

 ISSN NO. 2320-5407	Journal Homepage: - www.journalijar.com INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR) Article DOI: 10.21474/IJAR01/12644 DOI URL: http://dx.doi.org/10.21474/IJAR01/12644	 INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR) ISSN 2320-5407 Journal Homepage: http://www.journalijar.com Article DOI: 10.21474/IJAR01/12644
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RESEARCH ARTICLE

TEN-YEAR FOLLOW-UP OF PRELIMINARY BICEPS BRACHIAL MUSCLE CONTRACTION IN THE REHABILITATION AND PROPHYLAXIS OF RECURRENT SHOULDER PAIN DUE TO TENDON DEGENERATION

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Manuscript Info

Manuscript History

Received: 25 January 2021

Final Accepted: 28 February 2021

Published: March 2021

Key words:-

Exercise, Physiotherapy, Preliminary Biceps Brachial Muscle Contraction, Recurrent Shoulder Pain, Tendon Degeneration

Abstract

Introduction:- One of the overlooked facilitating factors of recurrent shoulder pain due to tendon degeneration is the periarticular muscle latency (M1, M2, and M3). It leads to a lack of muscle protection against the external loads on the shoulder during the initiation of every shoulder movement. This creates multiple repetitive micro-traumas, gradually accumulating to tendon degeneration. The only way to overtake the periarticular muscle latency and its consequences is the preliminary biceps brachial muscle contraction.

Aim:- To study the effect of the preliminary biceps brachial muscle contraction on the short-term rehabilitation and the long-term prophylaxis of recurrent shoulder pain due to tendon degeneration.

Material and Methods:- For 10 years were followed 44 outpatients (age 50.1 ± 14.8 years) with recurrent shoulder pain due to tendon degeneration. They were randomized into two groups – “standard” (n=22) and “maneuver” (n=22). Both groups received prophylactic recommendations and were treated for two weeks with exercise, interferential current, and laser. The “maneuver” group received an additional recommendation to perform preliminary biceps brachial muscle contraction before every movement of the shoulder during the daily activities. Pain intensity, shoulder mobility, periarticular muscle strength, number of recurrences, number of rehabilitation courses, and success rate of the “maneuver” were followed-up for two weeks and ten consecutive years. For the statistical analysis, ANOVA with Bonferroni's tests and Pearson's correlation with regression tests were used.

Results:- The pain decreased significantly after the first day in the “maneuver group” ($P < 0.05$), and after the fifth day in the “standard group” ($P < 0.05$). All results improved significantly after two weeks ($P < 0.05$) and after one year ($P < 0.05$) in both groups. The “maneuver group” showed superior results versus the “standard group” after two weeks ($P < 0.05$) and after 10 consecutive years ($P < 0.05$). With increasing the “maneuver” success rate, the short-term treatment effect and the long-term prophylactic effect increased in the “maneuver group” ($P < 0.05$). There were no dropouts, side effects, or complications.

Conclusion:- The preliminary biceps muscle contraction is appropriate an important additional recommendation in short-term treatment and long-term prophylaxis of recurrent shoulder pain due to tendon degeneration. It is simple, quick, effective, and without side effects or complications. It requires no allocation of space, time, or resources. This “maneuver” protects the shoulder before the initial external forces, avoiding the repetitive micro-traumas during the muscle latency, which is otherwise inevitable in daily activities. Another protecting factor is the increased muscle strength and co-contraction of all periarticular muscles, as a result of this bracing “maneuver”, leading to lesser pain with higher shoulder stability and mobility.

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..... **Introduction:-**

One of the overlooked facilitating factors for recurrent shoulder pain due to tendon degeneration is the latency of the periarticular muscles (1-4). The short monosynaptic reflex (M1) has shorter muscle latency versus the short polysynaptic reflex (M2), but the corresponding muscle reactions are uncontrollable and ineffective (1, 5, 6). The central motor reaction (M3 long reflex) has the longest latency (1, 5, 6). The corresponding central muscle reaction is fully controllable and effective, but it takes too much time before the periarticular muscle counteraction (1, 5, 6). The inert structures (joints, cartilages, ligaments, tendons, insertions, and bursas) are vulnerable during the muscle latency even in very short durations and low impacts (1, 5-7). The initiations of the movements have the highest injury potential on the inert structures because the periarticular muscles cannot counteract the initial external forces due to muscle latency (1, 5, 6). This periarticular muscle delay is happening thousands of times daily, leading to multiple repetitive micro-traumas of the shoulder inert structures (1). Aging and pain lead to increased muscle latency and to accelerated degeneration (1, 6).

One of the major problems about recurrent shoulder pain due to tendon degeneration is the dramatic reduction of the upper limb daily activities due to pain, muscle imbalance, and shoulder instability (1, 7-11). The only way to overtake the periarticular muscle latency and its consequences is the preliminary biceps brachial muscle contraction before every movement of the shoulder, i.e. before dressing, undressing, lifting or lowering of objects, opening or closing doors (1). The shoulder stability could be augmented by bracing “maneuvers” producing muscle pre-activation and co-activation of all periarticular muscles (1, 4, 7-10, 12). The periarticular muscle co-contraction is associated with a corresponding increase in shoulder stability, reducing the risk of tendon injury, degeneration, and pain (1, 4, 7-10, 12). The preliminary biceps brachial muscle contraction not only reduces pain during the initiation of movement but also afterward – until the completion of the shoulder movement (1, 8, 9). This can be explained by the co-contraction of the other muscles around the shoulder, which provides greater protection during shoulder movements (1, 8, 9).

