respect to the LET, Azevedo et al. (2003) studied the properties of LET composed of the same material (butadiene-styrene) with the same cross-sectional area ($84.83mm^2$ vs $84.78mm^2$). The LET tubing showed higher mean force response (12.7%) compared to used in that study, and they had the same manufacturing specifications at 0 cycles and 300% deformation (71.8 N vs. 62.7 N). The differences can be attributed to the material and manufacturing methods, because they are manufactured by different companies and standardized by their cross-sectional area and not their resistance. In the present study, LET showed an mean reduction of force response respectively 1000 and 3000 cycles of 15.75% – 15.13% to 100% elongation, 10.28% – 9.5% to 200% and 10.41% – 8.57% to 250%. The lower stiffness reduction observed at 200% and 250% in comparison to 100% strain can be explained by the difference in the number of loading and unloading cycles experienced at or beyond each strain length (Simoneau et al., 2001; Hibbeler, 2013). Figure 3 shows the force behavior depending on the deformation with the loss of potential generation of resistance of LET.

The mean force values obtained at 100%, 200% and 250% deformation to NRET are similar to those obtained in studies by Patterson et al. (2001) testing similar characteristics to 0 cycles stretching (84N vs 80 N). Regarding the study of Hughes et al. (1999) the percentage differences of 4.8%, 15.2% and 25.5% were found at 100%, 200%, and 250% elongation of the original length, respectively. The differences can be attributed to the method used to quantify the elastic loads. Hughes et al. (1999) quantified the force depending on five deformation percentages and determined a linear regression model for six types of NRET (thera-tubing yellow, red, blue, green, black and silver), disregarding the material's viscoelastic characteristic. The elastic tubing has a nonlinear behavior in the initial phase of the stretching and linear behavior after 100% deformation, which is typical to elastomeric materials (Hibbeler, 2013; Mcmaster et al., 2010; Patterson et al., 2001). Figure 2B shows the force behavior vs. deformation with the loss of generation potential of resistance for NRET.

Similarly to the LET, NRET showed force reduction of 15.64% – 14.81 % at 100%, 9.34% – 10.43% at 200% and 9.22% – 10.57% at 250% deformation, respectively 1000 and 3000 cycles. In contrast, the study of Patterson et al. (2001) reported no change in the force response for silver tubing with the same displacement rate of 0.5 Hz (1800mm/min), a higher number of stretching cycles (5000 cycles) and the same strain during cycling (100%). Based on these findings, the potential effect of preconditioning as described by Patterson et al. (2001) must be disregarded. In this study, the tubing was equally conditioned at each treatment being deformed manually before each testing of its initial length (20 cycles/sample).

Simoneau et al. (2001) evaluated the resistance descriptively as well as its relationship to the stiffness reduction of NRET (yellow, white, and black) with a piezoelectric force transducer associated with a linear actuator during 500 load-unload cycles with a deformation of 0–100% and 0-200%. The sample consisted of four samples of elastic tubing of each color. After testing there was mean reduction for yellow, green and black tubing of 4.76%, 5.02%, and 6.14% with cycling at 100% and 13.43%, 9.62%, and 15.36% at 200% cycling, respectively.

For both types of tubing tests there was greater force reduction at 100% strain (15.23 – 15.45%). Apparently, this may occur from the formation of tiny cracks in the tube structure leading to failure with repeated material stretching (Hibbeler, 2013). The strain band (0 – 100%) chosen for the cycling testing of materials produced greater reduction in the potential to generate resistance. In deformation percentages of the strain band chose in the trials, the reduction in the percentage values was similar (9.89-9.9% at 200%; 9.5-9.9% at 250%).

The dynamic determination on ER, just like on the present study, has been performed from the initial-length samples (< 100 mm) shorter than those used in practice (Azevedo et al., 2003; Patterson et al., 2001; Santos et al., 2009; Simoneau et al., 2001). Nevertheless, force versus deformation relationships have been commonly applied instead of the original length (%), which is based on the assumption that the elastic material properties are constant (Patterson et al., 2001; Santos et al., 2009; Simoneau et al., 2001; Thomas et al., 2005). In support of this argument, Patterson et al. (2001) and Thomas et al. (2005) showed that different lengths could produce similar-force responses with the same relative deformation.

Based on the polynomial regression equations provided, it is possible to determine the resistance offered by the elastic tubing tested, as well as the possible replacement, if necessary, of NRET for that LET to lower cost. For example, NRET with a resting length of 0.6m deformed 150% provides 63 N or 6.4 Kg of resistance; where as LET with a resting of 0.48m deformed to 210% offers same resistance.

The same reasoning will apply if only one type of tubes is available (NRET or LET) and if there is a need to adequately reduce the length of tubes to meet a maximum or average ER, considering the individual anthropometric characteristics. This means that, given the relative resistance and excursion (deformation) for an exercise, when replacing those values on the calibration polynomials, it is possible to adjust the length and choose which tube to use (Santos et al., 2009).

However, after successive cycling during rehabilitation and training sessions as evidenced in the trials, the elastic tubing loses its ability to generate the same 62.76N. Therefore, knowing the stiffness reduction, it is possible to decrease the initial length of tubing to adjust it to the load and target final length of the session (Thomas et al., 2005), given the reduction in the percentages of force response of tubing. On the other hand, with the manipulation of the initial length (reducing the initial length by cutting), the resistance throughout the range of motion should be increased (Anderson et al., 2008), both by replacing an NRET tube with an LET tube with repeated use and by adapting the resistance for a particular task. After the cutting the tubes, this procedure should require a greater torque for the same deformation (%) from the individual during the execution of the exercise, especially at the beginning of the movement (Anderson et al., 2008).

A possible limitation of this study may be associated with the adopted interpolation method (Lagrange Interpolation). Like all numerical approximation of a polynomial, this one has a small error in the data manipulation. However, the estimation error should not interfere on the results because the method aims to optimize the curve that better fits the data set. Moreover, the coefficient of determination (R^2) of the models obtained with the regression models was high (above .99). As seen the tests (FIGURES 2A AND 2B), due the non – linear behavior of elastic tubes the use of linear models is inadvisable.

Possible methodological improvements for future research include the measurement of the tubing hysteresis, more samples, the use of higher rates of displacement, increasing the number of cycles and evaluation of other types of elastic for to provide information to therapists, physical education teachers and coaches with this information. Therefore, these factors are considered limiting in this study, and still require further understanding of the limits of mechanical testing in the practice of rehabilitation programs and sports training (real exercises).

CONCLUSION

The current findings indicate that the subsequent use of viscoelastic material (natural rubber NRET and latex LET) leads to a reduced ability to provide resistance, which must be considered during rehabilitation and training. This information may be useful in the selection and suitability of tubing, as well as the reduction of operational costs in rehabilitation programs and training. The exercise prescription with the use of ER must take into account the resistance loss of tubing to ensure that the training intensity and volume are achieved in resistance training. Finally, both the NRET and LET, commonly called “surgical tubes”, present with a similar reduction (as percentages) of the force response to cycling.

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