

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

185,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



Degeneration/Regeneration as a Mechanism Contributing to the Effect of Manual Acupuncture-Induced Injury on Rat Skeletal Muscle

Kamal Ameis¹, Annapurni Jayam Trouth²,
Vernon Bond² and Yasmine Kanaan²

¹*Georgetown University*

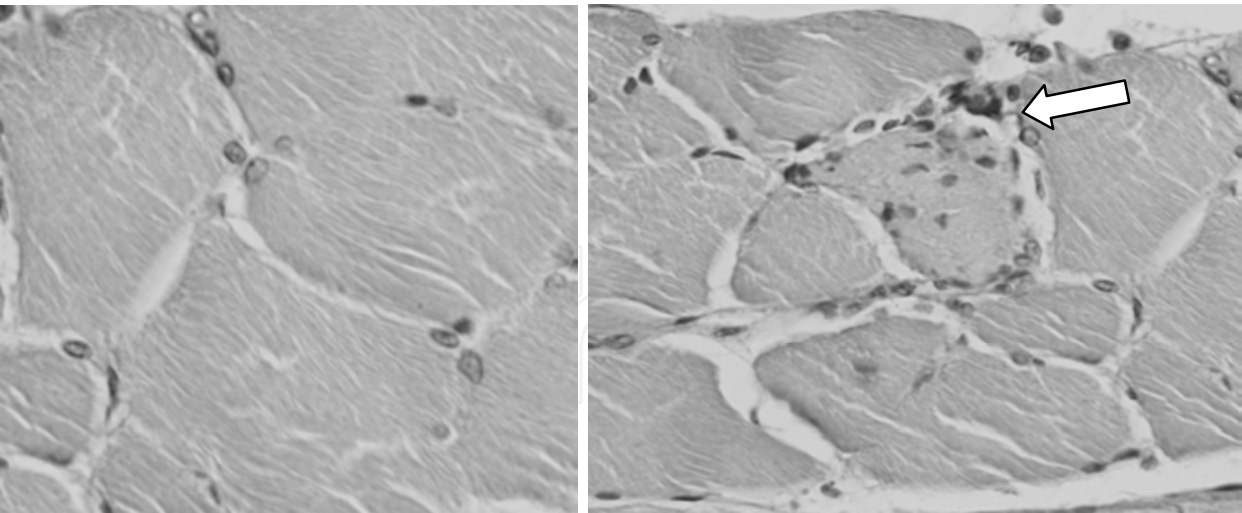
²*Howard University*
U.S.A.

1. Introduction

This book chapter is to further improve our understanding of the underlying mechanism of local injury that occurs after manual acupuncture needle manipulation that initiates muscle degeneration/regeneration process, which is essential for muscle maintenance and adaptation. Muscle injury triggers a sequence of events that begins with the host inflammation, secretion of myogenic transcription factor and various growth factors that are important for the activation and proliferation of muscle satellite (stem) cells.

Skeletal muscle is maintained by resident stem cells call muscle satellite cells because of their location on the periphery of the myofiber under the surrounding basal lamina (Mauro, 1961). Satellite cells are quiescent mononuclear cells that are present in different types of skeletal muscle and are associated with all muscle fiber types, although the distribution might be unequal. For instance the percentage of satellite cell in adult tibialis anterior muscle is larger than other muscles (Pavlati et al., 1998). Satellite cells are responsible for post natal growth, hypertrophy and repair of skeletal muscle (Grounds, 1999).

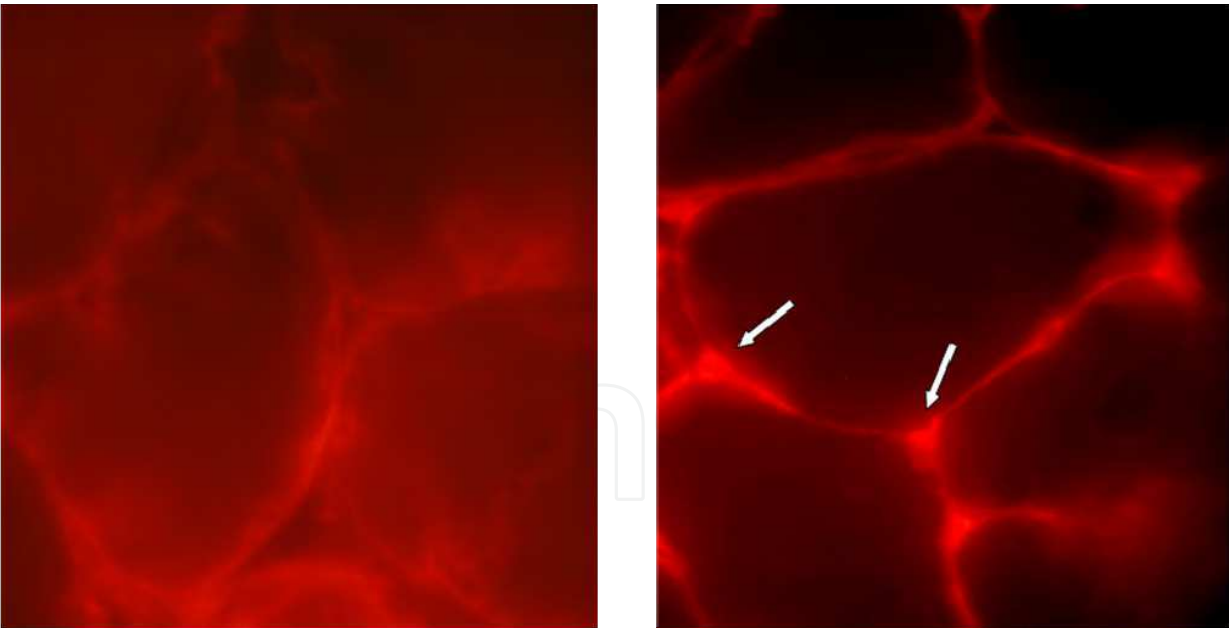
In normal undisturbed muscle, these cells remain in a quiescent stage (Schultz et al., 1985). After muscle injury, satellite cells become mitotically active, proliferate, differentiate and eventually fuse together to regenerate new muscle fiber, which is well-innervated, fully vascularized, through a process that resembles in some aspects embryonic (Seale et al., 2001). During muscle differentiation, satellite cells exhibit increased expression of the myogenic transcription factor MyoD (Cooper et al., 1999). Analysis of muscle regeneration has previously been studied using experimental models that induce muscle injury by various protocol such as eccentric contraction (Rathbone et al., 2003) or treadmill exercise (Smith et al., 2001). Although exercise induces injury-related satellite cell activation (Smith et al. 2001), its use is limited in patients with restricted exercise capacity during long periods of bed rest. Instead, such injury can be induced during acupuncture needle manipulation, which has been shown to induce muscle injury on acupuncture point (ST-36) in the tibialis anterior (TA) muscle (see Figure 1) and produce muscle regeneration via up-regulation of MyoD (see Figure 2 and Figure 3).