Common conservative treatment for recurrent shoulder pain due to tendon degeneration is rehabilitation including exercise, physical factors, and prophylactic recommendations (1, 8, 9, 13). The rationale for exercise is that strengthening of the flabby (dynamic) shoulder muscles corrects muscle imbalance, compensates lack of passive stability, and assists in active control of the shoulder (1, 7-10, 12, 13). The relaxation of the shortened (static) shoulder muscles corrects the muscle imbalance between them and the corresponding elongated (dynamic) antagonists (1, 7-10, 12, 13). The rationale for physical factors is their symptomatic (analgesic) effect (1, 8, 9, 13). The rationale for recommendations is to reduce the accelerating factors of tendon degeneration (1, 8, 9, 13).

The purpose of this research was to study the effect of preliminary biceps brachial muscle contraction, incorporated in the daily activities, on the short-term treatment, and the long-term prophylaxis of recurrent shoulder pain due to tendon degeneration.

Material And Methods:-

During the enrolment process, 56 outpatients with recurrent shoulder pain due to tendon degeneration were assessed for eligibility. From them, 12 were excluded – 8 did not meet the inclusion criteria, and 4 declined to participate. The inclusion criteria were age over 18 years, anamnesis of more than one episode of shoulder pain in the past 2

years, lasting more than one month, resulting from tendon degeneration. The exclusion criteria were shoulder surgery, shoulder injury (including fractures, dislocations, sprains, strains, rotator cuff tears, and glenoid labral tears), adhesive capsulitis, frozen shoulder, osteoarthritis, infections, malignancies, acute inflammatory disorders, structural abnormalities, neurological complications, as well as severe deficiencies – cardiovascular, respiratory, hepatic, metabolic, or renal.

The enrolled 44 outpatients (age 50.1 ± 14.8 years) were randomly allocated into two equal groups – “standard” (n=22) and “maneuver” (n=22). Both groups received prophylactic recommendations and were treated with a 10-day rehabilitation course, consisting of three 10-minute daily procedures – exercise, interferential current, and laser. They were followed-up for two weeks and 10 consecutive years. The same two-week rehabilitation course was prescribed during the next recurrences. The “maneuver” group received additional recommendations to perform biceps muscle preliminary contraction before every movement of the shoulder during the daily activities, i.e. before dressing, undressing, lifting/lowering/handling objects, opening/closing doors, etc.

The prophylactic recommendations included:- avoiding the extreme range of motions, intensive overloading (including carrying heavyweights), over-warming or over-cooling (over-acclimatization), tight compression with bandages, and intensive massage.

Flexibility and strengthening exercises were used (14, 15). They were supervised by rehabilitators for 10 minutes once daily and were applied for 10 working days (excluding the weekends). The flexibility exercises included post-isometric muscle relaxation of the predominantly static muscles, which were prone to shortening, increased muscle tone, muscle spasm, or rigidity – m.biceps brachii, m.brachialis, m.brachio-radialis, m.trapezius descendens, m.levator scapulae, m.pectoralis major and minor (14, 15). The strengthening exercises included progressive resistance exercises (16) of the predominantly dynamic muscles, which were prone to elongation, flabbiness, reduced tone, hypotrophy, and atrophy – m.deltoideus, m.supraspinatus, m.infraspinatus, m.trapezius ascendens, mm.rhomboidei, and m.latissimus dorsi (14, 15). At the end of the two-week rehabilitation course, all patients were instructed to perform at home the same exercises more than once daily for 10 minutes (17, 18).

The “maneuver group” was trained additionally to perform biceps muscle preliminary contraction (before any shoulder movement), incorporated in the daily activities, i.e. before dressing, undressing, lifting or lowering of objects, and opening or closing doors. The training process of this “maneuver” was easy, short, and effective for every outpatient. During the first “maneuver” attempt, the fingers of the intact hand were placed over the biceps brachial muscle of the affected side, for tactile sensation (exteroceptive feedback) of the increased muscle tone, as a result of the increased voluntary muscle contraction. Every outpatient succeeded to perform the “maneuver” during the first attempt with exteroceptive feedback, and after that – without it.

The interferential current procedure lasted 10 minutes. It was applied once daily for 10 working days (excluding the weekends). The painful shoulder was surrounded by four electrodes, covered by hydrophilic pillows, placed directly on the skin. Fixed frequency of 100 Hz without vector was used – “Gate-theory” (19, 20) electro-analgesics protocol. The current intensity was dosed subjectively (by the patient’s sensations). The acceptable sensations were light tingling, minor irritation, vibration, or pinching. The non-acceptable sensations were pain or burning. The same procedure was used for the next recurrences.

The laser procedure lasted 10 minutes. It was applied once daily for 10 working days (excluding the weekends). The painful area was treated with a scanning method of low-intensity He-Ne laser. The wavelength was 632.8 nm with a corresponding frequency of 900 Hz. The total energy for the entire procedure was 2.592 J. The same procedure was used for the next recurrences.

The pain intensity was measured 30 times by visual-analogue scale (21, 22) – twice daily (before and after the procedures) during the two-week course (20 times), and at the end of 10 consecutive years (10 times).

The shoulder mobility was recorded 12 times by standard goniometry using the “SFTR” (Sagittal, Frontal, Transversal, Rotation) method (23) at the beginning and at the end of the two-week course (2 times), as well as at the end of 10 consecutive years (10 times). To calculate the total result of the goniometry, the angular degrees were transformed into percentages from the normal range of motion. The average range of motion percentage (SFTR%)

of the shoulder in all planes was equal to the sum of the percentages in all directions [flexion (%) + extension (%) + abduction (%) + adduction (%) + external rotation (%) + internal rotation (%)], divided by 6.

