Health, Sports & Rehabilitation Medicine
Vol. 20, no. 3, July-September 2019, 130–133

Shock wave therapy applications in Sports Medicine

Andreea-Marilena Ionescu
Physical Medicine and Rehabilitation Department, "Prof. Dr. Agrippa Ionescu" Clinical Emergency Hospital Bucharest

Abstract

Shock wave therapy has been successfully applied since the early 1990's. Shock wave represents a sudden change of acoustic wave pressure, which carries high speed energy through different tissues, of which speed is higher than sound speed. Biological processes that have been described at cellular level following shock wave applications have been mentioned by authors in a large number of scientific studies. Therapeutic indications have been integrated by the International Society of Medical ShockWave Treatment. Shock wave therapy has multiple applications even in athletes' specific pathology, with limited side effects and contraindications.

Keywords: shock wave, athletes, cellular level, sports medicine.

General considerations

Sound is a mechanical longitudinal wave, which can travel through any type of medium except for traveling through a vacuum. A sound wave results from a variation of pressure and is characterized by its amplitude, intensity, volume, speed and frequency (***, 1998-2019).

The speed of sound varies depending on the conditions of the environment it travels through, being approximately 345 m/s through air and increasing with the rise in air temperature. Acoustic frequency is measured in Hertz, the human ear being capable of detecting sounds with frequencies between 20 Hz and 20 kHz (Dietz-Laursonn et al., 2016).

A shock wave is a sudden, almost discontinuous change in pressure, with a propagating speed that is higher than the local speed of sound in the medium it travels through.

A focused shock wave is described as an impulse that is characterized by:

- a wide frequency range, between 150kHz-100MHz;
- high amplitude pressure, with sudden variation - up to 150 Mpa;
- a low traction wave - up to 25 Mp;
- low pulse depth – reduced penetration;
- a short pressure rise interval - up to a few hundred nanoseconds – non-periodicity.

The mechanism of action

A shock wave will be subject to the laws of physics: reflection, refraction, diffraction and absorption. Thus, the amplitude, as well as the shape of the acoustic field can be changed by interacting with different layers of tissue inside the human body. Shock wave reflection through air determines these changes. Because approximately 99% of shock waves pass through air bubbles, a contact substance is used between the probe of the shock wave generator and the patient's skin, which interferes with the human body.

Any shock therapy applied in the vicinity of air interfaces, such as the intestines or lungs, might lead to injury to those tissues, causing serious adverse effects (Pishchalnikov et al., 2006; ***, 1998).

The parameters of focused shock wave therapy, such as absorbed energy, density, pressure range and spatial expansion of shock waves, are defined as standard IEC (***, 2019).

The shock wave is actually an acoustic wave that carries very high levels of energy which are transmitted to painful spots and to the musculoskeletal tissue with subacute, acute or chronic damage. This energy causes regeneration and repair processes of the bones, tendons or soft tissues.

The kinetic energy of the projectile created by the compressed air is transferred through the transmitter to the terminal end of the applicator and further to the tissues (Wang et al., 2006).

Therapeutic biological effects

High-energy acoustic waves used in shock wave therapy

The following biological processes take place simultaneously:

Received: 2019, July 31; *Accepted for publication:* 2019, August 6
Address for correspondence: Călimănești, Calea lui Traian, 555, Vâlcea County, Romania
E-mail: andreea2a@yahoo.com
Corresponding author: Andreea-Marilena Ionescu, andreea2a@yahoo.com
https://doi.org/10.26659/pm3.2019.20.3.130

1. Formation of new blood vessels - a blood flow rich in nutrients is absolutely necessary to initiate and maintain tissue repair processes. The application of shock waves causes capillary micro-breaks in the treated tendons and bone structures. Due to these micro-breaks there is increased expression of growth factors for angiogenesis: eNOS (nitric oxide synthase), VEGF (vascular endothelial growth factor), BMP-2 (bone morphogenetic protein). The newly formed blood vessels improve oxygenation and circulation in the treated areas, resulting in accelerated healing of tendons and bone structures.

2. Reduction of chronic inflammation. Chronic inflammation occurs when the body's inflammatory response is not permanently stopped. It can cause injury to healthy tissues resulting in chronic pain. Mast cells are a key component of the inflammatory process. Their activity is stimulated by the widespread use of acoustic waves. This process is followed by the production of proinflammatory cytokines and chemokines, which in the next stage determine the restoration of the normal healing and regeneration process.

