Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XI, ISSUE 2 Supplement, 2011, Romania
The JOURNAL is nationally acknowledged by C.N.C.S.I.S., being included in the B+ category publications, 2008-2011.
The journal is indexed in: Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengace Learning

TYPOLOGY AND PROFILE OF SPINE MUSCLES. STRUCTURE OF MYOFIBRILS AND ROLE OF PROTEIN COMPONENTS – REVIEW OF CURRENT LITERATURE

STRATON ALEXANDRU[1], ENE-VOICULESCU CARMEN[1], GIDU DIANA[1], PETRESCU ANDREI[1]

Abstract. Muscular profile of spine muscles has a great importance in trunk stability. It seems that muscles which support the spine show a high content of red muscle fiber with a cross section area equal or higher than white muscle fibers. It is possible that lumbar extensor muscles to have different functional capacity between sexes. Most of the myofibril structural proteins except protein actin and protein myosin have a role in maintaining the structural integrity of muscle cell.
Key words: muscle, fibres, myofibrils, proteins, spine.

Introduction

Proper understanding of muscle fibers profile of muscles supporting the spine and the role of muscle cell structural proteins leads to better achievements in performance training and rehabilitation.

Muscle fibers typology

Skeletal muscle contains two major types of muscle fibers: slow twitch red or type I fibers) and fast twitch white or type II fibers). Slow fibers reach peak tension in about 110ms milliseconds) from the moment of stimulation, and rapid fibers reach peak tension in about 50ms from the moment of stimulation. So, fast twitch fibers have a rapid response time to stimulation, more than twice reported to slow twitch fibers.

Until now, we have identified only one type of slow twitch fibers and four types of fast twitch fibers: IIa oxidative-glycolitic, IIx oxidative glycolitic which has some physiological and biochemical differences, such as time of contraction, motoneuron size, fatigue resistance or oxidative capacity, maximum time of use, power output, mitochondrial density, etc., than IIa fibers), IIb predominantly glycolitic and IIc A. Nicu şi L. Baroga, 1993) which contain transformation myosin, characterized by the shift from the fast twitch fibers to slow twitch fibers G. Dumitru, 1994). The difference between type IIa fibers and type IIb predominantly glycolitic is characterized mainly by fatigue and oxidative capacity and frequency of recruitment type IIa fibers, it seems that are frequently recruited, than type IIb fibers); slow fibers are mostly recruited and type IIc fibers are poorly recruited.

On average, the vast majority of muscles are composed of 50% type I fibres, 25% type IIa fibers, 22-24% type IIb fibers, and 1-3% type IIc fibers. However the exact percentage of these types of muscle fibers varies considerably in different subjects and different muscles J. H. Wilmore and D. L. Costill, 1994).

Muscular profile at the level of thoraco-lumbar spine

Sirca A. and Kostevc V., 1985) showed that thoracic muscle structure lying superficial and deep is composed of 74% type I fibers, lumbar muscle structure located superficially is composed of 57% type I fibers and lumbar muscle structure located deep is composed of 63% type I fibers. Type I muscle fiber diameter is significantly larger than that of type II fibers. Another study, conducted on 42 patients divided into two groups - 21 patients with lumbar back pain and 21 patients without lumbar back pain almost identical groups as gender, age and body mass index) showed that back muscles of patients with lumbar back pain, has a higher glycolitic profile rich in white fibers) A. F. Mannion et al., 1997b).