The strength of the shoulder muscles was recorded 12 times by manual muscle testing (24) at the beginning and at the end of the two-week course (2 times), and at the end of 10 consecutive years (10 times). To calculate the total result, the MMT grades were transformed into percentages from the normal muscle strength. The average percentage strength (MMT%) was equal to the sum of the percentages of all shoulder muscles [flexors (%) + extensors (%) + abductors (%) + adductors (%) + external rotators (%) + internal rotators (%)], divided by 6.

The success rate of performing the preliminary contraction of the biceps brachial muscle in the “maneuver group” was recorded 11 times at the end of the two-week course (1 time), and at the end of 10 consecutive years (10 times). The success rate referred to how often the patient was performing the preliminary brachial biceps muscle contraction before every movement of the shoulder. The success rate was estimated subjectively by the patients. For example, if the patient forgets to contract the biceps muscle before every second shoulder movement, the success rate is 50%, every third movement – 66%, every fourth – 75%, every fifth – 80%, etc.

The number of recurrences and the number of rehabilitation courses were recorded for 10 consecutive years (10 times).

Statistical analysis:-

For the statistical analysis was used 2-way ANOVA with Bonferroni's multiple post-hoc tests and Pearson's correlation analysis with post-hoc regression test.

Results:-

Regarding the pain intensity (VAS), the 2-way ANOVA showed significant interactions between the 2 groups ($P < 0.05$) and between the 21 measurements ($P < 0.05$). Bonferroni's post-hoc test found that the pain in the “maneuver” group was lower versus the “standard” group for the 20 follow-ups ($P < 0.05$), except the one at the beginning of the study ($P > 0.05$) (Figure 1). The mean statistical reduction of the pain, after the daily procedures versus before them during the first day, was significantly greater in the “maneuver” group versus the “standard” group ($P < 0.05$) (Figure 1). In the “maneuver” group, the pain decreased significantly during the first day (after the first procedures versus before them, including the training in biceps muscle preliminary contraction) ($P < 0.05$), while in the “standard” group – after the fourth day ($P < 0.05$) (Figure 1). In the “standard” group, the pain increased significantly during the weekend ($P < 0.05$), while in the “maneuver” group – it did not ($P > 0.05$) (Figure 1). In both groups, the pain decreased after the two-week therapeutic course versus before it ($P < 0.05$), as well as after one year versus after the two-week therapeutic course ($P < 0.05$) (Figure 1). The “maneuver group” showed lower pain versus the “standard group” after two weeks ($P < 0.05$) and at the end of the consecutive 10 years ($P < 0.05$) (Figure 1). Within every group, the pain was comparable between the consecutive 10 years ($P > 0.05$) (Figure 1:-).