1.A Control TA Muscle

1.B Treated TA Muscle

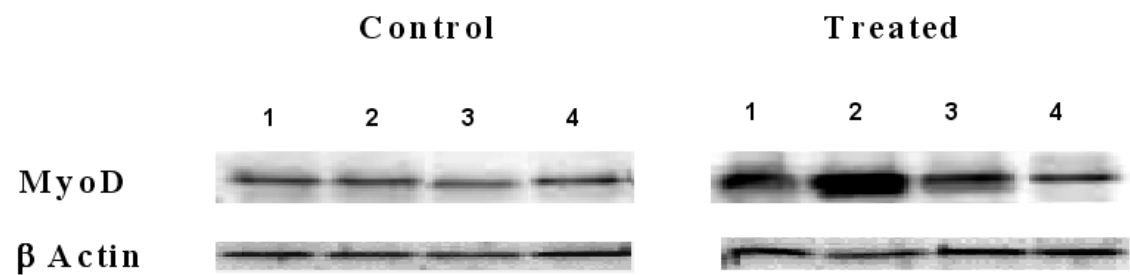
Fig. 1. **Acupuncture needling-induced signs of muscle injury**
Characteristic sagittal sections of hematoxylin-stained TA muscle. (A-left slide) Non-treated control TA muscle reveals a uniform labeling of compact myofibers and resident nuclei. (B-right slide) Acupuncture needling of the right TA muscle induced loss of myofiber integrity and apparent myonecrosis. Needling also stimulated the infiltration of mononucleated cells to the injured sites within the muscle tissue (arrow). Bar = 100 microns. (Ameis et al. 2008)



2.A Control TA Muscle

2.B Treated TA Muscle

Fig. 2. **Evidence of myogenic potential with TA muscle.** (A) Serial sections of control TA muscle incubated with antibodies specific for MyoD routinely displayed low levels of immunoreactivity. (B) MyoD-positive cells (arrows) were consistently observed in subsets of cells within the acupunctured TA muscle tissue. Immunoreactive profiles identified dense, nuclear staining that was localized at the periphery of the fiber membrane (arrows). Bar = 50 microns. (Ameis et al., 2008).



Western Blot Analysis

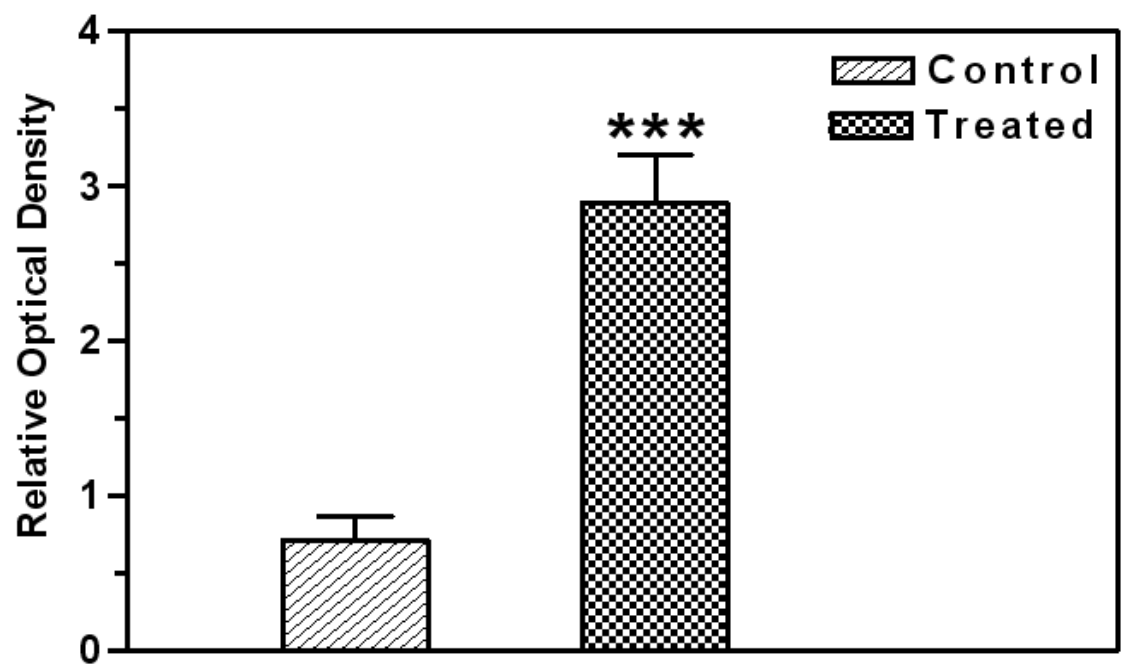


Fig. 3. Acupuncture needling-induced MyoD protein level as determined by Western Blot analysis. (A) The gel image of MyoD and beta-actin in control and treated TA muscle tissue. Lane (1, 2, 3 and 4 represent the different leg muscles) (B) Relative optical density. The results indicated a significant increase in treated compared with control (***p*<0.001) using Student *t* test. (Ameis et al., 2008)

2. Acupuncture and skeletal muscle regeneration

Acupuncture is an ancient Chinese therapy with a mode of action that is controversial. In traditional Chinese medicine (TCM) theory, needle manipulation is an important element associated with the efficacy of manual acupuncture. The acupuncture needles are manually manipulated after their insertions into a specific acupuncture point. Needle manipulation typically consists of rapid back-and-forth rotation, which can be brief (a few seconds) or prolonged (several minutes). Traditionally, in humans, needle manipulation is performed to elicit the characteristic reaction of acupuncture needling known as *de'qi* (Park et al., 2002). *De'qi* has a sensory component that is perceived by the patient as a pinching-type pain or heaviness in the area surrounding the needle. The acupuncturist administering treatment

perceives *de'qi* by needle grasp, or resistance to further manipulation. *De'qi* is widely viewed as essential to acupuncture's therapeutic effectiveness. It is possible that the *de'qi* reaction is a sign of muscle fiber injury or degeneration with subsequent regeneration.

3. Muscle injury and the degenerative phase

The degenerative phase of skeletal muscle injury involves inflammatory cells which is a critical component for successful regeneration to occur (Chargé & Rudnicki, 2004). Among inflammatory cells is a macrophages that infiltrate the injury site to phagocytose muscle debris (Robertson et al., 1993) and release interleukin-6 (IL-6) (Allen et al., 1995). IL-6 has the potential to regulate many critical process related to skeletal muscle including the regulation of cell proliferation, cell differentiation and overall tissue regeneration response (Baeza-Raja & Muñoz-Cánoves, 2004; Cantini et al., 1995; Kami et al., 2000). It has been shown that IL-6 plays an essential role in regulation of satellite cell (Serrano et al., 2008). Loss of IL-6 results in reduced satellite cell proliferation and migration (Serrano et al., 2008). Although IL-6 is classified as a pro-inflammatory cytokine it has a variety of biological functions. IL-6 can also act as in anti-inflammatory manner to inhibit the inflammatory response (Bunn et al., 2004; Xing et al., 1998).

