Ergojump evaluation of the explosive strength in volleyball athletes pre- and post-fascial treatment

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Received October 8, 2017; Accepted December 28, 2018

DOI: 10.3892/etm.2019.7628

Abstract. It has previously been demonstrated that physiological mechanisms are involved in muscle pain and fatigue, as the nociceptive afferents of the fascial system are able to modulate the afferent response of the central nervous system. The purpose of the present study was to evaluate a sample of volleyball players, and investigate whether osteopathic treatment of the lower limb muscle groups improved the explosive force of the limbs, whilst reducing spasms and tension, releasing tissue strain and correcting posture. A randomized control study was performed to evaluate 57 athletes who underwent fascial manipulative treatment to assess if such treatment affected the muscle strength of the lower limbs. The treatment group demonstrated a statistically significant improvement in the squatting jump test (P<0.0001) and in the counter movement jump test (P<0.0001). Furthermore, the control group did not exhibit any improvement in the squatting jump test (P>0.56) or in the counter movement jump test (P>0.32). The results suggested that correction of the fascial system required a minimum time of 30 days in order to obtain an improvement of fascial mechanics and sports performance. Therefore, use of a fascial protocol during athletic training will help improve the balance of the bands and, as a direct consequence, improve the efficiency of the musculoskeletal system, thereby reducing the risk of injury. It would therefore be advisable to perform osteopathic treatment techniques every two months during an athletic season to maintain the balance of the fascial system and obtain the most efficient results.

Introduction

Force is an innate ability of a body that enables an individual to modify their body and environment. It is possible to produce muscle power through effectors muscles. The proper function of muscles allows for them to efficiently express adequate levels of strength and forms the basis of health and well-being in individuals. Furthermore, muscle strength is indispensable for proper performance in sports and inevitably affects the practice of any sports disciplines. Numerous studies (1-7) have identified a significant role of the connective tissue that surrounds muscles during contraction. Bransilav et al (8), hypothesized that the force produced by muscle causes a deformation of the surrounding connective tissue that affects strength. The transmission of muscle strength is made possible by the contiguous nature of the fascia as well as its integrity. These features facilitate the transmission of force, which results in motor activity (7,9-11). Bordoni and Zanier (2) stated that ‘connective tissue can control the orientation of the muscle fibres, so as to reflect the vector of the direction of the force, and to make the transition of the more fluid and ergonomic voltage’. Fascial tissue alterations may induce various symptoms that influence the quality of life of the subject (12-13). In many instances, these symptoms are debilitating and difficult to detect using conventional diagnostic tests (14-17). For example, chronic fatigue is a common symptom (18). Recent studies have demonstrated that many physiological mechanisms are involved in the development of muscle pain and fatigue, as the nociceptive afferents of the fascial system are able to modulate the afferent response of the central nervous system (18).

In the present study, we examined athletes who play volleyball, a sport for which strength is needed and jumping...
is needed too, this could be mentioned here as strength is needed in many sports, but jumping is specific to volleyball. Many authors have examined the concept of training of explosive strength (19-23) and have concluded that jumping ability can be a decisive factor in succeeding in volleyball as it facilitates both attack and in defense (24-27). Studies by Newton et al (28,29) demonstrated that performing specific training tasks increases power and strength of the muscles of the lower limbs, thereby resulting in improvements in the height achieved during a vertical jump.

The main goal of the present study was to evaluate if undergoing specific osteopathic treatment of the lower limb muscle groups in a sample of volleyball players could improve the explosive force of the limbs. Our working hypothesis is that osteopathic treatment, capable to reduce the stiffness of lower limbs (30), make more efficient expression of produced explosive force. Simultaneously, the osteopathic treatment would decrease spasms and tension and release tissue strain.

To this end, we have developed a protocol of manipulative techniques with the aim of improving the functionality of the lower limbs through the normalization of the fascial tissue, in order to reduce the stiffness and thus to improving the explosive force.

Materials and methods

Subjects. A total of 120 healthy semiprofessional male volleyball players were recruited into this study. We excluded athletes who had one or more of the following: scoliosis, ligamentous laxity, a history of surgery (e.g., anterior cruciate ligament reconstruction, deep scars type varicocele, appendectomy), medication use, previous ligament injuries, or a muscle-tendon reconstruction, deep scars type varicocele, appendectomy), medication use, previous ligament injuries, or a muscle-tendon reconstruction, deep scars type varicocele, appendectomy). The sample was divided into the FTG and CG. The FTG underwent osteopathic treatment of the lower limb, while the CG received only a non-specific surface massage. Then, all other subjects. In fact, the athletes of CG received only a non-specific surface massage. Then, all other subjects.