3. Stimulation of collagen production. The production of sufficient collagen is a necessary precondition for the repair processes of the muscle and ligament structures. Shock wave therapy accelerates procollagen synthesis, thus forcing the alignment of newly formed collagen fibers into longitudinal structures that cause the healed tendon to become denser, stiffer and firmer.

4. Dislocation of calcified fibroblasts. Abnormal calcium deposits occur as a result of microtrauma or other types of trauma to the tendons. Acoustic waves dislocate these calcifications. Shock wave therapy initiates the biochemical decalcification of the constituent deposits (having the consistency of toothpaste), thus healing the tendon. As a result, granular calcium particles will be resorbed by the lymphatic system.

5. Dispersion of "substance P" - pain mediator. Substance P is a neurotransmitter that mediates the transmission of pain information through type C fibers. This neuropeptide is associated with intense, persistent chronic pain, relocating pain signals to the central nervous system. Shock wave therapy contributes to a decrease in the concentration of substance P, which reduces the stimulation of nociceptive fibers, thus reducing the intensity of pain, as well as inflammatory edema (Wang et al., 2016) (1).

6. Inactivation of trigger points. Trigger points are the main cause of pain in the spine or limbs. They represent the most sensitive circumscribed point from a band of palpable contracture in skeletal muscle fibers. Shock wave therapy is a treatment modality used to inactivate trigger points. The assumed mechanism of action is that the emitted acoustic energy unlocks the calcium pump by releasing this electrolyte into myofilaments, which leads to the desensitization of that trigger point, followed by analgesia (Travell & Simons, 1983) (2).

Therapeutic indications

The International Society for Medical Shockwave Treatment (ISMT) decided through its management board to publish clinical recommendations for the use of shock wave therapy in 2016. Their recommendations are based on corroborating the results of numerous clinical studies.

The therapeutic protocol is recommended only as a result of clinical-functional examination of the patient, imaging determinations, laboratory tests, as well as other investigations, where appropriate, all aimed at highlighting the diagnosis (Eid, 2016).

1. Approved standard indications:

- *Chronic tendinopathy:* calcifying tendinopathy of the shoulder, lateral epicondylopathy of the elbow (tennis elbow), greater trochanter pain syndrome, patellar tendinopathy, Achilles tendinopathy, plantar fasciitis.
- *Bone pathologies*: delayed bone healing, pseudarthroses, stress fracture, avascular bone necrosis without articular derangement, osteochondritis dissecans without articular derangement
- *Skin pathologies*: delayed healing or lack of wound closure, skin ulcers, non-circumferential burn wounds

2. Empirically tested clinical indications:

- *Tendinopathies*: rotator cuff tendinopathy without calcifications, medial epicondylopathy of the elbow, adductor tendinopathy syndrome, pes anserinus tendinopathy syndrome, peroneal tendinopathy, foot and ankle tendinopathies.
- *Bone pathologies*: bone marrow edema, apophysitis of the anterior tibial tubercle, anterior tibial stress syndrome.
- Muscular pathologies: myofascial syndrome, muscle sprain without tearing.
- Skin pathologies: cellulite

3. *Exceptional indications*:

- *Musculoskeletal pathologies*: osteoarthritis, Dupuytren disease, plantar fibromatosis, De Quervain disease, trigger finger
- *Neurological pathologies*: spasticity, polyneuropathy, carpal tunnel syndrome
- *Urological pathologies*: chronic pelvic pain syndrome, erectile dysfunction, Peyronie's disease
- *Others*: lymphedema

4. *Experimental indications*:

- Heart muscle ischemia
- Peripheral nerve lesions
- Central nervous system pathology
- Skin calcinosis
- Periodontal disease
- Jawbone pathologies
- Complex regional pain syndrome (algoneurodystrophy)
- Osteoporosis

In sports medicine, patients suffering from shoulder tendinopathy, epicondylopathies, plantar fasciitis, calcaneal spurs, achyllodynia, contractures / trigger points of the trapezius muscle, bursitis, tendinopathies, osteoarthritis of the knees, or coxofemoral joints benefit from shock wave therapy.

Numerous scientific studies, most of them clinical, demonstrate the benefits of shock wave therapy.

Thus, 95% of patients with knee osteoarthritis treated with shock waves responded positively by a minimization of pain, a reduction of joint stiffness and an improvement of functionality (Sheveleva & Minbaeva, 2014). Knee osteoarthritis has deterioration and loss of cartilage as a

pathophysiological substrate, changes of the subchondral and periarticular bone with pathological sclerosis, bone cysts and osteophyte formation. In the animal model of knee osteoarthritis, it has been demonstrated experimentally that shock wave treatment resulted in remodeling of the subchondral bone and reduction of articular cartilage deterioration (Wang et al., 2017).