The expression of IL-6 mRNA was detected in different injury models of muscle regeneration (Balasubramaniam et al., 2009; Sheriff et al., 2009; Warren et al., 2002). For example, Bunn et al. (2004) investigated the increase of IL-6 during regeneration following crush injury in rat muscle at different time points: 2, 4, 8, 16, and 24 days. The results showed a high level increase on day 2 post injury, decrease on day 4 and then increase again on day 8. Our current, unpublished data using acupuncture induced injury showed the expression of IL-6 mRNA was elevated rapidly in response to manual acupuncture in the treated rats TA muscle than the control at day 1. The expression was decreased at day 3 and increased again at day 7. It decreased again at day 21 post treatment (see Figure 4).

Taken together, the results of the studies discussed show that the inflammatory response seen after acupuncture injury is in many ways similar to those reported after other types of skeletal muscle injury. However acupuncture-induced model of injury has the added benefit that it could be applied in humans to study the recovery process following injury. Muscle injury common in contact sport has been studied in animal models and recently particular attention has been paid to skeletal muscle regeneration after injury. Attention has also focused on various treatment modalities in order to speed up the recovery process as well as to facilitate anti-inflammatory actions.

Although it is known that the immune system plays a major role in the skeletal muscle regeneration after injury, little detailed research has been done on the immune components of physiological response to injury so that conclusions are currently quite generalized or even conflicting. This makes it difficult to suggest incontrovertible evidence-based recommendations for treatment. Acupuncture has been accepted as a technique which can be used in humans, in contrast to other muscle-injury models (such as injection of toxins, freezing or crushing).

4. Muscle injury and regeneration

The regeneration phase, in which muscle stem cell are activated and rapidly up-regulate the expression of myogenic regulatory factor (MyoD). This cellular and molecular phenotype is a

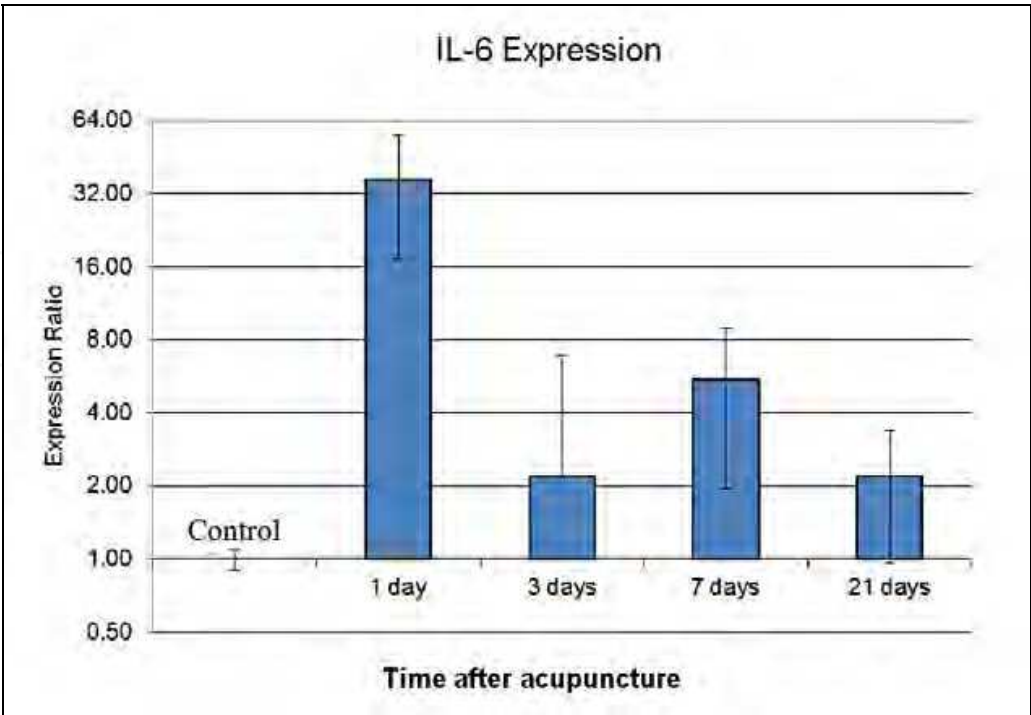


Fig. 4. **IL-6 Expression** Data represent fold changes in *IL-6* mRNA as assessed by RT-PCR after 0 (control), 1, 3, 7 and 21 days post acupuncture treatment of TA muscle. Differences in expression between groups were assessed by two-sided Pair Wise Fixed Reallocation Randomization Test. Level of probability was set at $P < 0.05$ as statistically significant. Values are mean \pm SEM (19.44, 4.74, 3.53, 1.23 folds) different from control. (unpublished data, Ameis et al.)

presumed prerequisite for muscle regeneration and repair. At the molecular level, activation of satellite cells is characterized by the expression of MyoD (Cooper et al., 1999), which is routinely associated with cell determination, and is often highly expressed in actively proliferating myoblasts. Moreover, MyoD expression may be critical for the differentiation of myoblasts in response to stimuli that are produced during muscle injury (Seale and Rudnicki, 2002; Sabourin and Rudnicki, 2000) and remodeling. The absence of MyoD adversely affects muscle regeneration, delaying the transition of satellite cell-derived myoblast from proliferation to differentiation (Yablonka-Reuveni et al., 1999). Increased expression of MyoD has been shown to occur in both adult and aged skeletal muscle in response to injury (Becker et al., 2003; Krainak et al., 2006). It has been expressed also in young skeletal muscle following manual acupuncture treatment applied in acupuncture point ST36, located at the tibialis anterior (TA) muscle (Ameis et al., 2008).

The capacity of muscle regeneration is related to several factors, including the available pool of resident satellite cells in muscle fiber. TA muscle reportedly contains a greater pool of resident satellite cells than other muscle tissues (Kadi et al., 2004; Pavlath et al. 1998) and TA muscle regeneration and remodeling after injury is initiated at faster rates (Pavlath et al. 1998). These characteristics of the TA muscle are most likely related to its functional demand; TA muscle helps coordinate the control of balance and foot stability during normal walking, and is therefore active for extended periods daily. ST36 is the most commonly targeted acupuncture needle point in both clinical settings (Li et al., 2004), and experimental studies (Ameis, 1991).