Mannion A. F. et al., 1997a), in a study of 17 male subjects and 14 female subjects, using the method of muscle biopsies performed in the corresponding spinal extensor of ten thoracic vertebrae and three lumbar vertebrae, showed that the ratio of cross-sectional area and the smallest diameter of the corresponding muscle fiber is higher in the thoracic region, compared to the lumbar region. Also, no significant differences were found between the two regions on the percentage of type I fibers, cross-sectional relative area of type I fibers and the ratio of cross sectional areas of type I fibers and, respectively, type II fibers. Male subjects have a muscle fiber cross-sectional area bigger than female subjects for all types of muscle fibers and in both regions - thoracic and lumbar - of the spine. Also, male subjects have a similar average of cross-sectional area for all types of muscle fibers, compared to female subjects, who have an average cross-sectional area increased in type I muscle fibers than type IIa fibers and IIb fibers, the latter showing no significant differences in average cross-sectional area. Therefore, fiber characteristics of spine extensor muscles differ from those of skeletal muscles by, the relative predominance in size of type I fibers slow twitch fibers or red fibers), reflecting the complex role of those muscles in maintaining posture Mannion A. F. et al., 1997a).

Also at the level of the spine extensor muscles, in a study of 16 subjects 9 male and 7 female, aged between 20 and 30 years) using the muscle biopsies method performed in the lumbar region of the human erector spinae on multifidus and the longissimus muscles, showed no significant differences between

[1] Faculty of Physical Education and Sport, Ovidius University of Constanta, ROMANIA
Email: stratonalex@gmail.com
Received 23.04.2011 / Accepted 19.06.2011

the two muscles on the relative occurrence of type I fibers 62% versus 57%), type IIa fibers 20% vs. 22%), type IIb fibers 18% vs. 22%) and, on the absolute size of muscle fibers average between 58 and 66 microns). In female subjects, type I fibers occupied a larger relative area than male subjects 70-75% vs. 54-58%), even though the relative number of type I fibers was similar for both sexes. This can be explained by a cross-sectional area of type II fibers smaller than the cross sectional area of type I fibers, in women. These data suggest a different functional capacity of the lumbar extensor muscles between sexes A. Thorstensson and H. Carlson, 1987).

Another study realised on 13 subjects 9 females and 4 males, aged between 24 and 55), using the muscle biopsy from the abdominal muscles right abdominal muscle, oblique external abdominal muscle, oblique internal abdominal muscle and transversal abdominal muscle) showed that there are significant differences between subjects, in muscle fiber type variation. Mean distribution of muscle fibers was 55-58% type I fibers, 15-23% of type IIa fibers, 21-28% of type IIb fibers and 0-1% type IIc fiber. Muscle fibers diameter was similar for most muscle groups studied average 50-54 microns), except transversal abdominal muscles which had a smaller diameter for the type II fibers average 45 microns). Also, muscle fiber composition, histochemically studied at different abdominal muscles, appear to exert similar functional capacity T. Häqqmark and A. Thorstensson, 1979).

Structure of myofibrils and role of protein components

Muscle-tendon structure is a complex biological organ capable of generating considerable force in order to stabilize and/or move the body segments and in energy absorption, which acts on the human body. This muscle-tendon structure is controlled by neural impulses, generating power by converting chemical energy into mechanical energy. Mechanical behavior of muscle contraction is directly related to macroscopic and microscopic structures and properties of muscle-specific proteins, which constitute the structure of muscle. Muscle-tendon unit is very adaptable, adjusting the structure and form of component protein in response to environmental stimuli changes.

Muscle fiber is formed by myofibrils, which in turn are divided longitudinally in sarcomere the region between two Z lines) and radial in myofilaments. Myofilaments are often classified in thick filaments and thin filaments.