Experimental design. The working protocol included: T0 (Fig. 1): 57 athletes participated in 10 min of warm up and stretching, before being subjected to the first battery of tests that assessed the power of the lower limbs. The sample was then divided into the FTG and CG. The FTG underwent osteopathic manipulative techniques (PFT) and the CG waited in the locker room, received only a non-specific surface massage. Then, all subjects underwent a second test to measure the power of the lower limbs. T1: After seven days, the FTG was subjected to a second treatment. T2: After seven more days (i.e., after 14 days from the first treatment), the FTG was subjected to the third treatment. T3: After seven more days (i.e., after 21 days from the first treatment), the FTG was subjected to the fourth treatment. T4: After nine more days (i.e., a month later (30 days)), the first test was again conducted on both the FTG and CG groups (Fig. 1). The subjects completed a total of four treatments, with a follow-up measurement performed after 30 days of treatment.

Lower limbs power rating. The evaluation of the power of the lower limbs was conducted using jumping tests. As described by Bosco et al (31), these tests involved a platform that was placed on a rubber-coated contact mat connected to a digital timer (Ergojump, Globus Inc., Treviso, Italy). The protocol outlined in Bosco et al (31) and mathematical criteria established by Bosco et al (31-32), were followed to perform two different jumping motions: the jump squat jump (SJ) and the counter movement jump (CMJ) (33).

The increase in flight time (FT) due to the muscle pre-stretch in CMJ with respect to the jump without pre-stretch in SJ, has repeatedly been attributed primarily to the release of elastic energy (34-36). The height of the jump was measured in centimeters. An expert in physiology and psychobiology who was blinded to the study groups measured the power of the lower limbs.

Squatting jump (SJ). This type of jump allows for the detection of the explosive force of the extensor muscles of the lower limbs. It is an easily performable and repeatable test that consists of a vertical jump at maximum intensity from the starting position, without making any downward movement (countermovement). The subject is in a starting position that includes having their feet evenly in contact with the ground. The knees are bent starting from a semisquat position with an angle of 90°. The opening angle of the knee in the first jump is checked with a hands goniometer. The hips and trunk are vertical to the ground during this type of jump.

Counter movement jump (CMJ). This type of jump indicates the relief of the elastic reuse capacity of the extensor muscles of the lower limbs. It consists of a vertical jump at maximum intensity, starting from the upright position, that is preceded by counter movement with bending of the knees up to approximately 90° (muscle stretch-shortening cycle). The subject then falls with spread knees and lands on their toes with subsequent cushioning to prevent injury. The test was performed with the subject's hands on their hips. The subject begins in the starting position taking (as described above).

For each of the two sessions, we conducted a preliminary stage consisting of heating: i) running at a gentle pace for approximately 10 min on a treadmill; ii) approximately 5 min of stretching and iii) a test jump. After warm-up standards, all players performed on a contact-time platform (Ergojump R, Finland) following the test protocol (32).

Protocol of myofascial treatment. The myofascial treatment protocol included the execution of the below-described techniques. Each osteopathic technique was performed on
a single point for 90 sec and each technique performed on a single district was administered only once during the treatment session (37). The protocol was performed by a physical therapist with 14 years of experience in technical manipulation and five years of experience in osteopathic manipulation. The osteopath was not involved in measurements and was not aware of the values obtained during measurements.

Superficial dorsal fascia. The fascia that covers the tendons of the long extensor muscles, the extensor hallucis longus and the anterior peroneus. The top portion of the fascia follows the annular ligament (upper and lower retinaculum mm extensors), while the inner and outer edges of fascia are along the foot and is often confused with the plantar fascia. At this point of the foot, the therapist places their fingers. With the patient in a supine position and with the osteopathic practitioner at the side of the foot, the therapist places one hand cranially to the retinacula of the ankle and the other hand is placed caudally around the metatarsal heads (Fig. 2A).

Pedidia fascia. This portion of the superficial fascia splits to cover the pedio muscle, the pedidei vessels and nerve, and the tibialis anterior. The fascia extends to the outer edge of the foot and is often confused with the superficial fascia. The points of origin and insertion are the dorsal surface of the cuboid and the fifth toe, respectively (Fig. 2B). With the patient in a supine position, the therapist places one hand below the ankle and the other hand distal to the site of articulation with the digits. The therapist then performs a helical pulling movement.