Several pathways, including insulin-like growth factor (IGF-1) play vital role in regulating muscle regeneration (Machida & Booth, 2004). IGF-1 is a member of the family of insulin-related peptides. It is a widely distributed trophic hormone capable of mediating autocrine, paracrine or endocrine effect. IGF-1 was originally referred to as “somatomedin” to reflect its expression response to growth hormone stimulation and its ability to mediate some of the growth-promoting effect of growth hormones (de Moor et al., 1994). IGF-1 plays important roles in both embryonic and post-natal mammalian growth (vanBuul-Offers et al., 1994). Early studies compared the metabolic effect of IGF-1 and insulin on muscles including stimulation of protein metabolism, glucose transport and glycogen and triglyceride synthesis.

IGF-1 has been associated specifically with increasing proliferation of satellite cells (Hill & Goldspink, 2003). IGF-1 has been showed to be increased following acute muscle damage or chronic aerobic exercise (Bamman et al., 2001; Hambrecht et al., 2005). Several pathways, including IGF-1 regulate muscle regeneration. *IGF-1* has been specifically associated with increasing proliferation of satellite cells (Machida & Booth 2004). The local up-regulation of IGF-1 mRNA has been induced in skeletal muscle by various models of muscle injury, such as myotoxin injection (Hill & Goldspink, 2003; Keller et al., 1999; McKoy et al. 1999) or eccentric contraction (Hill & Goldspink, 2003; Hill et al., 2003; Jennische & Hansson, 1987). In our published study using acupuncture-induced injury, IGF-1 was higher in the TA muscle after manual acupuncture treat than control (see Figure 5). IGF-1 remained higher than control at day 1 of post acupuncture treatment and peaked at day 3. On day 7 and day 21, *IGF-1* had started to return to basal normal.

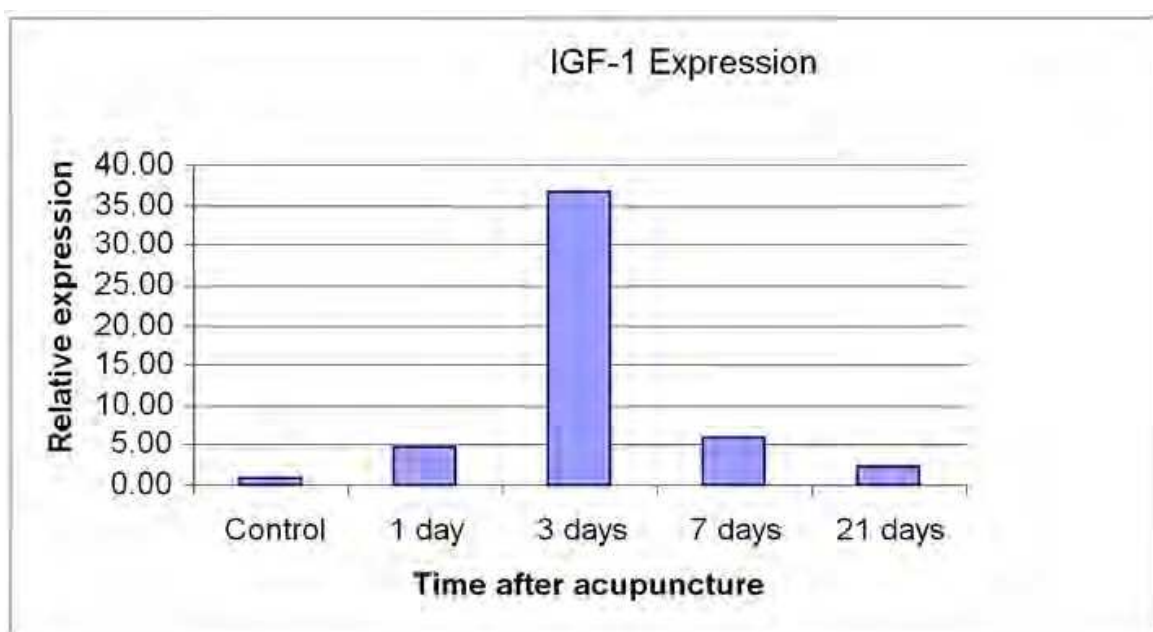


Fig. 5. **IGF-1** Data represent fold changes in *IGF-1* as assessed by RT-PCR after 0 (control), 1, 3, 7 and 21 days post acupuncture treatment of TA muscle. Differences in expression between groups were assessed by two-sided Pair Wise Fixed Reallocation Randomization Test. Level of probability was set at $P < 0.05$ as statistically significant. Values are mean \pm SEM (0.6, 0.31, 0.96, 0.19 folds) different from control. (unpublished data, Ameis et al.)

5. Acupuncture as a model of muscle injury

After pathological or experimental injury, the muscle undergoes regeneration processes. This regenerative capacity is due to the presence of a tissue-specific population of myogenetic stem cells. These specialized somatic stem cells are termed satellite cell because of their location on the periphery of the myofiber under the surrounding basal lamina (Mauro, 1961). During muscle development, satellite cells also mediate the post natal growth and are the primary means by which the mass of adult muscle is formed (Grounds, 1999). During post natal muscle development, satellite cells fuse with new or pre-existing myofiber. In adult muscle, in response to stress induced by weight-bearing exercise or trauma, satellite cells become mitotically active, proliferate, differentiate, and eventually fuse together to regenerate new muscle fiber (Seale et al., 2001; Chargé and Rudnicki, 2004). The essential role of satellite cells in muscle regeneration is well documented. However, an understanding of the molecular mechanism that regulates the activation and foundation of muscle stem cells has remained elusive and is a topic of extensive research targeting the crucial involvement of satellite cells in muscle reconstruction.

At the molecular level, activation, proliferation and differentiation of satellite cells is characterized by the up regulation of myogenic regulatory factor (MRFs). MRFs are skeletal muscle-specific transcription factor. The family consists of MyoD, Myogenin, MYF-5, MRF-4 to a larger basic-helix-loop-helix (bHLH) class of transcription factor. MyoD has been shown to up-regulate at the early stage of satellite cell proliferation. Myogenin and MRF-4 is up-regulated in cells, beginning their terminal differentiation program (Chargé and Rudnicki, 2004, review).

Analysis of muscle regeneration has previously been reported using different treatments to first induce degeneration of the muscle tissue, such as freezing (Warren et al., 2002) or snake toxins (such as notexin or cardiotoxin) (Mendler et al., 1998; Yan et al., 2003). Instead, such muscle injury can be induced using acupuncture, a minimally invasive technique. A study showed that a single session of manual acupuncture, consisting of needle manipulation in rat TA muscle, lead to focal injury and activation of satellite cell via up-regulated MyoD protein within muscle fiber (Ameis et al., 2008). A recent unpublished study has shown that manual acupuncture-induced injury in rat TA muscle up-regulated the expression of myogenic regulatory factor MyoD mRNA and peaked at 24 h post manual acupuncture treatment (see Figure 6). MyoD mRNA expression that peaked at 24 h has also been reported in rat pantais and soleus muscle in response to mechanical overload and stretch (Owino et al., 2001; Peviani et al., 2007).