Each thin filament which consists mainly of actin protein) is composed of two macromolecular subunits as wire) twisted together. These wires are composed of repeated subunits monomers) of protein G-actin globular actin). A G-actin molecule contains about 374 amino acids. These small ellipsoid molecules are joined front-to-back in long chains forms, twisted to form a helix structure F-actin), which at seven G-actin monomers is twisted by about half arc circle. Each chain of F-actin is a polymer composed of about 200 G-actin molecules R. M. Enoka, 1994). Each G-actin monomer has an active site in which myosin molecules can couple during muscle contraction. The groove formed along the helix structure is a series of fibrous elongated protein molecules called tropomyosin. Each tropomyosin molecule spans on a distance of seven G-actin monomers along F-actin groove R. R. Seeley et al., 2004). At one of the ends of the tropomyosin molecule there is a protein complex called troponin consisting of three adjacent subunits: troponin-C capable to reversibly bind calcium ions, troponin-T which attaches the this complex troponin) on tropomyosin and troponin-I that has an inhibitory function inhibits four to seven G-actin molecules to bind on the myosin, when tropomyosin is present). Troponin-C has four binding sites, two for Ca^{2+} ions and two for Ca^{2+} ions or Mg^{2+} ions R. M. Enoka, 1994). There are also, differences in troponin-C protein, corresponding to fast fibers compared to slow fibers S. V. Perry, 1985). Troponin-tropomyosin complex regulates skeletal muscle contraction, through the influence of actin activity R. M. Enoka, 1994).

Fundamental unit of thick filaments is myosin, a complex molecule with several distinct regions. Most of the length of this molecule forms a region often called the "tail" composed of light meromyosin LMM). The rest of the molecule, heavy meromyosin HMM), is composed of a protein chain that ends with a section called globular head. Globular portion, called the S1 region subfragment 1) is responsible for chemical and enzymatic activity, which produces muscle contraction. It also contains the actin binding site, which can interact with the thin filament, and the place of ATP binding site, which is involved in energy supply to achieve muscle contraction process. The chain protein, called S2 region subfragment 2) serves as the flexible bind like a hinge) between the globular portion and the tail region. Associated to S1 region, there are two opened peptide chains attached, with a much lower molecular weight. Essential peptide chain is necessary for the functioning of myosin and regulating peptide chain can be phosphorylated during muscular activity and modulate muscle functioning. Functional myosin molecules are paired, tails and S2 regions are twisted throughout all their length, and the two globular ends both showing the two peptide chains, essential and regulating, the actin binding site and ATP binding site) are adjacent to each other.

In addition to proteins directly involved in the process of muscle contraction actin and myosin proteins), there are other important structural protein in the maintenance of sarcomere structure during muscle contraction.

Titin is a large filamentary elastic protein, which spans from the Z line to the unisolated portion of the myosin filament line M) S. I. Fox, 2003), with role in

preventing sarcomere supra-elongation and in maintaining of A band in center A. J. Vander et al., 2001). Protein titin also acts as sarcomere regulator during myofibrilogenesis. Basically, titin is responsible for passive elastic properties of the relaxed muscle. Titin has a strong connection with M protein, corresponding to M line P. V. Komi, 1992).

M-protein maintain thick filaments in a regular order. Myomesin form strong anchor points for titin protein P. V. Komi, 1992), interacts with protein myosin and is located in the M band. Both myomesin and M-protein are involved in anchoring thick filament from the third elastic filament system formed primarily from titin protein), because both proteins have affinity for thick filament components, myosin, and titin W. M. Obermann et al., 1997). Myomesin protein seems to be the primary link between the thick filaments and elastic filaments because, in contrast with M-protein found only in type II fibers, it is found in all types of skeletal muscle fibers B. K. Grove et al., 1989, D. Auerbach et al., 1999). M-protein appears to have function only in fast motor units composed of type II muscle fibers.

M-creatine kinase protein M-CK, Muscle-Creatine Kinase) participates in the production of ATP from creatine phosphate CP or PCr), and is located near the myosin head Komi P. V., 1992).

Nebulin is a filamentary protein, which lies along the thin filaments composed primarily of actin protein, with role in stabilizing the thin filament elongation during muscle development and in guiding the thin filaments in the moment of interpenetration with thick filaments, after the return to normal of supra-elongated myofibril G. Dumitru, 1994).