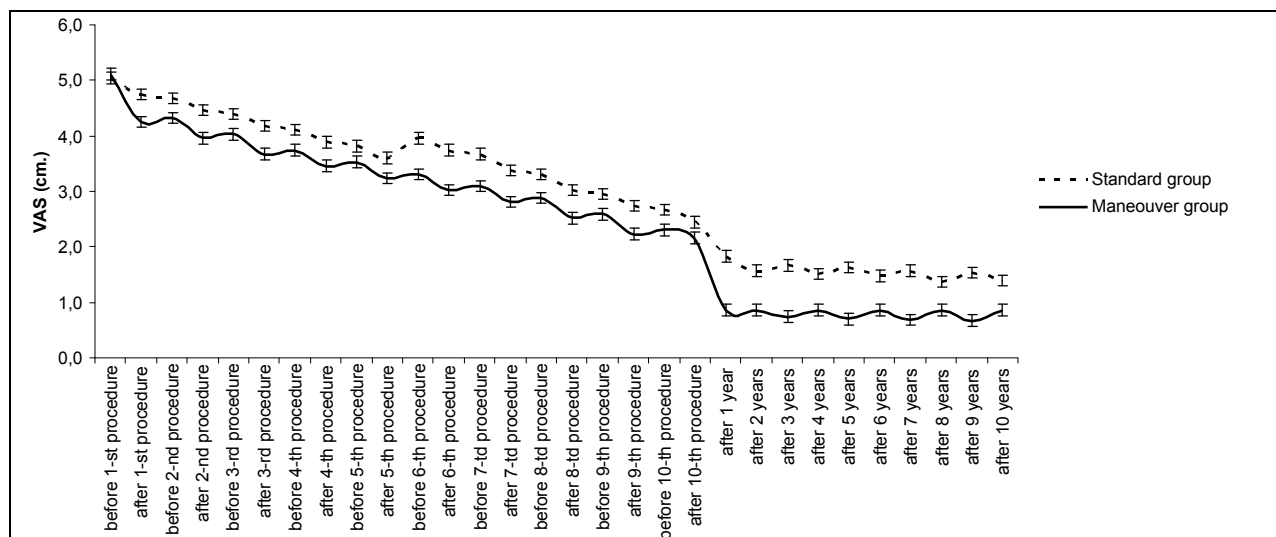
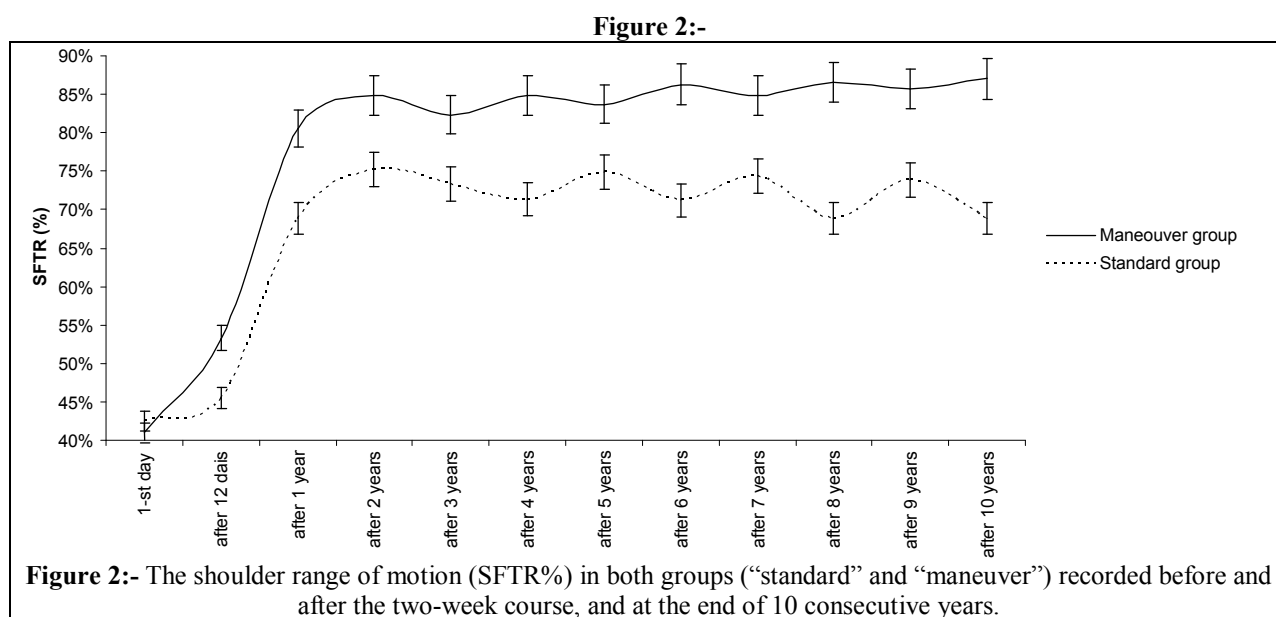
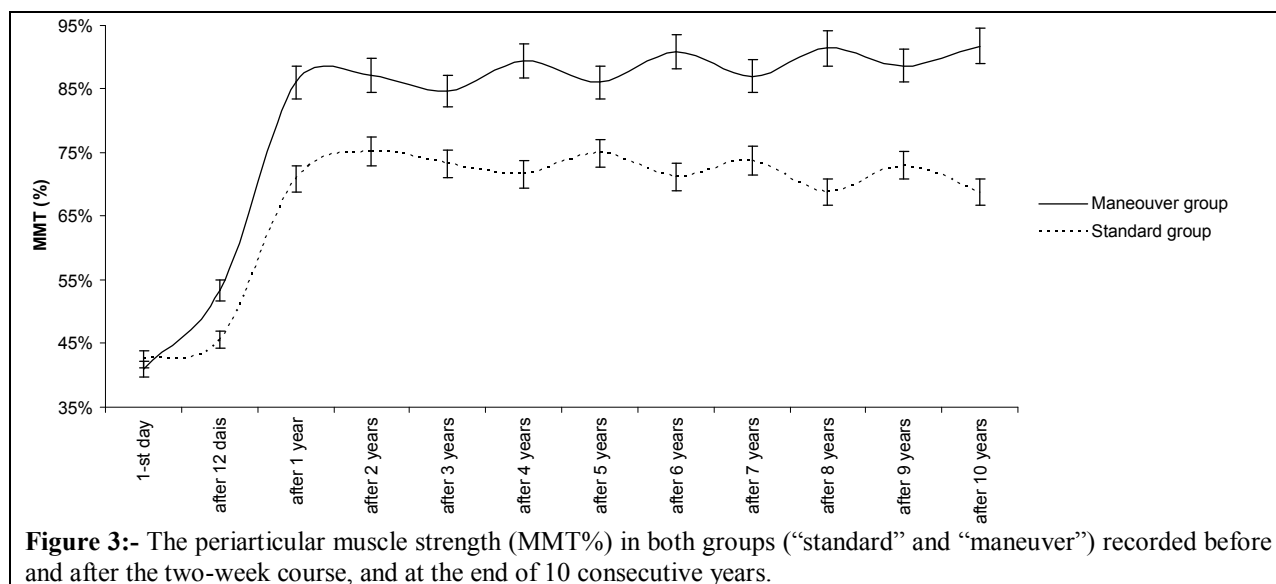


Figure 1:- The pain intensity (visual-analogue scale - VAS in cm.) in both groups (“standard” and “maneuver”) recorded twice daily (before and after the daily procedures) during the two-week course, and at the end of 10 consecutive years.

Regarding the shoulder range of motion (SFTR%), the 2-way ANOVA showed significant interactions between the 2 groups ($P < 0.05$) and between the 12 measurements ($P < 0.05$). Bonferroni's post-hoc test found that the range of motion in the “maneuver” group was higher versus the “standard” group for the 11 follow-ups ($P < 0.05$), except the one at the beginning of the study ($P > 0.05$) (Figure 2). In both groups, the range of motion increased after the two-week therapeutic course versus before it ($P < 0.05$), as well as after one year versus after the two-week therapeutic course ($P < 0.05$) (Figure 2). The “maneuver group” showed a higher range of motion versus the “standard group” after two weeks ($P < 0.05$) and after consecutive 10 years ($P < 0.05$) (Figure 2). Within every group, the range of motion was comparable between the consecutive 10 years ($P > 0.05$)



Regarding the periarticular muscle strength (MMT%), the 2-way ANOVA showed significant interactions between the 2 groups ($P < 0.05$) and between the 12 measurements ($P < 0.05$). Bonferroni's post-hoc test found that the muscle strength in the “maneuver” group was higher versus the “standard” group for the 11 follow-ups ($P < 0.05$), except the one at the beginning of the study ($P > 0.05$) (Figure 3). In both groups, the muscle strength increased after the two-week therapeutic course versus before it ($P < 0.05$), as well as after one year versus after the two-week therapeutic course ($P < 0.05$) (Figure 3). The “maneuver group” showed a higher muscle strength versus the “standard group” after two weeks ($P < 0.05$) and after consecutive 10 years ($P < 0.05$) (Figure 3). Within every group, the muscle strength was comparable between the consecutive 10 years ($P > 0.05$) (**Figure 3:-**).