In contrast to those using non-physiological models of muscle damage, other injury models have shown different time peak of MyoD. For example, Mendler et al. (1998) investigated the mRNA expression of MyoD during muscle regeneration following injection of myotixin in rat muscle found an increase of MyoD mRNA at 72 h post injury induced by injection of these myotoxin in rat muscle. Yan et al. (2003) using the same injury model using snake venom extract observed similar peak time point at 72h post injury in mice muscle. The reason for the difference in the time course of expression of MyoD mRNA between our study and those using venom toxin is unclear, but may be related to the severity of the insult that may lead to a partial loss of the satellite cell population (Polesskaya et al., 2003). However, whether this holds true is a topic for further investigation.

An alternative method to myotoxin which is considered more physiologically relevant is freeze injury (Chargé and Rudnicki, 2004). It has been shown that after freezing injury,

MyoD mRNA expression increased in mice TA muscle and peaked at 72 h time point (Warren et al., 2002).

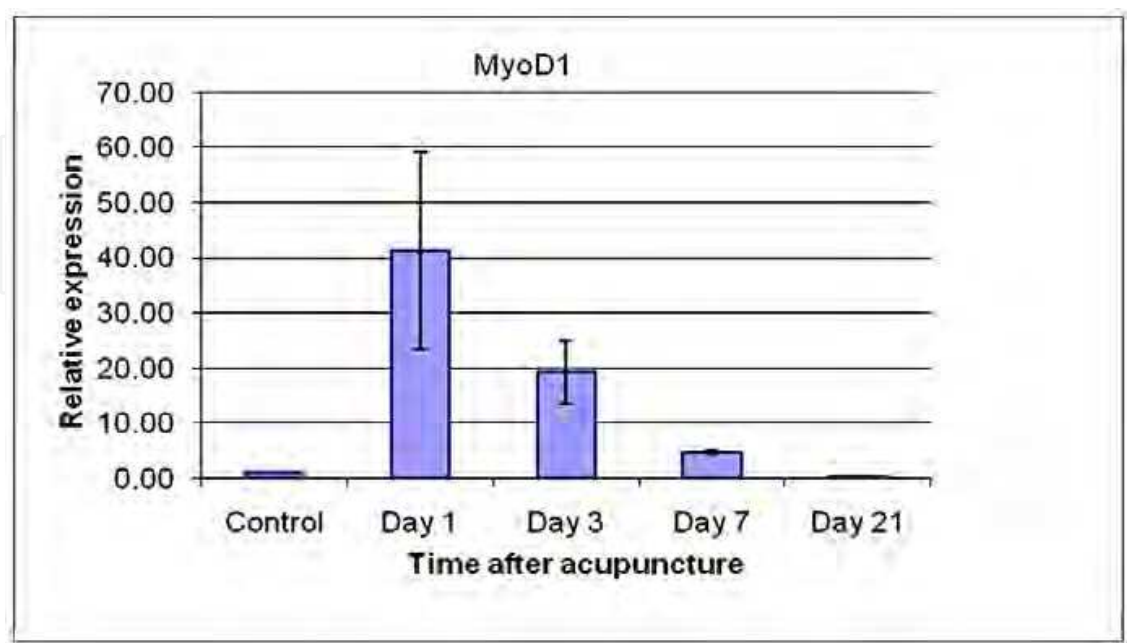


Fig. 6. *MyoD1* Data represent fold changes in *MyoD1* mRNA as assessed by RT-PCR after 0 (control), 1, 3, 7 and 21 days post acupuncture treatment of TA muscle. Differences in expression between groups were assessed by two-sided Pair Wise Fixed Reallocation Randomization Test. Level of probability was set at $P < 0.05$ as statistically significant. Values are mean +/- SEM (0.00, 17.88, 5.62, 0.34 folds) different from control. (unpublished data, Ameis et al.)

Comparing the effect of eccentric contraction and freezing shows that eccentric contraction exhibits a higher expression of MyoD mRNA than freezing (Warren et al., 2007). This might be explained by the observation that freezing induced freezing of satellite cells (Irintchev et al., 1997; Pastoret and Partridge, 1998).

The earlier peak expression of MyoD mRNA may be due to the nature of the intervention in the acupuncture needling model of muscle injury, which is similar to mechanical overload and stretch. The intervention involves a single insertion of a needle into acupuncture point ST36 in the rat TA muscle followed by a slight back-and-forth manipulation of the needle. During acupuncture needle manipulation, the muscle would be stretched and for normal muscle it is enough to hold a stretch for 15 to 30 seconds and repeat it for 3 to 5 times (Pezzullo & Irrgang, 2001). Therefore acupuncture needling model of injury, the needle is manipulated for 20 seconds every 3 minutes over duration of 15 minutes total. Therefore, this technique induces immediate and distant muscle injury--the needle insertion causes focal muscle injury at the point of insertion and the needle manipulation which stretches muscle fiber causes more distant muscle fiber injury.

There are several potential research advantages of acupuncture induced injury versus mechanical overload and stretch. The acupuncture injury model can be used to understand the process of muscle regeneration that will allow more precise comparison in future investigations of regenerative differences between age groups. It can also be used to study the regenerative process. Knowledge of the sets of genes associated specifically with the

nature of the injury may have application for developing new strategies for acceleration of the recovery process in injury skeletal muscle.

6. Possible role of acupuncture used as a countermeasure to forced inactivity

Forced inactivity during bed rest (Fitts et al., 1986) and space flight (Taylor et al., 2002) result in decrease of muscle regeneration. During activity, skeletal muscles are damaged and repaired repeatedly throughout life. Muscle regeneration maintains locomotor function during aging and delays the appearance of clinical symptoms of several conditions of muscle wasting. In humans, satellite cell function declines during aging (Gnocchi et al., 2008). However, in response to exercise, satellite cells increase in both young and old men and women, with significant increase particularly in adults (Dreyer et al., 2006; Kadi et al., 2004). In aged rats, satellite cells displayed a longer lag period before entering the cell cycle compared to adult rats (Gopinath and Rando, 2008). During inactivity (ex. hind limb unloading), the satellite cell mitotic activity is significantly reduced, especially in aged rats (Darr and Schultz 1989; Mozdziak et al., 2000; Siu et al., 2005). Therefore, it is suggested that activation of satellite cell may inhibit the loss of muscle function under atrophic conditions. Prevention of skeletal muscle atrophy during prolonged inactivity is important. A variety of potential counter measures have been tested and in many cases proved ineffective or unsatisfactory. In more recent study, daily injection of the complex IGF-1 during hind limb suspension or recovery showed to be beneficial (Chakravarthy et al., 2000; Zdanowica & Teichberg, 2003).