C-protein seems to keep thick filaments in a regular order. It is speculated that maintains H-protein equidistant near the thick filaments during force production, and controls the number of myosin molecules from the thick filament. C-protein, H-protein and X-protein are components of myosin thick filament K. Yamamoto, 1988, R. Starr et al., 1985). It has been demonstrated, in animal studies, that C-protein is present in high amounts in fast fibers white) type IIa, IIx and IIb fibers and is absent from red fibers slow or type I fibers), while X-protein is present in high amounts in type I fibers and type IIa fibers and absent in type IIb fibers. The presence of H-protein in the muscle fibers depends on which muscle is studied; for example, in the rabbit psoas muscle, H-protein is found in large quantities in white) type IIb fibers and is absent from slow) type I fibers and white) type IIa fibers, and in the rabbit plantaris muscle, H-protein is found only in a few type I fibers and is absent in white) type IIb fibers R. Starr et al., 1985, P. Bennett et al., 1986).

Dystrophin, which is inside of sarcolemma, participate in the transfer of force, from the contractile system to outside of the cell, through the membrane composed of integrin proteins. Dystrophin is a cytoplasmic protein and is a vital part of costamere or dystrophin associated protein complex. Costamere is a structural-functional component of striated muscle cells; is a subsarcolemal protein complex, circularly aligned in disc Z plane, linking peripheral myofibrils from sarcolemma. Many muscle proteins as α-dystrobrevin, syncoilin, synemin, sarcoglycan, distroglycan and sarcospan are parts of costamere along with dystrophin. Focal adhesion proteins or cell-matrix adhesions which are specific types of large macromolecular assemblies through which mechanical force and regulatory signals are transmitted) found in costamer include vinculin protein, talin protein, α-actinin protein and β_1-integrin protein J. M. Ervasti, 2003).

Dystrophin associated glycoprotein complex contains varied proteins as sarcoglycan and distroglycan which seems to be responsible for the relationship between the internal cytoskeleton system subsarcolemal) of a myofibril with extracellular matrix structural proteins ex. collagen and laminin) R. H. Crosbie et al., 1997).

Syncoilin is an intermediate filamentary protein which interacts with α-dystrobrevin protein and desmin protein, and is found in the neuromuscular junction, sarcolemma and Z lines. Is also possible that syncoilin protein is involved in anchoring desmin intermediate filament proteins networks in sarcolemma and in neuromuscular junction. This interaction appears to be important in maintaining muscle fiber integrity and may also bind dystrophin associated protein complex from cytoskeleton E. Poon et al., 2002; C. Moorwood, 2008).

Synemin or desmuslin) is an intermediate filament protein located in the Z disc, which interacts with α-dystrobrevin protein D. J. Blake and E. Martin-Rendon, 2002), α-actinin protein and desmin protein. Synemin protein or desmuslin protein) has a role in transmitting mechanical force laterally through the tissue, especially between myofibrils and extracellular matrix. Also, desmuslin protein or sinemin protein) serves as a binding system between the extracellular matrix and Z discs through plectin protein), playing an important role in maintaining the integrity of muscle cells Y. Mizuno et al., 2001).

Plectin protein have direct connection with subcomponents of three major cytoskeleton filamentary networks, skeleton of subplasma membrane proteins and a variety of plasma membrane-cytoskeleton junction complexes; more specifically plectin protein acts as a binding component between the three main components of the cytoskeleton: the actin microfilaments, microtubules polymer formed by macromolecular complexes of α-tubulin and β-tubulin, which are members of the protein tubulin) and intermediate filaments called intermediate because they are 10nm in diameter, placing itself in size between the actin microfilaments and microtubules) T. M. Svitkina et al., 1996). These data lead to the concept that protein plectin have an important role in organizing the cytoskeleton network,

with consequences for the viscoelastic properties of cytoplasm and resistance and mechanical integrity of cells and tissues G. Wiche, 1998).

Vimentin protein is part of the intermediate filament protein family, which together with microtubules and actin microfilaments forms the cytoskeleton, existing as a dynamic structure most of the intermediate filamentary protein presents stable structure) to provide flexibility to the cell. It is generally accepted that, vimentin protein is a component of the cytoskeleton responsible for maintaining cellular integrity.