Pearson’s product-moment correlation analysis established significant correlations between the following pairs of variables:- pain intensity (VAS) versus the range of motion (SFTR%) ($P < 0.05$), pain intensity (VAS) versus muscle strength (MMT%) ($P < 0.05$), muscle strength (MMT%) versus the range of motion (SFTR%) ($P < 0.05$), pain intensity (VAS) versus “maneuver” success rate (%) ($P < 0.05$), muscle strength (MMT%) versus “maneuver” success rate (%) ($P < 0.05$), and range of motion (SFTR%) versus “maneuver” success rate (%) ($P < 0.05$).

The regression post-hoc analysis found that with increasing of the “maneuver” success rate, the pain intensity was significantly reducing ($P < 0.05$) by the following formula:-

$VAS (cm.) = 4.96 - (4.05 * \text{maneuver success rate})$. According to this real formula, with increasing the “maneuver” success rate from 0% to 100%, the pain intensity was reducing from 4.96 to 0.91 (VAS cm.).

The regression post-hoc analysis found that with increasing of the “maneuver” success rate, the range of motion (SFTR%) was significantly increasing ($P < 0.05$) by the formula:-

$SFTR\% = 41\% + (49\% * \text{maneuver success rate})$. According to this real formula, with increasing the “maneuver” success rate from 0% to 100%, the range of motion (SFTR%) was increasing from 41% to 90%.

The regression post-hoc analysis found that with increasing of the “maneuver” success rate, the muscle strength (MMT%) was significantly increasing ($P < 0.05$) by the formula:-

$MMT\% = 35\% + (59\% * \text{maneuver success rate})$ ($P < 0.05$). According to this real formula, with increasing the “maneuver” success rate from 0% to 100%, the muscle strength (MMT%) was increasing from 35% to 94%.

The three-dimensional multiple linear regressions between the “maneuver” success rate (in %), the range of motion (SFTR%), and the muscle strength (MMT%) ($P < 0.05$) are presented in **Figure 4:-**

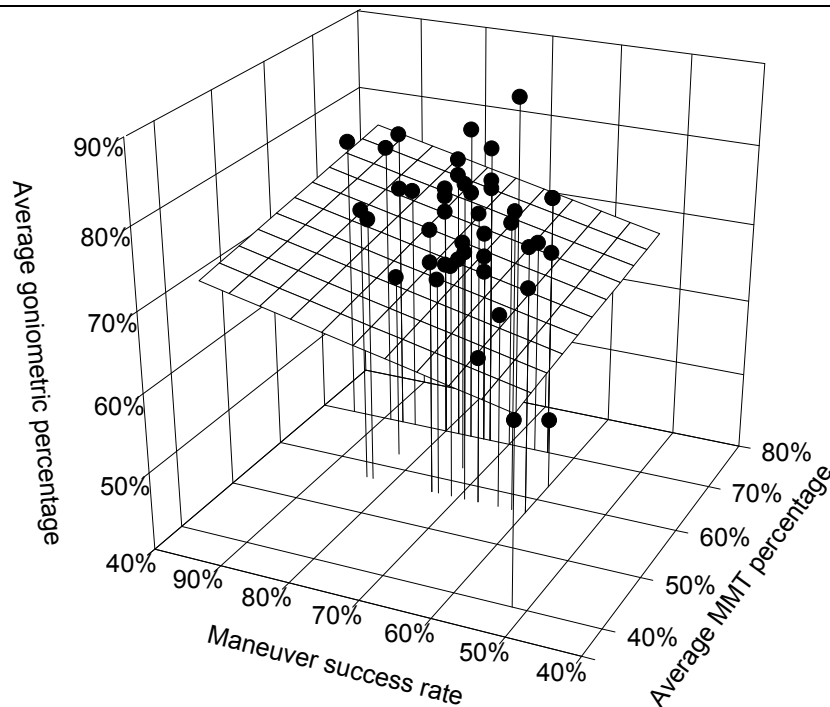


Figure 4:- The three-dimensional multiple linear regression between the “maneuver” success rate (in %), the average goniometric percentage (SFTR%), and the average MMT percentage (MMT%).

Discussion:-

The lower pain in both groups after the two-week rehabilitation course could be explained by the short-term analgesic effect of the natural healing process, physiotherapy factors (“interferential current” and “laser”), exercise, and prophylactic recommendations. The lower pain in the “maneuver” group versus the “standard” group after two weeks could be explained by the additional short-term analgesic effect of the “maneuver” over the natural healing process, physiotherapy, exercise, and prophylactic recommendations. The most probable reason for this upgrading effect is that the “maneuver” was protecting the shoulder by eliminating the latency between the initial external forces on the shoulder and the internal counter forces of the muscles. The higher pain in the “standard” group after the weekend versus before it, in contrast to the unchanged pain in the “maneuver” group for the same period, could be explained by the analgesic effect of the preliminary abdominal muscle contraction. The same pain contrast (between the groups over the weekend) proved the short-term effect of physiotherapy. Even two days without physiotherapy increased significantly the pain in the “standard” group. Therefore, physiotherapy added the analgesic effect of prophylactic recommendations and natural healing process, but not the one of exercise and “maneuver”. The analgesic effect of the “maneuver” was proven also by the significant correlation between the “maneuver” success rate and the pain intensity. The analgesic effect of the “maneuver” could be explained also by the higher increase of shoulder mobility in the “maneuver” group versus the “standard” group. Since the pain reflexively inhibited the range of motion (and vice versa), the increased range of motion reduced the pain indirectly. This was proven also by the significant correlation between the “maneuver” success rate and the shoulder range of motion. The analgesic effect of the “maneuver” could be explained also by the increase of muscle strength through the frequent preliminary biceps brachial muscle contractions, incorporated in the daily activities. They triggered frequent co-contractions of all shoulder muscles, increasing their strength. Since the pain reflexively inhibited the muscle strength (and vice versa), the increased muscle strength reduced the pain indirectly. This was proven also by the significant correlation between the “maneuver” success rate and the muscle strength.