Deep fascia. This portion of the fascia covers the metatarsal bones and the interosseous muscles. With the patient in a supine position, the osteopathic clinician sits at the feet of the patient and locks the last four digits and mobilizes the first metatarsal using up-and-down motions as well as flexed-and-extended motions. The therapist carefully tests the margin of the insertion of the metatarsal head and follows this procedure with the remaining digits (Fig. 2C).

Plantar fascia of the foot. This portion of the fascia originates from the anterior portion of the calcaneal tuberosity and extends to the metatarsal heads. With the patient in a prone position and a bent leg, the therapist sits to the side that is to be treated. The therapist then locks the heel bone and performs traction movements on the plantar fascia using a spiral motion (Fig. 2D).

Outside fascia anterior leg. This fascia follows the aponeurosis of the thigh and originates from the tuberosity of the tibia, rhyme under the joint outside of the tibia to the head.
of the fibula in his front. At this level, it receives aponeurotic expansions of some of the thigh muscles, the biceps femoris, sartorius and semitendinosus. From its deep surface, they are detached different plates, which compose the muscle sheaths as well as intermuscular septa front and outer. With the patient in a supine position, the therapist sits with one hand below the patellar tendon and the other hand on top of the ankle. The therapist then performs helical movements (Fig. 2E).

**Internal fascia posterior leg.** This portion of the fascia originates at the popliteal fossa, part of the tibia, and extends to the heel pulley. With the patient in a supine position, the therapist places their hand cranially to the cable below the popliteal tuberosity of the tibia. They then place the remaining hand distally to the heel and pull without bending or stretching the foot (Fig. 2F).

**Intersosseous membrane of the leg.** This portion of the fascia includes the tibia-peroneal intersosseous membrane. It is identifiable by its course, which appears as two beams that intersect. Beams ankle peroneal: from top to bottom, from the tibia to the fibula, from the inside to inward. Beams peroneal tibia: The other at the bottom, from the fibula to the tibia, from outside to inward. This portion of the fascia also covers the tibia periosteum where the medial aspect is appreciable any may indicate possibly dysfunction. With the patient in a supine position, the therapist palpates the leg for dense areas. The therapist then runs their hand over these regions to relax them (Fig. 2G).

**Condyle shells.** This portion of the fascia includes a thickening of the capsule at the level of each condyle. Through its peripheral components, the condyle shells ensures the transverse stability of the knee. This is particularly evident from the inner side where the shell goes to be confused with the internal lateral ligament. With the patient in a supine position, the therapist places hands in the popliteal area on the inter-condyle shells. The therapist then tests for tension using small thrusting motions of the hands (Fig. 2H).

**Front thigh superficial fascia.** This portion of the fascia includes the inguinal ligament and extends to the top margin of the patella. With the patient in a supine position, the therapist sits by the side of the limb that requires treatment. The therapist then places one hand cranially on the inguinal ligament under the anterior superior iliac spine and another hand distally above the knee. The therapist then pulls using helical movements (Fig. 2I).

**Posterior thigh superficial fascia.** This portion of the fascia originates from an imaginary line formed between the greater trochanter and the ischial tuberosity. It is part of the popliteal fossa above the femoral condyles. With the patient in a supine position, the therapist places one hand cranially and posteriorly to the trochanter of the femur and the other hand distally on the inter-condyle shells. The therapist then performs helical movements (Fig. 2J).

**Fascia lata.** With the patient in a supine position and with the therapist standing opposite the TFL that requires treatment,
the therapist places their hands on the muscle belly starting above the knee and then pull the muscle upward. With the patient in a supine position, the osteopathic doctor engages the fascia lata with both hands from the contralateral side and walk along its length (Fig. 2K).

Fascia lata. The portion of the fascia lata that covers the iliopsoas muscle was treated differently. With the patient in a supine position and with the therapist standing by the side of the muscle to be treated, the therapist places their hand cranially past the belly of the iliopsoas muscle, while the distal hand raises and mobilizes the ipsilateral limb, thereby creating tension in the muscle layer (Fig. 2L).

Technique ‘unrolling leg fascial’. With the patient in a supine position, the therapist compresses the limb by pulling the foot while one hand is placed at the knee to aid in mobilization of the entire limb.

Statistical analysis. We performed an ANOVA (Friedman test), which was followed by Dunn’s multiple comparison test. All data are reported as the mean ± standard deviation and P<0.05 was considered to indicate a statistically significant difference. Analyses were performed using GraphPad Prism v.6.0 for Windows (GraphPad Software, Inc., La Jolla, CA, USA).

