Journal of Bodywork & Movement Therapies (2015) 19, 119—123

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/jbmt

FASCIA SCIENCE AND CLINICAL APPLICATIONS: FORCE TRANSMISSION RESEARCH

Transmission of muscle force to fascia during exercise

Thomas Findley, M.D, Ph.D [a], Hans Chaudhry, Ph.D [b,*], Sunil Dhar, Ph.D [c]

[a] *Rutgers University and V.A. Medical Center, East Orange, NJ, USA*
[b] *Department of Biomedical Engineering, New Jersey Institute of Technology, Newark, NJ, USA*
[c] *Department of Mathematical Sciences, New Jersey Institute of Technology, Newark, NJ, USA*

Received 7 July 2014; received in revised form 24 August 2014; accepted 26 August 2014

KEYWORDS
Force transmission;
Fascia;
Ankle muscles;
Elbow muscles;
Exercise

Summary *Objective:* As the muscle contracts, fibers get thicker, forcing the fascial tubular layers surrounding the muscle (endomysium, perimysium and epimysium) to expand in diameter and hence to shorten in length. We develop a mathematical model to determine the fraction of force generated by extremity muscles during contraction that is transmitted to the surrounding tubes of fascia.
Methods: Theory of elasticity is used to determine the modulus of elasticity, radial strain and the radial stress transmitted to the fascia.
Results: Starting with published data on dimensions of muscle and muscle force, we find radial stress is 50% of longitudinal stress in the soleus, medial gastrocnemius, and elbow flexor and extensor muscles.
Conclusion: Substantial stress is transmitted to fascia during muscular exercise, which has implications for exercise therapies if they are designed for fascial as well as muscular stress. This adds additional perspective to myofascial force transmission research.
Published by Elsevier Ltd.

Introduction

There is a substantial literature finding that as much as 30—50% of the longitudinal stress exerted by the muscle on the proximal tendon may be transmitted to other structures besides the distal tendon (Huijing, 2009). This has been termed myofascial force transmission. This force also causes major sarcomere length heterogeneity in human lower leg muscles (Yucesoy, 2010) as forces are transmitted from fascia to muscle and this has been addressed with mathematical and finite element modeling. But our study in this paper is in the reverse direction, i.e. we want to know what fraction of muscle force generated by muscle contraction is

* Corresponding author. 176 Prestwick Way, Edison, NJ 08820, USA. Tel.: +1 973 642 7835; fax: +1 973 596 5222.
E-mail address: Chaudhry@njit.edu (H. Chaudhry).

http://dx.doi.org/10.1016/j.jbmt.2014.08.010
1360-8592/Published by Elsevier Ltd.

transmitted to the myofascial layer wrapping the muscle. There has been some work identifying fascial and vascular structures outside the muscle which can conduct these myofascial forces to both agonistic and antagonistic muscles (Huijing, 2009) but a comprehensive model of forces in the fascia is lacking. This paper will looks specifically at the tubular layers of fascia which by necessity must expand outward as the muscle shortens and increases in diameter. This outward force in the radial direction will occur along the entire shortened length of the muscle. While muscle fiber expansion is greater in the mid-muscle, our initial modeling assumes that the entire muscle expands uniformly for simplicity of calculations.

Understanding how epimuscular myofascial force transmission affects fascial mechanics provides a theoretical framework to address the structures outside the muscle/tendon unit itself which in turn may suggest modifications of traditional exercise protocols. These protocols have been designed primarily on the basis of how they affect the muscle (strength, endurance, fiber type, etc.) rather than on their effects on the muscle/fascia structure.

As a secondary and entirely different approach, in addition to the structural support of the body by muscle and fascia forces, we also explore implications at the cellular level. The importance of force on extra cellular matrix (ECM) is described by (Guang-Kui Xu, 2014). They report that '*Cells sense and respond to the elasticity of extracellular matrix (ECM) via integrin-mediated adhesion. Integrins switch among inactive, bound, and dissociated states, depending upon the variation of forces acting on them. A soft ECM can increase the activation level of integrins while a stiff ECM has a tendency to prevent the dissociation and internalization of bound integrins. In addition, more stable focal adhesions can form on stiffer and thinner ECMs*'. Recent experimental findings demonstrate that a stiff extracellular matrix is conducive to metastasis of cancer (Lu, 2012). Fascia is one such matrix. Heavy resistance muscular exercise has been found to reduce cancer mortality across many types of cancers (Allison, 2013), but there is as yet no understanding of why this happens and which types of exercise are most beneficial, except for some differences between aerobic and resistance training. Since resistance training generates much higher forces within the muscle, we are interested in how much of these forces are transmitted to the fascia, as this may possibly be transmitted to and affect the extracellular matrix.