The lower pain in both groups after a one-year follow-up could be explained by the long-term analgesic effect of the natural healing process, exercise, and prophylactic recommendations. The physiotherapy factors (“interferential current” and “laser”) had no long-term primary analgesic effects. The lower pain in the “maneuver” group versus the “standard” group for 10 consecutive years could be explained by the additional long-term analgesic effect of the

“maneuver” over the natural healing process, exercise, and prophylactic recommendations. This was proven also by the significant correlation between the “maneuver” success rate and the pain intensity.

The higher range of motion, after two weeks versus at the beginning in both groups, could be explained by the short-term mobility effect of the natural healing process and exercise. The physiotherapy factors (“interferential current” and “laser”) and the prophylactic recommendations had no short-term primary mobility effect. The higher range of motion of the “maneuver” group versus the “standard” group could be explained by the additional short-term mobility effect of the “maneuver” over the natural healing process and exercise. This was proven also by the significant correlation between the “maneuver” success rate and the shoulder range of motion. The higher mobility in the “maneuver” group versus the “standard” group could be explained also by the more successful pain reduction of the “maneuver”, allowing a greater short-term range of painless motion.

The higher range of motion, after one year versus after two weeks in both groups, could be explained by the long-term mobility effect of the natural healing process and exercise. The physiotherapy factors (“interferential current” and “laser”) and the prophylactic recommendations had no primary long-term mobility effect. The higher mobility of the “maneuver” group versus the “standard” group for 10 consecutive years could be explained by the additional long-term mobility effect of the “maneuver” over the natural healing process and exercise. This was proven also by the significant correlation between the “maneuver” success rate and the shoulder range of motion. The higher mobility in the “maneuver” group versus the “standard” group for 10 consecutive years could be explained also by the more successful pain reduction of the “maneuver”, allowing a greater range of painless motion in the long-term.

The higher muscle strength, after two weeks versus at the beginning in both groups, could be explained by the short-term strengthening effect of the natural healing process and exercise. The physiotherapy factors (“interferential current” and “laser”) and the prophylactic recommendations had no primary short-term strengthening effect. The higher short-term strength of the “maneuver” group versus the “standard” group could be explained by the additional short-term strengthening effect of the “maneuver” over the natural healing process and exercise. This was proven also by the significant correlation between the “maneuver” success rate and the muscle strength. The higher muscle strength in the “maneuver” group versus the “standard” group could be explained also by the more successful pain reduction of the “maneuver”, allowing greater and painless muscle voluntary contractions, leading to higher shoulder stability in the short-term.

The higher muscle strength, after one year versus after two weeks in both groups, could be explained by the long-term strengthening effect of the natural healing process and exercise. The physiotherapy factors (“interferential current” and “laser”) and the prophylactic recommendations had no primary long-term strengthening effect. The higher muscle strength of the “maneuver” group versus the “standard” group for 10 consecutive years could be explained by the additional long-term strengthening effect of the “maneuver” over the natural healing process and exercise. This was proven also by the significant correlation between the “maneuver” success rate and the muscle strength. The higher muscle strength in the “maneuver” group versus the “standard” group for 10 consecutive years could be explained also by the more successful pain reduction of the “maneuver”, allowing greater and painless muscle voluntary contractions, leading to higher shoulder stability in the long-term.

The physiotherapy factors “interferential current” and “laser” had lesser short-term symptomatic (analgesic) effect versus exercise, and no short-term pathogenetic effect (on the range of motion and muscle strength). These factors had no long-term prophylactic effect, because of a directly proportional correlation between the number of physiotherapy courses and the number of exacerbations. This correlation should have been inversely proportional if such a prophylactic effect has been detected. The short- and long-term symptomatic and pathogenetic effects were proven for exercise and preliminary biceps brachial muscle contraction. The “maneuver” added these effects over those of the exercise and the natural healing process.

Conclusion:-

The preliminary biceps brachial muscle contraction is appropriate addition for short-term treatment and long-term prophylaxis of recurrent pain due to shoulder tendon degeneration. It triggers corresponding preliminary co-contractions of the shoulder muscles before the initial mechanical load of the external forces on the joint. This protects the shoulder by avoiding the repetitive micro-injuries during the muscle latency, which is unavoidable under usual daily activities. Another protecting factor is the increased muscle strength as a result of this “maneuver”, leading to higher shoulder stability.

The preliminary biceps brachial muscle contraction is short (few seconds), simple, effective, and without side effects or complications. It does not require dedicating resources, time, or space and does not interrupt the daily activities, making them easier, faster, and painless. It improves the strength of the shoulder muscles, supporting the joint and reducing the risks from injuries and tendon degeneration. It improves the tone and the strength of the muscles, supporting the shape and the volume of the shoulder. Frequent muscle contraction is the most powerful mechanism against upper limb swelling. Therefore, in all conditions, leading to it, like cardiovascular and respiratory disorders, varices, lymphatic edema, and hypostatic postures, there are no contraindications for preliminary biceps brachial muscle contraction.

This “maneuver” could be useful in optimizing the treatment and prevention of recurrent shoulder pain due to tendon degeneration. It could save a lot of suffering, pain, and other negative emotions for many people at risk for a recurrent shoulder disability, and could reduce the number of lost working days due to shoulder tendon degeneration.