Vinculin protein is involved in the link between integrin adhesion protein molecules and actin cytoskeleton.

Catenin protein is found in complexes along with cadherin protein, cell adhesion protein molecules. There are four catenin proteins: alpha- α-), beta- β-), delta- δ-) and gamma γ-) catenin. α-catenin protein can bind with β-catenin protein or actin protein. β-catenin binds the cytoplasmic domain of some cadherin proteins. Cadherin is a class of type-1 transmembrane proteins that have important roles in cell adhesion, liaising between muscle cells; also caderin protein is functionally dependent Ca^{2+} ion. Cadherin protein family includes protocadherin proteins, desmogleina proteins, desmocollin proteins, etc..

Alfa-actinin α-actinin) protein associated with Z line, is anchoring thin filaments to Z line structure G. A. Tanner and R. A. Rhoades, 2003). It seems that the Z line corresponding to red fibers slow twitch) have a higher amount of α-actinin than Z line corresponding to white fibers fast twitch) P. V. Komi, 1992).

Intermediate filamentary protein desmin is mainly located in the peripheral area of the Z disc, as one of the physical links between the Z disc and sarcolemma; it forms a "scaffold" around Z disc, connecting Z disc by subsarcolemal cytoskeleton. Desmin protein forms lateral links between myofibrils by connecting the Z discs, maintaining sarcomers in order. The essential role of this intermediate filament protein is found in maintaining structural and mechanical integrity of the contractile apparatus, during and after muscle contraction D. Paulin and Z. Li, 2004; Z. Li et al., 1997), but also in force transmission through the cytoskeleton S. B. Shah et al., 2004).

Connections between intermediate filament protein system, dystrophin protein and specialized membrane complexes provides the path of force transmission to extracellular matrix material T. J. Patel and R. L. Lieber, 1997).

Outside the cell, laminin protein forms a link between integrin proteins and extracellular matrix G. A. Tanner and R. A. Rhoades, 2003). Integrin proteins are receptors which mediate attachment between cells and surrounding tissue. Also, integrin proteins have a role in cellular signals complex system of communication that governs basic cellular activities and coordinates cell actions) and, therefore, regulates cell shape, motility and cell division cycle. Integrin proteins work together with other proteins such as cadherin proteins, selectin proteins and syndecan proteins to mediate cell to cell and cell to matrix interaction and communication. Integrin protein binds the surface cellular components as fibronectin, vitronectin, laminin and collagen. Functional and structural defect of laminin proteins can cause an inappropriate muscle development, leading to some form of muscular dystrophy.

Collagen is a natural group of proteins constituting 1% to 2% of muscle tissue. In human body there are several types of collagen so far, only 29 types of collagen have been identified), but only type I collagen is the most abundant protein in the human body G. A. Di Lullo et al., 2002), representing over 90% of body collagen. Type I collagen is found in tendons, skin, artery walls, myofibrils endomysium, fibrocartilage and is an organic part of bones and teeth. Type II collagen is the base of hyaline cartilage and articular cartilage; it represents 50% of all cartilage proteins and 85-90% of articular cartilage collagen.

Parvalbumin is a protein located in the fast twitch fibers cytosol, which accelerates the relaxation of muscle after rapid contractions, by coupling the cytosolic Ca^{2+} in exchange of Mg^{2+}. Affinity for Ca^{2+} of parvalbumin is greater than that of troponin-C A. Despopoulos and S. Silbernagl, 2003).

Conclusion

At the level of the spine muscles the number of red muscle fibers is higher than white muscle fibers and red muscle fibers have an equal or higher cross sectional area than white muscle fibers, reflecting the complex role of those muscles in maintaining posture. Differences between red and white fibers type in lumbar extensor muscles registered between sexes may lead to a different functional capacity of those muscles. The most important aspect of the myofibril structural proteins, except protein actin and protein myosin, is to maintain the structural integrity of muscle cell.