Because of the importance of IGF-1 to muscle regeneration, therapeutic applications are beginning to be explored. For example, experimentation on aged rat recovering from hindlimb immobilization shows that exogenously administration IGF-1 stimulates muscle recovery and an increase in satellite cell proliferation potential in hindlimb musculature (Chakravarthy et al., 2000). IGF-1 has been naturally expressed following manual acupuncture, therefore we suggest that acupuncture may be used as an approach to enhance muscle regeneration during forced inactivity such as bed rest.

This book chapter has sought to enhance our understanding of the underlying mechanism of local injury that occurs after manual acupuncture needle manipulation that initiates the degeneration/regeneration process. Muscle injury induced by acupuncture needling triggers a sequence of events that begins with the host inflammation, secretion of myogenic transcription factor and various growth factors that are important for the activation and proliferation of muscle satellite (stem) cells.

7. References

- Allen, R.; Sheehan, S.; Taylor, R.; Kendall, T. & Rice, G. (1995). Hepatocyte Growth Factor Activates Quiescent Skeletal Muscle Satellite Cells In Vitro. *Journal of Cell Physiology*, Vol.165, No.2, (November 1995), pp. 307-12.
- Ameis, K. (1991). Analgesic Effect of Captopril and Electroacupuncture Stimulation. *Proceedings of First Guangzhou International Conference of Traditional Chinese Medicine*, Gangzhou, China; 1991.

- Ameis, K.; Kanaan, Y.; Das, J. & George, M. (2008). Effect Of Manual Acupuncture-Induced Injury On Rat Skeletal Muscle, *Medical Acupuncture*, Vol.20, No. 4, (December 2008), pp. 225-230.
- Becker, C.; Della Gaspera, Guyot, M.; Donsez, E.; Armand, A.; Charbonnier, F.; Launay, T. & Chanoine, C. (2003). Expression Of MRF4 Protein In Adult And In Regenerating Muscles In *Xenopus*. *Developmental Dynamics*, Vol. 227 (July 2003), pp. 2445-459.
- Baeza-Raja, B. & Muñoz-Cánoves, P. (2004). MAPK-induced Nuclear Factor-KappaB Activity Is Required For Skeletal Muscle Differentiation: Role Of Interleukin-6. *Molecular Biology of the Cell*, (2004) Vol. 15, No. 4, pp. 2013-2026. doi:10.1091/mbc.E03-08-0585
- Balasubramaniam, A.; Joshi, R.; Su, C.; Friend, L.; Sheriff, S.; Kagan, R. & James, J. (2009). Ghrelin Inhibits Skeletal Muscle Protein Breakdown In Rats With Thermal Injury Through Normalizing Elevated Expression Of E3 Ubiquitin Ligases MuRF1 and MAFbx. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology*, Vol. 296, No. 4, pp. R893-901. doi:10.1152/ajpregu.00015.2008
- Bamman, M. ; Shipp, J.; Jiang, J.; Gower, B.; Hunter, G.; Goodman, A. & McLafferty, C. (2001). Mechanical load increases muscle IGF-I and androgen receptor mRNA concentrations in humans. *American Journal of Physiology. Endocrinology and Metabolism*, (2001), Vol. 280, No. 3, pp.E383-390.
- Bunn, J.; Canning, J.; Burke, G.; Mushipe, M.; Marsh, D. & Li, G. (2004). Production of Consistent Crush Lesions In Murine Quadriceps Muscle--A Biomechanical, Histomorphological And Immunohistochemical Study. *Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society*, (2004), Vol. 22, No. 6, pp. 1336-1344. doi:10.1016/j.orthres.2004.03.013
- Cantini, M.; Massimino, M.; Rapizzi, E.; Rossini, K.; Catani, C.; Dalla Libera, L. & Carraro, U. (1995). Human satellite Cell Proliferation In Vitro Is Regulated By Autocrine Secretion Of IL-6 Stimulated By A Soluble Factor(S) Released By Activated Monocytes. *Biochemical and Biophysical Research Communications*, (1995), Vol. 216, No. 1, pp. 49-53.
- Chakravarthy, M.; Davis, B. & Booth, F. (2000). IGF-I Restores Satellite Cell Proliferative Potential In Immobilized Old Skeletal Muscle. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, Vol. 89, No. 4, pp. 1365-1379.
- Chargé, S. & Rudnicki, M. (2004). Cellular And Molecular Regulation Of Muscle Regeneration. *Physiological Reviews*, Vol. 84, No. 1, pp. 209-238. doi:10.1152/physrev.00019.2003
- Cooper, R.; Tajbakhsh, S.; Mouly, V.; Cossu, G.; Buckingham, M. & Butler-Browne, G. (1999). In Vivo Satellite Cell Activation Via Myf5 and Myod in Regenerating Mouse Skeletal Muscle. *Journal of Cell Science*. (1999), Vol.112 (Pt 17), pp.2895-2901.
- Darr, K. & Schultz, E. (1989). Hindlimb Suspension Suppresses Muscle Growth And Satellite Cell Proliferation. *Journal of Applied Physiology* (1989), Vol. 67, No. 5, pp. 1827-1834.
- De Moor, C.; Jansen, M.; Bonte, E.; Thomas, A. ; Sussenbach, J. & Van den Brande, J. (1994). Influence Of The Four Leader Sequences Of The Human Insulin-Like-Growth-Factor-2 Mrnas On The Expression Of Reporter Genes. *European Journal of Biochemistry / FEBS*, Vol. 226, No. 3, (October 1994), pp. 1039-1047.