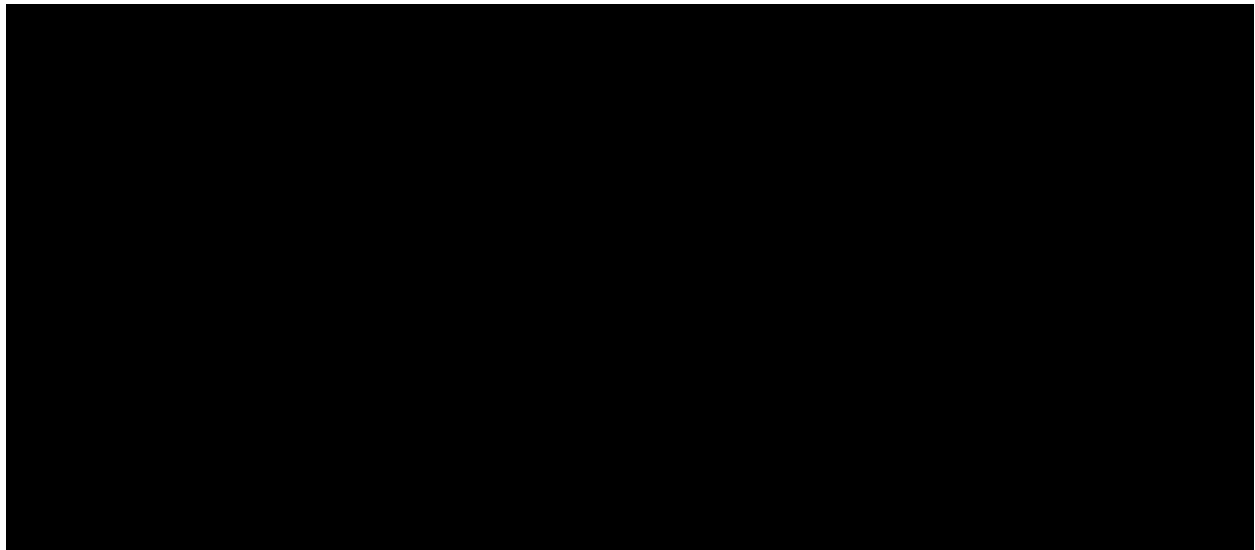


Figure 1:- The pain intensity (visual-analogue scale - VAS in cm.) in both groups (“standard” and “maneuver”) recorded twice daily (before and after the daily procedures) during the two-week course, and at the end of 10 consecutive years.

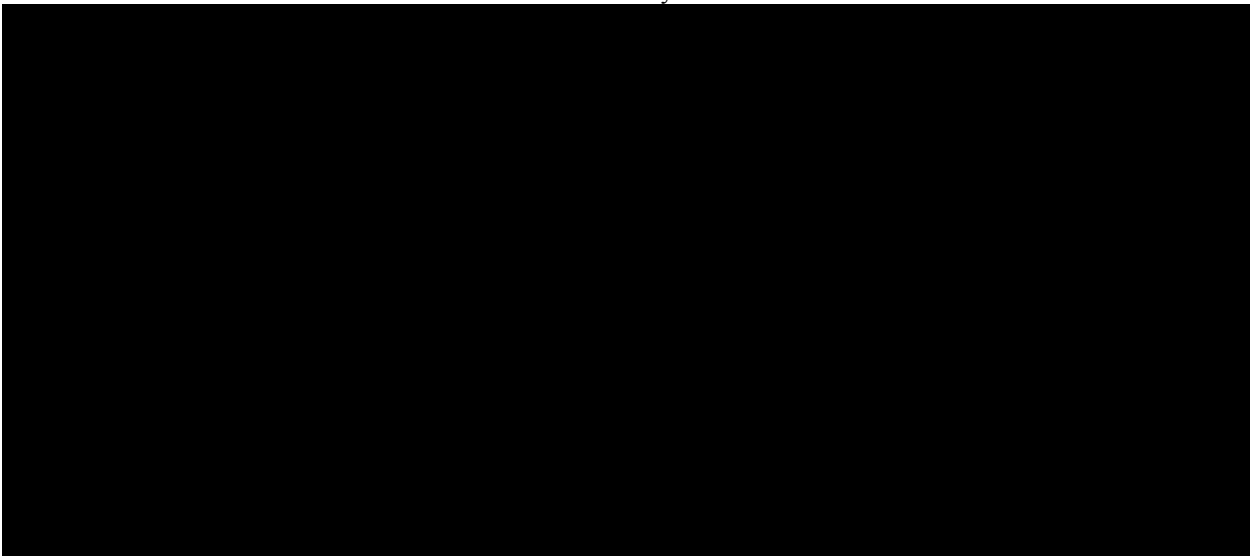


Figure 2:- The shoulder range of motion (SFTR%) in both groups (“standard” and “maneuver”) recorded before and after the two-week course, and at the end of 10 consecutive years.

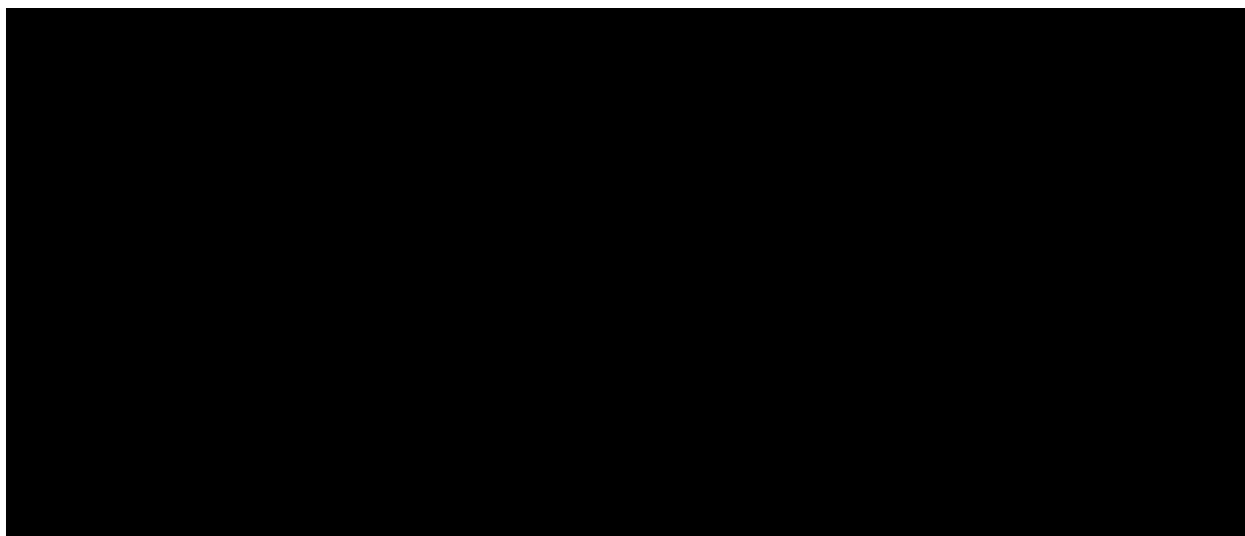


Figure 3:- The periarticular muscle strength (MMT%) in both groups (“standard” and “maneuver”) recorded before and after the two-week course, and at the end of 10 consecutive years.

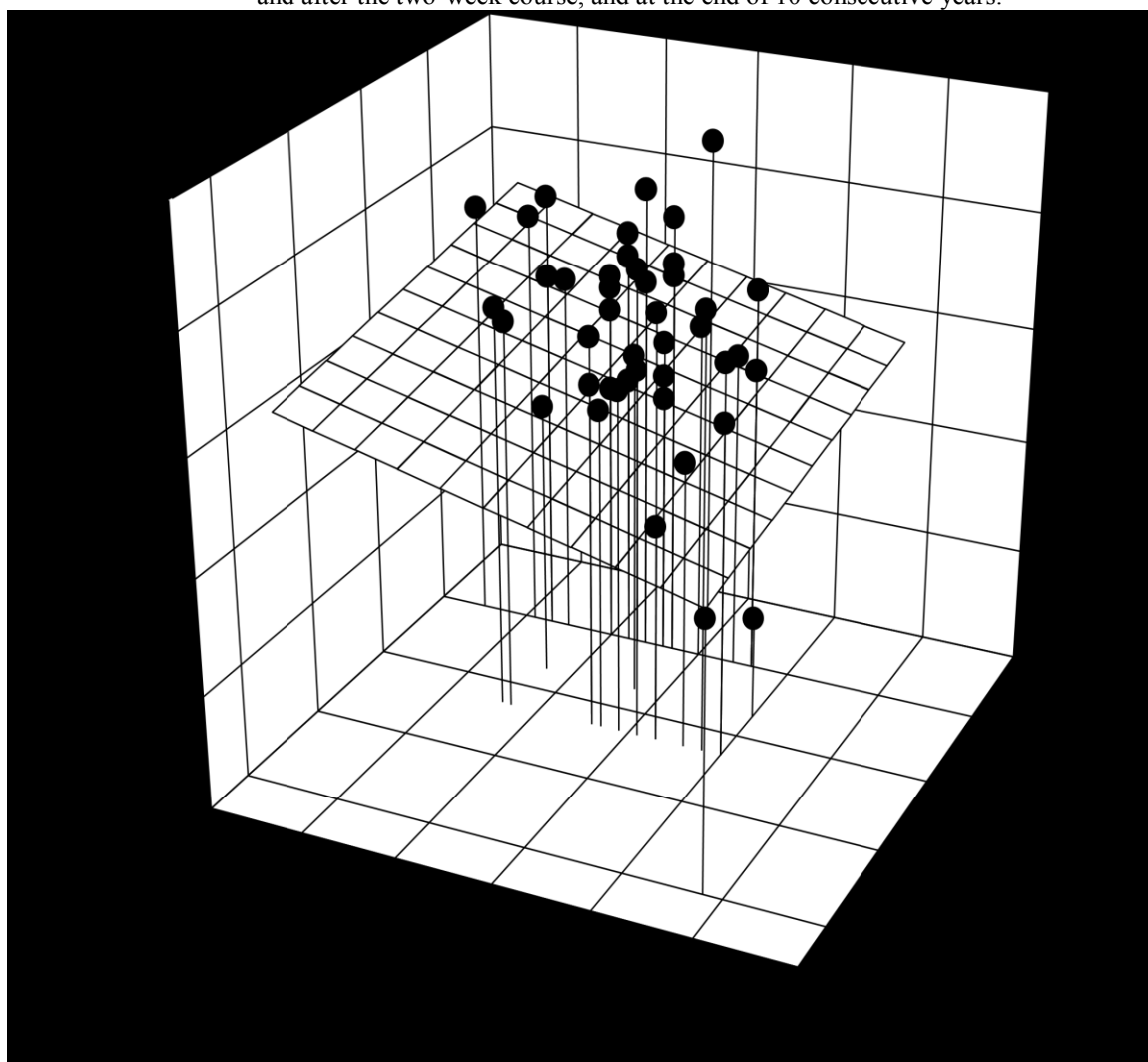


Figure 4:- The three-dimensional multiple linear regression between the “maneuver” success rate (in %), the average goniometric percentage (SFTR%), and the average MMT percentage (MMT%).

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