Shock therapy has also been shown to be effective for lateral epicondylitis, as evidenced by another clinical study (Dobreci & Dobrescu, 2014). Lateral epicondylitis usually occurs in sporting subjects who play tennis, but also in violinists, surgeons, dentists, people who use the computer keyboard and mouse constantly (e.g. secretaries, accountants), with an increased incidence among adults aged between 40-50 years. Conventional therapy is complex in this pathology, and the recurrence of symptomatology is relatively increased at around 3 months. In cases refractory to conventional therapy, shock wave treatment with bi-weekly frequency is indicated. In these cases, shock wave therapy resulted in pain reduction on the visual analogue scale, lack of pain upon palpation, as well as improvement of daily activities.

Shock wave therapy has also proven its safety and efficacy in refractory cases of *chronic plantar fasciitis*, resulting in a 72.1% reduction in pain, improved function and improved quality of life (Gerdesmeyer et al., 2008).

Chronic tendinopathy of proximal hamstrings is an overuse syndrome whose treatment is non-invasive. Shock wave therapy results in reduced pain and improved mobility compared to conventional therapy - non-steroidal anti-inflammatory drugs, physiotherapy, kinetotherapy (Cacchio et al., 2011), as demonstrated in a study carried out by professional athletes.

Shock wave therapy is also effective for insertion tendinopathies, such as *medial tibial stress syndrome*, a disease commonly encountered in professional athletes, which causes pain along the path of the posterior tibial nerve, at the solitary muscle level. Thus, 85% of patients resumed sports activity much faster than those who had used conventional therapy (Rompe at al., 2010).

Lumbar facet joint pain syndrome contributes to one third of lumbosacralgia cases, being common both in the general population and in athletes in particular. Shock wave therapy led to significant pain reduction on the visual analogue scale in these patients compared with corticosteroid infiltration and radiofrequency neurotomy (Nedelka et al., 2014).

Shock wave therapy is also useful for *greater trochanteric pain syndrome*, having long-term results (patients were followed up for 1 year). Greater trochanteric pain syndrome has a tendinopathy of the buttocks as a substrate, often caused by overloading, frequently found among athletes (Furia et al., 2009).

Chronic Achilles tendinopathy is caused by mechanical overload, being the most common disease in sports medicine, equally distributed among athletes and sedentary people. Conservative therapy, consisting of changes in sports activity, plantar supports, stretching exercises, non-steroidal anti-inflammatory drugs, conventional physiotherapy, has less proven results. From the published studies to date, it appears that shock wave therapy is an effective treatment option for patients with chronic Achilles tendinopathy (Gerdesmeyer et al., 2015).

Shock wave therapy has proven effective in treating *adhesive capsulitis*, a disease that causes significant discomfort in performing daily activities, limiting the arch of movement in the affected shoulder (especially external rotation), and pain at rest and especially during active or passive movements. In these patients, shock waves stabilized tissues by accelerating the healing process, facilitating angiogenesis, improving blood flow in the affected area (Lee et al., 2017).

Contraindications

1. *Contraindications of low energy radial shock waves*:
   - Malignant tumors in the treatment area
   - Pregnant uterus in the treatment area
2. *Contraindications of high energy shock waves*:
   - Lung tissue in the treatment area
   - Malignant tumor in the treatment area
   - Epiphyseal plate in the treatment area
   - Central nervous tissue in the treated area
   - Severe coagulopathy
   - Pregnant uterus in the treatment area

Conclusions

Shock wave therapy is considered a safe and effective method for treating numerous pathologies in the musculoskeletal sphere, having positive biological tissue repair and regeneration effects through clearly defined mechanisms, contraindications being limited.

References

Cacchio A, Rompe JD, Furia JP, Susi P, Santilli V, De Paulis F. Shockwave therapy for the treatment of chronic proximal hamstring tendinopathy in professional athletes. Am J Sports Med 2011;39: 1146-1153. DOI: 10.1177/0363546510379324.

Dietz-Laursonn K, Beckmann R, Ginter S, Radermache K, de la Fuente M. In-vitro cell treatment with focused shockwaves - influence of the experimental setup on the sound field and biological reaction. J Ther Ultrasound 2016;4:2-14. doi: 10.1186/s40349-016-0053-z.

Dobreci DL, Dobrescu T. The effects of extracorporeal shock wave therapy (ESWT) in treating lateral epicondylitis in people between 40 and 50 years old. Procedia - Social and behavioral sciences 2014;137:32-36. doi:10.1016/j.sbspro.2014.05.248.