Bibliography

AUERBACH, D., BANTLE S., KELLER S., HINDERLING V., LEU M., EHLER E., PERRIARD J. C. 1999, *Different domains of the M-band protein myomesin are involved in myosin binding and M-band targeting.* Molecular biology of the cell, 10 5): 1297-1308.

BENNETT, P., CRAIG R., STARR R., OFFER G. 1986, *The ultrastructural location of C-protein, X-protein and H-protein in rabbit muscle.* Journal of muscle research and cell motility, 7 6): 550-567.

CROSBIE, R. H., HEIGHWAY, J., VENZKE, D. P., LEE, J. C., CAMPBELL, K. P. 1997).

Sarcospan, the 25-kDa transmembrane component of the dystrophin-glycoprotein complex. The Journal of biological chemistry, 272 50): 31221-31224.

DESPOPOULOS, A., SILBERNAGL S., 2003, *Color Atlas of Physiology.* 5th ed., Thieme, New York, NY: 42-77.

DI LULLO, G. A., SWEENEY, S. M., KORKKO ,J., ALA-KOKKO L., SAN ANTONIO J. D. 2002. *Mapping the ligand-binding sites and disease-associated mutations on the most abundant protein in the human, type I collagen.* The Journal of biological chemistry, 277 6): 4223-4231.

DUMITRU, G., 1994, *Suferinţele musculare ale sportivilor.* Ed. Mondograf, Constanţa: 14-29.

ENOKA R. M., 1994, *Neuromechanical Basis of Kinesiology.* 2nd ed., Human Kinetics, Champaign, IL.: 129-134.

ERVASTI, J. M. 2003. *Costameres: the Achilles' heel of Herculean muscle.* The Journal of biological chemistry, 278 16): 13591-13594.

FOX S. I., 2003, *Human Physiology.* 8th ed., The McGraw-Hill Companies, Columbus, OH: 324-363.

GROVE, B. K., CERNY, L., PERRIARD, J. C., EPPENBERGER, H. M., THORNELL, L. E. 1989. *Fiber type-specific distribution of M-band proteins in chicken muscle.* The journal of histochemistry and cytochemistry: official journal of the Histochemistry Society, 37 4): 447-454.

HÄQQMARK, T., THORSTENSSON, A., 1979, *Fibre types in human abdominal muscles.* Acta Physiologica Scandinavica, 107 4): 319-325.

KOMI, P. V., 1992, *Strength and power in sport.* Blackwell Science, London: 39-64.

LI Z., MERICSKAY, M., AGBULUT, O., BUTLER-BROWNE, G., CARLSSON, L., THORNELL, L. E., BABINET, C., PAULIN, D. 1997. *Desmin is essential for the tensile strength and integrity of myofibrils but not for myogenic commitment, differentiation, and fusion of skeletal muscle.* The Journal of cell biology, 139 1): 129-144.

MANNION, A. F., DUMAS G. A., COOPER R. G., ESPINOSA F. J., FARIS M. W., STEVENSON J. M., 1997a, *Muscle fibre size and type distribution in thoracic and lumbar regions of erector spinae in healthy subjects without low back pain: normal values and sex differences.* Journal of anatomy, 190 part 4): 505-513.

MANNION A. F., WEBER, B. R., DOVORAK, J., GROB, D., MUNTENER, M., 1997b, *Fibre type characteristics of the lumbar paraspinal muscles in normal healthy subjects and in patients with low back pain.* Journal of orthopaedic research: official publication of the Orthopaedic Research Society, 15 6): 881-887.

MIZUNO, Y., THOMPSON, T. G., GUYOR, J. R., LIDOV, H. G., BROSIUS M., IMAMURA M., OZAWA, E., WATKINS S. C., KUNKEL L. M. 2001). *Desmuslin, an intermediate filament protein that interacts with alpha-dystrobrevin and desmin.* Proceedings of the National Academy of Sciences of the United States of America, 8 11): 6156-6161.