- Dreyer, H.; Blanco, C.; Sattler, F.; Schroeder, E. & Wiswell R. (2006). Satellite Cell Numbers In Young And Older Men 24 Hours After Eccentric Exercise. *Muscle & Nerve*. (2006), Vol.33, No. 2, pp.242-253.
- Fitts, R.; Metzger, J., Riley, D. & Unsworth, B. (1986). Models Of Disuse: A Comparison Of Hindlimb Suspension And Immobilization. *Journal of Applied Physiology*, Vol.60, No. 6, pp.1946-1953.
- Gnocchi, V.; Ellis, J. & Zammit, P. (2008). Does Satellite Cell Dysfunction Contribute To Disease Progression In Emery-Dreifuss Muscular Dystrophy? *Biochemical Society Transactions*. Vol. 36(Pt 6), pp.1344-1349. Review.
- Gopinath, S. & Rando, T. (2008). Stem Cell Review Series: Aging Of The Skeletal Muscle Stem Cell Niche. *Aging Cell*, Vol.7, No.4, pp. 590-598. Review.
- Grounds, M. (1999). Muscle Regeneration: Molecular Aspects And Therapeutic Implications. *Current Opinion in Neurology*. Vol.12, pp. 535-543.
- Hambrecht, R.; Schulze, P.; Gielen, S.; Linke, A.; Möbius-Winkler, S.; Erbs, S. & Kratzsch, J. (2005). Effects Of Exercise Training On Insulin-Like Growth Factor-I Expression In The Skeletal Muscle Of Non-Cachectic Patients With Chronic Heart Failure. *European Journal of Cardiovascular Prevention and Rehabilitation: Official Journal of the European Society of Cardiology, Working Groups on Epidemiology & Prevention and Cardiac Rehabilitation and Exercise Physiology*, Vol. 12, No. 4, pp. 401-406.
- Hill, M. & Goldspink, G. (2003). Expression And Splicing Of The Insulin-Like Growth Factor Gene In Rodent Muscle Is Associated With Muscle Satellite (Stem) Cell Activation Following Local Tissue Damage. *Journal of Physiology*, Vol. 549 (Pt 2) (June 2003), pp.409-418.
- Hill, M.; Wernig, A. & Goldspink, G. (2003). Muscle Satellite (Stem) Cell Activation During Local Tissue Injury And Repair. *Journal of Anatomy*, Vol. 203, No. 1 (July 2003), pp.89-99.
- Irintchev, A.; Langer, M.; Zweyer, M.; Theisen, R. & Wernig, A. (1997). Functional Improvement Of Damaged Adult Mouse Muscle By Implantation Of Primary Myoblasts. *Journal of Physiology*, Vol. 500 (Pt 3), pp. 775-785.
- Jennische, E. & Hansson, H. (1987). Regenerating Skeletal Muscle Cells Express Insulin-Like Growth Factor I. *Acta Physiologica Scandinavica*, Vol. 130, No. 2, (June 1987), pp. 327-332.
- Kadi, F.; Charifi, N.; Christian, D. & Lexell, J. (2004). Satellite Cells And Myonuclei In Young And Elderly Women And Men. *Muscle & Nerve*, Vol.29, pp. 120-127.
- Kami, K.; Morikawa, Y.; Sekimoto, M. & Senba, E. (2000). Gene Expression Of Receptors For IL-6, LIF, And CNTF In Regenerating Skeletal Muscles. *The Journal of Histochemistry and Cytochemistry: Official Journal of the Histochemistry Society*, Vol. 48, No. 9, pp. 1203-1213.
- Keller, H.; St Pierre Schneider, B.; Eppihimer, L. & Cannon, J. (1999), Association of IGF-I and IGF-II with Myofiber Regeneration in Vivo. *Muscle & Nerve*, Vol. 22, No.3, (March 1999), pp.347-54.
- Krajnak, K.; Waugh, S.; Miller, R.; Baker, B.; Geronilla, K.; Always, S. & Cutlip, R. (2006). Proapoptotic Factor Bax Is Increased In Satellite Cells In The Tibialis Anterior Muscles Of Old Rats. *Muscle & Nerve*, Vol.34, No. 6, (December 2006), pp.720-730.

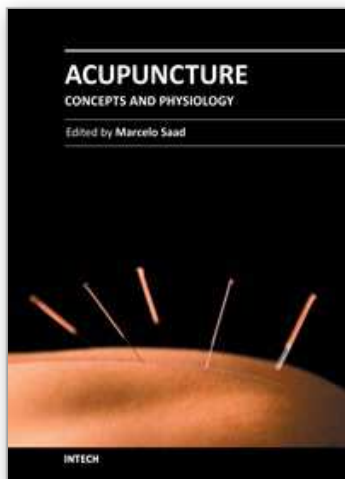
- Li, X.; Hirokawa, M.; Inoue, Y.; Sugano, N.; Qian, S. & Iwai, T. (2004). Effects Of Acupressure On Lower Limb Blood Flow For The Treatment Of Peripheral Arterial Occlusive Diseases. *Surgery Today* Vol.37, No.2, pp.103-108.
- Machida, S. & Booth, F. (2004). Insulin-like Growth Factor 1 And Muscle Growth: Implication For Satellite Cell Proliferation. *The Proceedings of the Nutrition Society*, Vol. 63, No. 2, pp. 337-340. doi:10.1079/PNS2004354
- McKoy, G.; Ashley, W.; Mander, J.; Yang, S.; Williams, N.; Russell, B. & Goldspink, G. (1999). Expression Of Insulin Growth Factor-1 Splice Variants And Structural Genes In Rabbit Skeletal Muscle Induced By Stretch And Stimulation. *Journal of Physiology*, Vol. 516 (Pt 2) (April 15, 1999), pp.583-92.
- Mendler, L.; Zádor, E.; Dux, L. & Wuytack, F. (1998). mRNA Levels Of Myogenic Regulatory Factors In Rat Slow And Fast Muscles Regenerating From Notexin-Induced Necrosis. *Neuromuscular Disorders* (December 1998), Vol.8, No. 8, pp. 533-41.
- Mozdziak, P.; Pulvermacher, P. & Schultz, E. (2000). Unloading Of Juvenile Muscle Results In A Reduced Muscle Size 9 Wk After Reloading. *Journal of Applied Physiology*, Vol. 88, No. 1, pp. 158-164.
- Owino, V.; Yang, S. & Goldspink, G. (2001). Age-related Loss Of Skeletal Muscle Function And The Inability To Express The Autocrine Form Of Insulin-Like Growth Factor-1 (MGF) In Response To Mechanical Overload. *FEBS Letters*, Vol. 505, No. 2 (September 2001), pp. 259-263.
- Pastoret, C. & Partridge, T. (1998). Muscle regeneration. In: P. Ferretti and J. Géraudie, Editors, *Cellular and Molecular Basis of Regeneration: From Invertebrates to Humans*. Wiley, Chichester (1998), pp. 309-333.
- Pavlat, G.; Thalloor, D.; Rando, T.; Cheong, M.; English, A. & Zheng, B. (1998). Heterogeneity Among Muscle Precursor Cells in adult skeletal muscles with differing regenerative capacities. *Developmental Dynamics*, Vol. 212, No. 4, pp. 495-508.
- Peviani, S.; Gomes, A.; Moreira, R.; Moriscot, A. & Salvini, T. (2007). Short Bouts Of Stretching Increase Myo-D, Myostatin And Atrogin-1 In Rat Soleus Muscle. *Muscle & Nerve*, Vol. 35, No. 3, (March 2007), pp. 363-70.
- Polesskaya, A.; Seale, P. & Rudnicki, M. (2003). Wnt Signaling Induces The Myogenic Specification Of Resident CD45+ Adult Stem Cells During Muscle Regeneration. *Cell* (2003), Vol. 113, pp. 841-852.
- Rathbone, C.; Wenke, J.; Warren, G. & Armstrong, R. (2003). Importance Of Satellite Cells In The Strength Recovery After Eccentric Contraction-Induced Muscle Injury. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology*, Vol. 285, No. 6, pp. R1490-1495. doi:10.1152/ajpregu.00032.2003
- Sabourin, L. & Rudnicki, M. (2000). The Molecular Regulation Of Myogenesis. *Clinical Genetics*, Vol. 57, No. 1, pp. 16-25. Review.
- Schultz, E.; Jaryszak, D. & Valliere, C. (1985). Response Of Satellite Cells To Focal Skeletal Muscle Injury. *Muscle & Nerve*, Vol.8, pp. 217-222. doi:10.1002/mus.880080307
- Seale, P.; Asakura, A. & Rudnicki, M. (2001). The Potential Of Muscle Stem Cells. *Developmental Cell*, Vol.1, No. 3, pp. 333-342.