Eid J. Consensus Statement on ESWT Indications and Contraindication. Int Soc Med Shockwave Treat (ISMST). 2016:1-4.

Furia JP, Rompe JD, Maffulli M. Low energy extracorporeal shock wave therapy as a treatment for greater trochanteric pain syndrome. Am J Sports Med 2009;37(9):1806-1813. doi: 10.1177/0363546509333014.

Gerdesmeyer L, Frey C, Vester Y, Maier M, Weil L, Russlies M, Stienstra J, Scurran B, Fedder K, Diehl P, Lohrer H, Henne M, Gollwitzer H. Radial Extracorporeal Shock Wave Therapy is safe and effective in the treatment of chronic recalcitrant plantar fasciitis. Results of a confirmatory randomized placebo-controlled multicenter study. Am J Sports Med 2008;36(11):2100-2109. doi: 10.1177/0363546508324176.

Gerdesmeyer L, Mittermayr R, Fuerst M, Al Muderis M, Thiele R, Saxena A, Gollwitzer H. Current evidence of extracorporeal

shock wave therapy in chronic Achilles tendinopathy. Intl J Surg 2015;24(PtB):154-159. doi: 10.1016/j.ijsu.2015.07.718.

Lee S, Sangyong L, Jeong M, Oh H, Lee K. The effects of extracorporeal shock wave therapy on pain and range of motion in patients with adhesive capsulitis. J Phys Ther Sci 2017;29(11):1907-1909. doi: 10.1589/jpts.29.1907.

Nedelka T, Nedelka J, Schlenker J, Hankins G, Mazanec R. Mechano-transduction effect of shockwaves in the treatment of lumbar facet joint pain: comparative effectiveness evaluation of shockwave therapy, steroid injections and radiofrequency medial brunch neurotomy. Neuro Endocrinol Lett 2014;35(5):393-397.

Pishchalnikov YA, Neucks JS, VonDerHaar RJ, Pishchalnikov IV, McAteer JA. Air Pockets Trapped during Routine Coupling in Dry Head Lithotripsy Can Significantly Reduce the Delivery of Shock Wave Energy. J Urol 2006;176(6Pt1): 2706-2710. doi:10.1016/j.juro.2006.07.149.

Rompe JD, Cacchio A, Furia JP, Maffulli N. Low energy extracorporeal shock wave therapy as a treatment for medial tibial stress syndrome. Am J Sports Med 2010; 38: 125. doi: 10.1177/0363546509343804.

Sheveleva NI, Minbaeva LS. Shockwave therapy for knee osteoarthritis. Glavnyj Vrach 2014*;*4(10). Available at: https://www.btlshockwave.co.uk/scientific-support-study-2. Accessed online: 25 May 2019.

Travell JG, Simons DG. Myofascial pain and dysfunction: the trigger point manual. Williams & Wilkins Baltimore, 1983.

Wang CJ, Cheng JH, Chou WY, Hsu SL, Chen JH, Huang CY. Changes of articular cartilage and subchondral bone after extracorporeal shockwave therapy in osteoarthritis of the knee. Int J Med Sci 2017;14(3):213-223. doi:10.7150/ijms.17469.

Wang CJ, Wang FS, Yang KD. Biological Mechanism of Musculoskeletal Shockwaves. The Department of Orthopedic Surgery and Medical Research Chang Jung Memorial Hospital Taiwan, 2016.

Wang CJ, Wang FS, Yang KD. Biological mechanism of musculoskeletal shockwaves. ISMST Newsletter 2006;1(1):5-11.

*** The Nature of Sound - The Physics Hypertextbook. 1998. Available at: https://physics.info/sound/. Accessed online: 20 May 2019.

*** IEC 61846. Ultrasonics - Pressure pulse lithotripters - Characteristics of fields. Available at: https://www.shockwavetherapy.org/about-eswt/physical-principles-of-eswt/. Accessed online: 22 April 2019.

*** Storz Medical - History of shock wave therapy: pseudarthroses. 2015. Availablea at: https://www.storzmedical.com/en/news-press/entry/history-of-shock-wave-therapy-pseudarthroses.html. Accessed online: 15 April 2019.

*** Shockwave Therapy european oficial website. 2019. Available at: https://www.shockwavetherapy.eu/subpage. Accessed online: 22 May 2019.

Websites

(1) http://physics.info/shock/. Accessed online: 21 April 2019.

(2) https://www.btlshockwave.co.uk/subpage Accessed online: 21 May 2019.