Results
The baseline measurements indicated that the sample was homogeneous relative to strength with athletes obtaining average values of 42.49 and 48.54 cm in the SJ test and in the CMJ, respectively.

The results obtained during the SJ test are shown in Fig. 3. The FTG exhibited a statistically significant improvement in the values obtained before and after 30 days, with the measurements increasing from 43.08±0.42 cm at baseline to 44.6±0.44 cm after 30 days (P<0.0001). Conversely, there was no improvement in the CG, with the measurements increasing from 42.56±0.40 cm at baseline to 42.52±0.41 after 30 days (P<0.56).

The results obtained in the CMJ test are shown in Fig. 4. The FTG exhibited a statistically significant improvement in the values obtained before and after 30 days, with the measurements increasing from 50.72±0.49 cm at baseline to 52.38±0.37 cm after 30 days (P<0.0001). Meanwhile, there was no improvement in the CG, with the measurements increasing from 49.48±0.43 cm at baseline to 49.48±0.44 cm after 30 days (P<0.32).

Discussion
The findings from this research show that that removing the somatic dysfunction borne by the fascial system of the lower
improve athlete’s performances. Future research is required to
study tissue damages with residual sore, and in a sports setting to
protocol is twofold: in a clinical field, to recover post-traumatic
both in term of techniques and timing. The applicability of this
work could be the athlete, if you did not perform the jump
whole fascial system of the lower limb. A weak point of the
job is certainly to have put in place a protocol of techniques
and ligaments acting across joints) of lower limb during move-
ment and defines the capability of those structures to act in
unison in a springlike manner (42). The improvements that we
observed indicated that myo-fascial treatment stimulates the
fascia, thereby facilitating the reaction of connection tissue
resulting in improvements.

Thirty days of treatment led us to hypothesize that the
metabolic activity of the fascia can, over time, restore the body
to optimal biomechanical conditions. We further determined
that correction of the fascial system requires a relatively long
period of time to obtain the best results.

The observed improvement of 2 cm in the measurement
of jump in athletes treated with osteopathic techniques has
a significant clinical relevance as it shows that, with equal
training, the treated group has a better response to the
tone/trophism of lower limbs' musculature.

Osteopathic tests and manipulative techniques facilitated
the troubleshooting and resolution of somatic dysfunction.
It also improved the mechanical function of the organism.
Muscles contract actively to generate force, which they then
transfer by deforming the surrounding connective tissue.
This action influences the application of force by modifying
the magnitude and direction of connective tissue deforma-
tion (43-46) and, therefore, of stiffness. The introduction
of a fascial protocol during athletic training can improve
the balance of the bands and, as a direct result, improve
the performance and efficiency of the musculoskeletal system,
thereby reducing the risk of injury. The strong point of the
job is certainly to have put in place a protocol of techniques
that allow to investigate in a sectoral and specific way the
whole fascial system of the lower limb. A weak point of the
work could be the athlete, if you did not perform the jump
properly. In this way, would to may be to perform osteopathic
techniques every two months during an athletic season so as to
maintain the balance of the fascial system and obtain excellent
performance.

The purpose of this study was largely achieved the sample
of volleyball players that has been subjected to osteopathic
treatment of the lower limb muscle groups has shown an
improvement the explosive force of the limbs, while reducing
spasms and tension, releasing tissue strain, and correcting
posture. The strength of the present work is undoubtedly the
development of a detailed and widely reproducible protocol
both in term of techniques and timing. The applicability of this
protocol is twofold: in a clinical field, to recover post-traumatic
tissue damages with residual sore, and in a sports setting to
improve athlete's performances. Future research is required to
develop a new treatment protocol suitable for the upper limbs
and trunk.

Acknowledgements
The study was supported and conducted by a multi-discipli-
tary team with the collaboration of CSDOI (Centro Studi
Osteopatia Italiano) of Catania, Italy.

Funding
No funding was received.

Availability of data and materials
The datasets used and/or analyzed during the current study are
available from the corresponding author on reasonable request.

Authors’ contributions
AB, CP and CM conceived and designed the experiments. AB,
CP and CM performed the experiments. TR, AB, MCP, AR,
CP, ViP, VaP, DDC and CM analyzed the data. AB and CM
wrote the paper.

Ethics approval and consent to participate
The paper was approved by the Internal Review Board of the
Research in Psychology at the Kore University of Enna (Enna,
Italy). The subjects signed an informed consent document that
was prepared according to the ethical standards laid down in the
Declaration of Helsinki.

Consent for publication
Written informed consent was provided by all subjects.

Competing interests
The authors declare that they have no competing interests.

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