In this paper we develop a mathematical model to determine the fraction of force generated by extremity muscles assumed to be of cylindrical shape under contraction. For this purpose we use simple formulas of theory of elasticity valid for isotropic material to determine longitudinal and radial stresses and strains as well as modulus of elasticity. For simplicity of calculation we assume the modulus of elasticity in radial direction is the same as that along the longitudinal direction.

Methods

To understand the mechanism of the force transmitted to the fascia during muscle contraction, we need to know the variables such as the muscle force, the fiber length, the volume of the muscle, its radius and cross section area. For this paper, we take these values from existing publications. Maganaris (2001) estimated the in vivo force-length characteristics of the human soleus and tibialis anterior (TA) muscles for six healthy males (age 24–32 years, height 167–183 cm, body mass 70–82 kg) at ankles angles from 30° of dorsiflexion to 45° of plantar flexion in steps of 15°. Barber et al. (2013) compared the voluntary and involuntary force generating capacity of the triceps surae muscles in 16 older adults and 18 young adults during isometric and isokinetic contractions at five ankle angles. Albracht et al. (2008) assessed the muscle volume and physiological cross sectional area of the human triceps surae muscle in vivo for thirteen male adults. Wright et al. (1984) studied the elastic properties of plantar fascia in vivo. Kawakami et al. (1994) determined all the above variables for extensor and flexor muscles at the elbow. We use these variables in evaluating the stress/force transmitted to the fascia enveloping the peripheral length of the muscles.

Results

A. We first examine the soleus muscle at the ankle to calculate the magnitude of force transmitted by soleus muscle to fascia during dorsiflexion and plantar flexion (see Fig. 1).

We assume the muscle as cylinder with length l and radius r. The variables given as a function of ankle angles in the Soleus muscle (Maganaris, 2001) are given in Table 1 below:

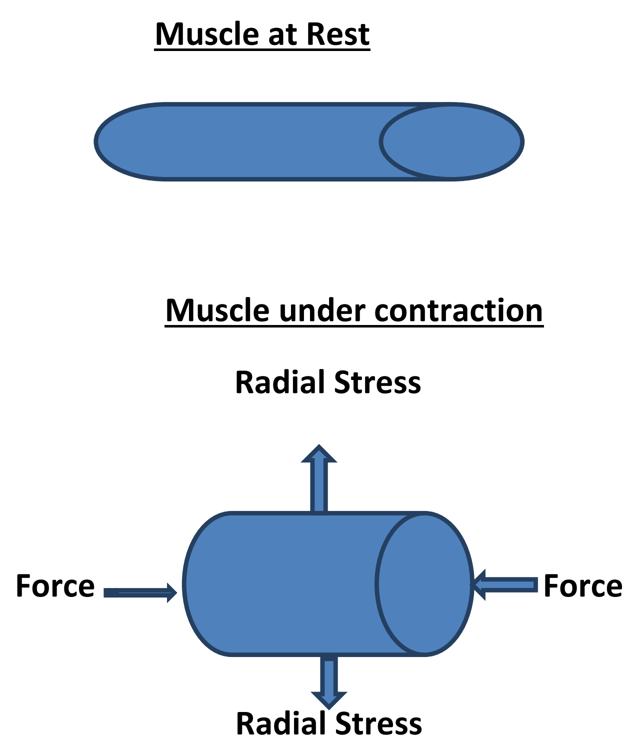

Figure. 1 In the un-deformed state, muscle is at rest. In the deformed state, muscle is under contraction. The length shortens and the radius becomes larger for constant volume of the muscle. The radial stress is produced which is transmitted to the fascia wrapping the muscle.

Download English Version:

https://daneshyari.com/en/article/2619083

Download Persian Version:

https://daneshyari.com/article/2619083

Daneshyari.com