MOORWOOD, C. 2008. *Syncoilin, an intermediate filament-like protein linked to the dystrophin associated protein complex in skeletal muscle.* Cellular and molecular life sciences: CMLS, 65 19): 2957-2963.

NICU A., BAROGA L., 1993, *Dezvoltarea calităţii motrice - forţa.* În: Antrenamentul sportiv modern. Nicu A. [Editor] 1993. Ed. EDITIS, Bucureşti: 313-330.

OBERMANN W. M., GAUTEL M., WEBER K., FÜRST D. O. 1997). *Molecular structure of the sarcomeric M band: mapping of titin and myosin binding domains in myomesin and the identification of a potential regulatory phosphorylation site in myomesin.* The EMBO journal, 16 2): 211-220.

PATEL T. J., LIEBER R. L. 1997). *Force transmission in skeletal muscle: from actomyosin to external tendons.* Exercise and sport sciences reviews, 25: 321-363.

PAULIN D., LI Z. 2004). *Desmin: a major intermediate filament protein essential for the structural integrity and function of muscle.* Experimental cell research, 301 1): 1-7.

PERRY S. V., 1985, *Properties of the muscle proteins: a comparative approach.* The Journal of experimental biology, 115: 31-42.

POON E., HOWMAN E. V., NEWEY S. E., DAVIES K. E. 2002). *Association of syncoilin and desmin: linking intermediate filament proteins to the dystrophin-associated protein complex.* The Journal of biological chemistry, 277 5): 3433-3439.

SEELEY, R. R., STEPHENS, T. D., TATE, P., 2004, *Anatomy and Physiology.* 6th ed., The McGraw-Hill Companies, Columbus, OH: 271-360.

SHAH, S. B., DAVIS J., WEISLEDER, N., KOSTAVASSILI, I., MCCULLOCH, A. D., RALSTON, E., CAPETANAKI, Y., LIEBER, R. L. 2004). *Structural and functional roles of desmin in mouse skeletal muscle during passive deformation.* Biophysical journal, 86 5): 2993-3008.

SIRCA, A., KOSTEVC, V., 1985, *The fibre type composition of thoracic and lumbar paravertebral muscles in man.* Journal of anatomy, 141: 131-137.

STARR, R., ALMOND, R., OFFER G. 1985. *Location of C-protein, H-protein and X-protein in rabbit skeletal muscle fibre types.* Journal of muscle research and cell motility, 6 2): 227-256.

SVITKINA, T. M., VERKHOVSKY, A. B., BORISY G. G. 1996. *Plectin sidearms mediate interaction of intermediate filaments with microtubules and other components of the cytoskeleton.* The Journal of cell biology, 135 4): 991-1007.

TANNER, G. A., RHOADES R. A., 2003, *Medical Physiology.* 2nd ed., Lippincott Williams and Wilkins, Baltimore: 137-150.

THORSTENSSON, A., CARLSON ,H., 1987, *Fibre types in human lumbar back muscles.* Acta Physiologica Scandinavica, 131 2): 195-202.

VANDER, A. J., SHERMAN, J. H., LUCIANO D. S., 2001, *Human Physiology.* The Mechanisms of Body Function. 8ht ed., The McGraw-Hill Companies, Columbus, OH: 291-332.

WICHE, G. 1998. *Role of plectin in cytoskeleton organization and dynamics.* Journal of cell science, 111 pt. 17): 2477-2486.

WILMORE, J. H., COSTILL, D. L., 1994, *Physiology of sport and exercise.* Human Kinetics, Champaign, IL: 26-41.

YAMAMOTO, K. 1988. *Effect of H-protein on the formation of myosin filaments and light meromyosin paracrystals.* Journal of biochemistry, 103 2): 274-280

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