- Serrano, A.; Baeza-Raja, B.; Perdiguero, E.; Jardí, M. & Muñoz-Cánoves, P. (2008). Interleukin-6 Is An Essential Regulator Of Satellite Cell-Mediated Skeletal Muscle Hypertrophy. *Cell Metabolism*, Vol. 7, No. 1, pp. 33-44. doi:10.1016/j.cmet.2007.11.011
- Sheriff, S.; Joshi, R.; Friend, L.; James, J. & Balasubramaniam, A. (2009). Ghrelin Receptor Agonist, GHRP-2, Attenuates Burn Injury-Induced Murf-1 And Mafbx Expression and Muscle Proteolysis In Rats. *Peptides*, Vol. 30, No.10, pp. 1909-1913. doi:10.1016/j.peptides.2009.06.029
- Smith, H.; Maxwell, L.; Rodgers, C.; McKee, N. & Plyley, M. (2001). Exercise-enhanced Satellite Cell Proliferation And New Myonuclear Accretion In Rat Skeletal Muscle. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, Vol. 90, No.4, pp. 1407-1414.
- Siu, P.; Pistilli, E.; Butler, D. & Always, S. (2005) Aging Influences Cellular And Molecular Responses Of Apoptosis To Skeletal Muscle Unloading. *American Journal of Physiology - Cell Physiology*, Vol. 288, No.2, (February 2005), pp. C338-349.
- Taylor, W.; Bhasin, S.; Lalani, R.; Datta, A. & Gonzalez-Cadavid, N. (2002). Alteration Of Gene Expression Profiles In Skeletal Muscle Of Rats Exposed To Microgravity During A Spaceflight. *Journal of Gravitational Physiology*, Vol. 9, No. 2, (December 2002), pp. 61-70.
- van Buul-Offers, S.; Bloemen, R.; Reijnen-Gresnigt, M.; van Leiden, H., Hoogerbrugge, C. & Van den Brande, J. (1994). Insulin-Like Growth Factors-I And -II And Their Binding Proteins During Postnatal Development Of Dwarf Snell Mice Before And During Growth Hormone And Thyroxine Therapy. *The Journal of Endocrinology*, Vol. 143, No. 1, (December 1994), pp. 191-198.
- Warren, G.; Hulderman, T.; Jensen, N.; McKinstry, M.; Mishra, M.; Luster, M. & Simeonova, P. (2002). Physiological Role Of Tumor Necrosis Factor Alpha In Traumatic Muscle Injury. *The FASEB Journal: Official Publication of the Federation of American Societies for Experimental Biology*, Vol. 16, No. 12, pp. 1630-1632. doi:10.1096/fj.02-0187fje
- Warren, G.; Summan, M.; Gao, X.; Chapman, R.; Hulderman, T.; Simeonova, P. (2007). Mechanisms Of Skeletal Muscle Injury And Repair Revealed By Gene Expression Studies In Mouse Models. *Journal of Physiology*. July 2007 Vol.582 (Pt 2), pp.825-41.
- Xing, Z.; Gauldie, J.; Cox, G.; Baumann, H.; Jordana, M.; Lei, X. & Achong, M. (1998). IL-6 Is An Antiinflammatory Cytokine Required For Controlling Local Or Systemic Acute Inflammatory Responses. *The Journal of Clinical Investigation*, Vol. 101, No. 2, pp. 311-320. doi:10.1172/JCI1368
- Yablonka-Reuveni, Z.; Rudnicki, M.; Rivera, A.; Primig, M.; Anderson, J. & Natanson, P. (1999) The Transition From Proliferation To Differentiation Is Delayed In Satellite Cells From Mice Lacking *Myod*. *Developmental Biology*, (1999), Vol. 210, No. 2, pp. 440-55.
- Yan, Z.; Choi, S.; Liu, X.; Zhang, M.; Schageman, J.; Lee, S.; Hart, R.; Lin, L.; Thurmond, F. & Williams, R. (2003). Highly Coordinated Gene Regulation in Mouse Skeletal Muscle Regeneration. *Journal of Biology Chemistry*. Vol. 278, No. 10, (March 2003), pp. 8826-36.

Zdanowicz, M. & Teichberg, S. (2003). Effects of Insulin-like Growth Factor-1/binding Protein-3 Complex on Muscle Atrophy in Rats. *Experimental Biology and Medicine* (Maywood), Vol. 228, No. 8, (September 2003), pp. 891-897.

IntechOpen

IntechOpen



Acupuncture - Concepts and Physiology

Edited by Prof. Marcelo Saad

ISBN 978-953-307-410-8

Hard cover, 222 pages

Publisher InTech

Published online 10, October, 2011

Published in print edition October, 2011

Acupuncture and related techniques are useful tools for treating a spectrum of diseases. However, there are still many areas of controversy surrounding it. We hope this book can contribute to guide the advance of this ancient medical art. In the present work, the reader will find texts written by authors from different parts of the world. The chapters cover strategic areas to collaborate with the consolidation of the knowledge in acupuncture. The book doesn't intend to solve all the questions regarding this issue but the main objective is to share elements to make acupuncture more and better understood at health systems worldwide.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Kamal Ameis, Annapurni Jayam Trough, Vernon Bond and Yasmine Kanaan (2011).

Degeneration/Regeneration as a Mechanism Contributing to the Effect of Manual Acupuncture-Induced Injury on Rat Skeletal Muscle, Acupuncture - Concepts and Physiology, Prof. Marcelo Saad (Ed.), ISBN: 978-953-307-410-8, InTech, Available from: <http://www.intechopen.com/books/acupuncture-concepts-and-physiology/degeneration-regeneration-as-a-mechanism-contributing-to-the-effect-of-manual-acupuncture-induced-in>

INTech
open science | open minds

InTech Europe

University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China

Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2011 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the [Creative Commons Attribution 3.0 License](https://creativecommons.org/licenses/by/3.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen