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**Article type:** Research Article.

Title: Analysis of the effect of acupuncture and photobiomodulation on muscle fatigue.

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**ABSTRACT:** The goals is to analyze whether acupuncture and photobiomodulation have an effect on muscle fatigue, identify which is more efficient in reducing the fatigue effects, after the protocols applying individuals are able to perform the same workload, or improve it. It is a quantitative and experimental study, [72 active subjects (42 m. 32 f., 20 to 38 y), *η*: (age 25.79 y, *h* 172.01 cm, *w* 72.28 kg, BMI 24.37)]. Fatigue was assessed BOSCO modified protocol in a force plate, induced with 100 CMJ until failure. After the treatment protocols. Results show a significant difference after the intervention in groups A and D, (the sum of median heights, 2.60 cm and 2.45 cm, *d* 0.387 and 0.413, increasing *h* 14.44% and 12.36%, *p* < 0.001). Conclusion that acupuncture and photobiomodulation are efficient in minimizing fatigue, indicating that these treatment intervention protocols can improve muscular performance with jump height gain.

**KEYWORDS**: Acupuncture; Counter movement jump; Force Plate; Muscle Fatigue; Photobiomodulation.

**ABBREVIATIONS:** CMJ, counter movement jump; ECR, ethics committee of research; UNIFESP, Universidade Federal de São Paulo; CNS, central nervous system; ANS, autonomic nervous system; PGD2/PGE2, prostaglandin; LLLT, low level laser therapy; EMG, electromyography; JASP, Jeffrey's Amazing Statistics Program; H+, hydrogen ions; K+, O2, oxygen; potassium ions; CK, creatine kinase; BMI, s, seconds; min, minutes; mW, miliwatt; nm, nanometers; J, joule; *h*, height; *w*, weight; body mass index; kg, kilogram; cm, centimeters; y, years; *Σ*, sum; *η*, median; *p*, statistical difference; *η2*, eta squared; *d*, Cohen’s d or effect size; F, variance ratio; SD, standard deviation; df, degree of freedom; *≠*, difference; ANOVA, analysis of variance; Max, maximun; Min, minimun; %, percentual.

1. **INTRODUCTION**
   1. **Muscle Fatigue**

One of the most notable characteristics of skeletal muscles is their great adaptability whether resulting from immobilization, aging or physical exercise. In acute cases, these characteristics are even more notable, such as in the face of muscle fatigue. (3)

We can also define muscle fatigue as any reduction in the capacity of the neuromuscular system to generate force, which can be divided into central; with a reduction in the nerve impulse of motor neurons responsible for recruiting motor units during contraction; and the peripheral where there is failure or limitation in the contraction of the motor unit itself, in some studies we can see strong evidence that, during exhaustive workloads, the efficiency of muscular performance drops with fatigue. (1)

Fatigue involves the action of physiological processes in structures of the motor cortex, that control the contractile proteins of the muscle, due to neurological, electrophysiological, mechanical, metabolic factors, among others; which will directly interfere with the synchrony of the functioning of CNS and its peripheral pathways, and will generate an increase in the concentration of CK blood levels, causing partial destruction of the connective tissue. (29)

* 1. **Acupuncture**

There are many researches’ lines carried out in different areas, methods, and individuals, associated the use of acupuncture as a treatment for fatigue or muscle pain; these scientific papers, generally are more focused for the control of muscle pain and not too focused to muscle fatigue. (4; 20)

The acupuncture technique causes three local effects: 1 - electrical (stimulates synapses), 2 - neurochemical (due to tissue damage that releases substances), and 3 - mixed (due to the association of the first two). Cells release histamine, serotonin, K+ and bradykinin, which decreases the excitation threshold and membrane action potential. (22)

It is also related to peripheral and central mechanisms, as it stimulates type A afferent nerve fibers and mainly type C nociceptive fibers, which send the impulse to the spinal cord, activating analgesia mechanisms, generating inhibition of the effects of sympathetic transmission of nociceptive impulses to the CNS, thus resulting in analgesia and pain suppression, and the stimulation of various somatic, autonomic and hormonal reflex responses. Some supra-spinal mechanisms participate in the modulation of the nociceptive stimulus, and are related to the analgesia caused by acupuncture. (30)

Physiologically, acupuncture induces the production of neuronal hormones and neurotransmitters that are secreted into the blood, the humoral effect also depends indirectly on the central nervous system, which determines the release, at the endocrine level, of substances, causing an increase in the production of opioid peptides and inhibition of pain, being nowadays widely used to treat different types of pain such as neuralgia, headaches and delayed onset muscle pain. (8)

* 1. **Photobiomodulation**

Photobiomodulation as a rehabilitation method has been widely studied, its effects on skeletal muscle include reducing pain and tissue healing, reducing fatigue, gaining strength and relaxation, whether in active, sedentary individuals or even in athletes. (26)

Such results are due to the bio modulatory action exerted by light on the organism, through the photochemical effect where chromophores absorb light energy and transform it into chemical energy, producing local and/or systemic biological effects in the organism. (9)

Absorption occurs in the mitochondria, interfering with cellular respiration, for red and infrared waves, the chain of events involves the entry of O2 into the cell, resumption of respiration and acceleration of ATP, as muscle contraction has a great expense for the events in this chain and also interfere with the body functional performance. (2)

The ideal application parameters have not yet been completely determined, even with a large volume of studies in this field, knows the dose is what modulates the correct and beneficial effect on the muscle point, the energy density, type of emission, the form of application and which wavelengths are decisive for the result. (16)

1. **METHODS AND MATERAILS**
   1. **Ethical conditions**

The project was cleared by the Ethics Committee of Research, from Universidade Federal de São Paulo (CEP/UNIFESP) and receive the approval number: 6,157,636/2023.

All patients signed an Informed Consent Form, sent via electronic form (google forms) prior to the beginning of the study.

* 1. **Sample and sample division**

This research is a quantitative and experimental, composed of 72 subjects active; (42 male and 32 female); between 20 and 38 years, age median 25.79 years; heigh median 172, 01 cm; weight median 72.28 kg and BMI median 24.37, as shown on **table 1** with an anthropometric data and similarity analysis.

The sample will be made up of 72 individuals, select with in students from UNIFESP, São José dos Campos campus, divided into 4 groups composed of 18 members each, selected randomly and randomized by draw at the time of application of the protocols. The group A (acupuncture), was submitted by acupuncture treatment protocol; group B (placebo), was submitted by placebo acupuncture treatment protocol; group C (control), did not undergo any type of intervention, group D (photobiomodulation), was submitted by photobiomodulation treatment protocol. To determine the sample to be used in this research, we used the **equation** below where we work with an infinite population, which is the most suitable for this type of study:

* 1. **Fatigue analysis and Protocol for Fatigue induction**

The KOMI & BOSCO. protocol was used, modified through the execution of three successive CMJ exercises, with maximum power, performed on a force platform made by EMG System Brazil®, model Biomec 412, operated by EMGlab2 software, from the same manufacturer. The data was captured and saved in (.txt) format for later analysis. No prior warm up was done, we demonstrated in a video what the standard CMJ was to be performed, subsequently, the data was transported to a spreadsheet, where it was organized and tabulated. Statistical tests were carried out using JASP® software, for analysis, validation, conformation and verification. (11)

After completing the fatigue analysis protocol, we used modified protocol, to fatigue generation with 100 CMJ continuous performed on a rigid floor without prior warming up, each individual was informed that the test could be interrupted, for your’ s request, if were no longer able to continue, or at the evaluator’s request that monitored him, if it was identified that the movements were not within the standard parameters. (5; 23)

The individual was considered fatigued, if when was unable to continue the tests, or by evaluator's analysis, if detected an inadequate pattern of CMJ, like a reduced jump height due to the individual's lack of power in performing the CMJ. Becoming evident in these cases, the fatigue. After analyzing the data, we were able to compare the heights of the first three CMJ with the last three, and check whether or not there was fatigue, and whether or not there was recovery, after applying the treatment protocols. (18)

* 1. **Treatment protocols**
     1. **Group A - Acupuncture treatment protocol**

It is somewhat controversial try to explain, within the current scientific model used and accepted within the scientific community, the effects of the acupuncture inside to the Traditional Chinese Medicine, as well as trying to explain the circulation patterns of vital energy in the meridians. Because it is simply impossible to demonstrate by this same scientific method how this happens. Since this energy cannot be measured, quantified or even visualized. As well as the stimulation and sedation techniques used in acupuncture, such as the manipulation of needles with clockwise or counterclockwise rotation or the introduction of needles against or in favor of the circulation of the energy meridian.

The technique lasted thirty minutes; and the needles were manipulated during insertion with a 90° counter clockwise rotation with the aim of causing “sedation”, that is, a potential for local relaxation at the applied point, and applied bilaterally. (25)

We selected the points as described in **TABLE 2**, according to the bibliography consulted as being the most efficient indicated for the treatment of painful processes, fatigue, cramps in the lower limbs and lower back. (24)

* + 1. **Group B - Placebo treatment protocol**

The selected points according to the researched literature are located on the head and face, have their main actions not related to reducing pain in the lower and upper limbs, back or chest region, but have related to pathologies located on the face, like headache, orofacial pain, respiratory diseases, ocular and neurological disorders. (19)

We must highlight that, according to extensive bibliographical research carried out, also described by several authors, it is very difficult to create a placebo technique with needle insertion without causing any effect on the body. Several authors have tried placebos without insertion, which cannot be considered a placebo, as without there being physical action on the point it was, therefore, not stimulated, being equated to no action. So, we decided to use acupuncture with needle insertion for this group. (28)

The points chosen for this group are called occasional and are described in the **TABLE 3**, the technique lasted thirty minutes; without needle manipulation, the objective is not to cause relaxation as done in group A, they were punctured unilaterally and have no effect on the trunk and lower limbs, as previously reported. (25)

* + 1. **Group C - Control**

After applying the fatigue induction protocol, group C did not undergo any intervention. But they were asked to wait and rest in a sitting position for thirty minutes; so that the same recovery and rest time criteria were used as the other groups.

* + 1. **Group D - Photobiomodulation treatment protocol**

Underwent the photobiomodulation treatment protocol using the same anatomical locations of the acupuncture points used in group A, already described in **TABLE 2**.

The treatment lasted 12 min; and the individuals were asked to wait and rest in a sitting position for 18 minutes; so that the same recovery and rest time criteria were used as the other groups, The parameters used are described in **TABLE 4**, and are the same as those used in the study (14).

We are not using the same points in this study, because not all points are completely coincident with acupuncture points, and in our study, we aim to try to analyze whether acupuncture is effective or not. In this way, we will only use the parameters from the study mentioned below, with the points being the same as those from group A like as described in **TABLE 2**.

1. **RESULTS AND DISCUSSION**
   1. **Results**

We can consider that the sample was representative as it was selected from a group of university students who performed some type of physical activity during the week, and were therefore not sedentary and/or amateur or professional athletes.

TABLE 5 and GRAPHIC 1 and show that there is a significant difference before and after intervention in group A, and D the difference between of the sum of the height median for the CMJ 1 and 2, calculated using the equation:is (2.60 cm, and (2.45 cm) with (*d* = 0.387 and 0.413) respectively, for (*p*< 0.001). On GRAPHIC 2 we can see the evolution of height gain representing (14.44% and 12.36%) respectively.

When we analyze the same data in the other groups, we can also see in the same **TABLE 5** and **GRAPHIC 1** and **2**, that in group B the difference between the median height CMJ 1 and 2; using the same equation is (+ 0.08 cm), with (*d* = 0.013), for (*p* = 1), representing (0.44%) gain in jump height, this value it considered stable, demonstrating there is no statistical difference intra-group in this case. For group C where there was no intervention, the difference between the median heights between CMJ 1 and 2, is (-0.76 cm), with (*d* = - 0.122), for (*p* = 0.045), representing a yield loss of (- 4.49%), demonstrating there is no statistical difference intra-group in this case also, with and an evident worsening of results between one test and another. Making it clear that the fatigue generation protocol was able to fulfill its objective.

Analysis of variance (ANOVA) demonstrated that for the CMJ it statistically significant differences within groups, based on the interaction of group and treatment factors: , as we can see in **TABLE 6**. A posteriori paired comparisons indicated that the interventions had significant positive effects on post-intervention fatigue indices in groups A and D.

* 1. **Discussion**

In our study, the sample was composed of active individuals. During our bibliographical research, when we compared similar studies with the generation of fatigue through CMJ with compared treatment protocols, we no found similar researches with our work. So, we can say that according to the papers analyzed we do not have studies that compared acupuncture and photobiomodulation as a treatment method for the effects of fatigue.

In a study on fatigue (12), sought to verify the voluntary activation and mechanical performance of the triceps surae after fatigue, stating that there are several factors that cause fatigue, including the decrease in the pre-activation of the knee extensor muscle fibers (quadriceps) in association with central fatigue and peripheral which could explain the local fatigue. We verified, in our study, local fatigue when applying the fatigue protocol, and in most cases just after 30 repetitions of the CMJ, which does not correspond to central fatigue, but rather to peripheral fatigue**.**

When talking about acupuncture and post-intervention CMJ height (7) , sought to verify the immediate effects of acupuncture on strength performance and evaluated, through electromyography, the parameters of strength, height and power, determining that there was no significant increase in the height of the maximum jump with a bipedal fall, compared to the treatment with acupuncture, placebo acupuncture and control group; but identified a significant increase in the maximum isometric strength of the quadriceps. This corroborates our findings, although the placebo method in this study was different from ours, we found during our study, that there was a significant increase on CMJ height, especially in comparison with the control group, as already demonstrated in the results presented in **TABLE 5** and **GRAPHIC** **1** and **2**.

In the case of the CMJ(17), evaluated a group of elite sprinters using the CMJ and force platform and found that after applying the tests, the relationship between CMJ height and sprint capacity affects the competitive level of sprinters, establishing that it is possible that improvements in CMJ height in these group of athletes may result in better sprint performances, without however establishing the relationship between an increase in height in centimeters corresponding to an improvement in speed in seconds. This was also verified in our study, in the data presented in **TABLE 5** and in **GRAPHICS** **1** and **2** in both group A and D.

Analyzing the effect of photobiomodulation in athletes (13), identified that photobiomodulation can delay the perceived onset of muscle fatigue and exhaustion. Its photobiomodulation parameters are the same as those used in our study and corroborate our results. These same authors in a systematic review consisting of 13 articles (15), identified that there is an improvement in performance in skeletal muscles during exercise and can accelerate recovery when applied before exercise, according to their research.

In one study that analyzed the asymmetry of knee muscle stiffness, (27), identified that there was a reduction in knee joint stiffness, and the maintenance of vertical stiffness after the muscle fatigue induction protocol, but identified that there were no significant differences when comparing the asymmetry of knee joint stiffness and vertical movement stiffness of the lower limbs, in the eccentric action of the CMJ, before and immediately after carrying out a muscle fatigue induction protocol. We verified in our study, from the reports of the individuals tested that there was the appearance of muscular rigidity in some cases, however it was not evident that this rigidity was the factor that prevented the continuation of the execution of the CMJ, but the inability to generate force to continue the jumps.

Now for (21), the decline in the muscle ability to produce force was the main factor responsible for the decrease observed in jump height after fatigue. This was also verified by us when carrying out the fatigue induction protocol.

In the case of healthy and sedentary individuals (6), observed that, after undergoing a fatigue induction protocol, they presented changes in postural control during static stabilometric tests, which can be interpreted to increased neuromuscular response to try to overcome the instability generated by fatigue. Although we did not analyze stabilometry in our study, we were able to observe that during the application of the fatigue induction protocol, when the individuals were already close to reaching the point of muscular fatigue, we observe this postural instability, most likely resulting from the effects of fatigue on the muscle control.

Analyzing the performance of vertical jump (10), identified that shortly after applying the protocols there was an influence of the acute effects of fatigue on jumping performance, while the performance responses analyzed on 24h and 48h could indicate subacute responses to fatigue or muscle damage generated by the protocols.

Our study was carried out in a single moment for individuals for no more than 45 minutes, therefore it was not possible to evaluate what the effects of fatigue would be over longer intervals of time, and this would also open up another possibility, which would be the analysis of the effect of delayed onset muscle soreness on the generation of muscle strength and the jumping performance 24 and/or 48 hours after the interventions.

Our study sought to analyze active individuals who were subjected to a fatigue induction protocol and treated on a treatment protocol with acupuncture and photobiomodulation to try to minimize the effects of this fatigue, and in our bibliographical research. And we did not find similar studies with the same fatigue generation, treatment and sample characteristics as our study.

1. **CONCLUSION**

Therefore, when analyzing the primary goals, we found that both methods showed an improvement in the CMJ values, on the groups where the treatment protocol was applied (A and D), these data are equivalent to an improvement in performance in percentage points of the (+14.44%) for the group A and (+12.36)% for the group D, the effects of both acupuncture and photobiomodulation are positive and were able to minimize the effects of muscle fatigue, which may suggest that there was an increase in the generation of muscle contraction without presenting limitations in the execution of movements. Analyzing the secondary goals, due to the very close values, it is not possible to say that one treatment protocol stands out over the other, as both were efficient in minimizing the effects of muscle fatigue.

It is also possible to state that individuals were able to perform and even overcome the same workload after applying the intervention protocols, making it evident that groups A and D have a clearly more efficient response than groups B and C, so also according to the data presented, the protocol generate fatigue on group C, since the individuals were unable to reverse the initial condition.

We conclude that based on the results found and presented, there’s possible acupuncture and laser are efficient in minimizing the effects of fatigue after the application of a fatigue generation protocol. With an indication that these treatment protocols can enhance muscular performance and can be generate gain in height jump post-intervention.

More studies are needed in order to identify which factors may be responsible for this improvement in CMJ height, analyzing other variables, such as: pain, power and muscle strength to determine whether there is a gain in these indicators and what this value would be.

As well as different samples involving athletes and sedentary individuals with a larger number of individuals, thus being able to determine whether there is an adequate parameter of improvement compared to methods already extensively studied such as medication, cryotherapy treatments, thermotherapy, massage therapy, among others.

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**AUTHOR CONTRIBUTIONS**

**Author 1:** involved on conceptualization, investigation, carrying out tests, calling, selecting, drawing and defining study subjects, collecting data during tests, applying treatment protocols, writing original draft, data collection and data analysis, editing and writing the final version.

**Author 2:** involved on investigation, writing the original draft, selecting, drawing and defining study subjects, language and correction review.

**Author 3:** involved on the tabulation, review and data analysis, correction of statistical analysis and conformation and review of the data.

**Author 4:** involved on management, final review and scientific support.

**CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest financial or carrying out this scientific study.

**DATA AVAILABILITY STATEMENT**

The data that support the findings of this study are available with the author **(1)** upon reasonable request.

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**FIGURES AND TABLES**

**TABLE 1. Anthropometric data and similarity analysis.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variables | *η* | Max | Min | % Max | % Min | % *η* |
| *w* (kg) | 72.28 | 105.00 | 50.00 | 14.53% | 6.92% | 10.72% |
| *h* (cm) | 172.01 | 196.00 | 150.00 | 11.39% | 8.72% | 10.06% |
| age (y) | 25.79 | 38.00 | 20.00 | 14.73% | 7.75% | 11.24% |
| BMI | 24.37 | 31.02 | 19,077 | 12.73% | 7.83% | 10.28% |

Source: survey data

**TABLE 2. Description of circumstantial points of pain.**

|  |  |  |
| --- | --- | --- |
| Meridian | Point | Main Action |
| Bladder | BL37 | Atrophy, numbness, pain and paralysis of the muscles, leg. Distension and pain in the thigh. |
| Bladder | BL40 | Numbness, pain and paralysis of the lower limbs and lower back, relaxes muscles and tendons. |
| Bladder | BL58 | Weakness and pain in the lower limbs;  Backpain, |
| Bladder | BL60 | Pain in the heel, foot, ankle, lower back |
| Stomach | ST32 | Iliac and low back pain, motor imbalance, pain, weakness on quadriceps muscle. |
| Stomach | ST36 | Fatigue caused by excessive work, tiredness, low back pain, knee and calf pain. |
| Gallbladder | GB34 | Weakness, numbness, edema and pain in the lower limbs and heels. |

Source: SUSSMANN, DJ, 2000 (25)

**TABLE 3. Description of possible points.**

|  |  |  |
| --- | --- | --- |
| Meridian | Point | Main Action |
| Stomach | ST08 | Headache, migraine, eye pain, conjunctivitis, tearing, facial paralysis, dizziness, blurred vision. |
| Large Intestine | LI20 | Nasal obstruction, epistaxis, facial paralysis, trigeminal neuralgia, face and nose edema, rhinitis, sinusitis, tearing, toothache. |
| Small Intestine | SI18 | Facial redness and pain, mouth and eye deviation, toothache, trigeminal neuralgia, gingivitis. |
| Gallbladder | GB15 | Headache, nasal congestion, dizziness, tearing. |
| Bladder | BL04 | Headache, blurred vision, eye pain, decreased vision, nasal congestion, epistaxis, rhinitis, dyspnea, body heat. |

Source: SUSSMANN, DJ, 2000 (25)

**TABLE 4. Photobiomodulation protocol parameters.**

|  |  |
| --- | --- |
| Parameters | Values |
| Wave-length | 830nm |
| Power | 100mW |
| Dose | 1.785 j/cm2 |
| Time | 50s |

Source: LEAL JÚNIOR, ECP (14)

**TABLE 5. Statistic data.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| GROUP | % Improvement post-intervention | *≠* between *Σμ*(*h*)  post-intervention *(ΣμhJ2 – ΣμhJ1*) | *d* *Cohen* | SD | *p* *Tukey* |
| A (Acupuncture) | 14.44% | 2.60 | 0.387 | 7,060 | \*p < 0.001 |
| B (Placebo) | 0.44% | 0.08 | 0.013 | 6,113 | 1,000 |
| C (Control) | -4.49% | -0.76 | -0.122 | 6,136 | 0.045 |
| D (Laser) | 12.36% | 2.45 | 0.413 | 6,324 | \*p < 0.001 |

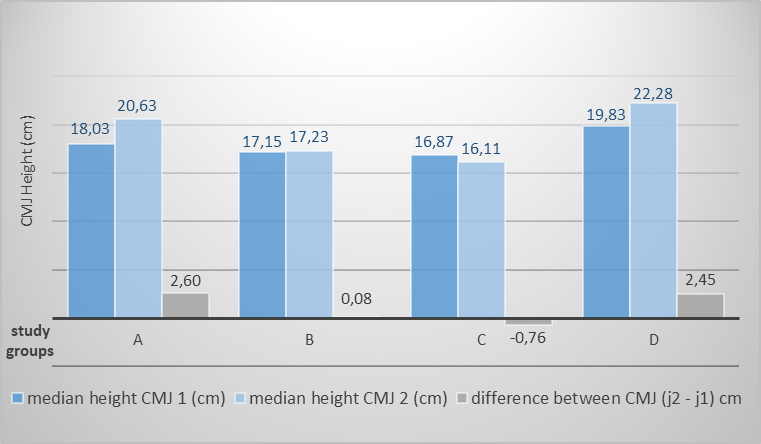
% of improvement height (*h*) after intervention of intra-group treatment protocols, difference (***≠***) between median (*Σμ*) of CMJ heights (*h*) (J2-J1), effect size (*d*), standard deviation (SD) and statistical difference (*p*). Source: research data.

**TABLE 6. Analysis of variance (ANOVA).**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ANALYSIS** | **sum of squares** | ***df*** | **median of squares** | ***F*** | ***P*** | ***η²*** |
| Median Residue (MR) | 40,625 | 1 | 40,625 | 35,659 | < 0.001 | 0.007 |
| MR Intra-groups | 72,913 | 3 | 24,304 | 21,334 | < 0.001 | 0.013 |
| residue | 72,911 | 64 | 1,139 |  |  |  |

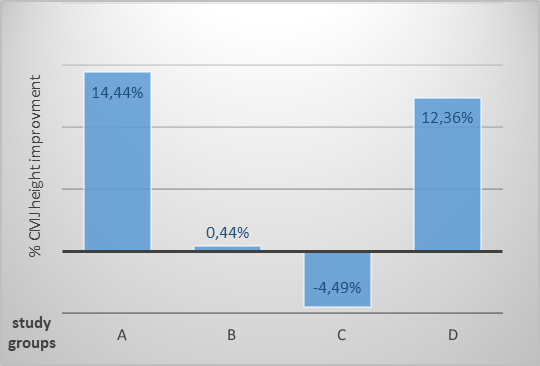
Source: research data.

**GRAPHIC 1 - Comparative analysis between the sum height median of (CMJ) 1 and 2, and difference between [CMJ (J2 - J1)].**

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Source: research data.

**GRAPHIC 2 – Percentage of improvement in CMJ height after treatment.**

****

Source: research data.