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Ten-Year Follow-Up of Preliminary Quadriceps Muscle Contraction in Rehabilitation and Prophylaxis of Recurrent Knee Pain Due to Osteoarthritis

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Abstract

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

Aim: To study the effect of the preliminary quadriceps muscle contraction on the short-term rehabilitation and the long-term prophylaxis of recurrent knee pain due to osteoarthritis.

Material and Methods: For 10 years were followed 68 outpatients (age 50.9 ± 15.4 years) with recurrent knee pain due to osteoarthritis. They were randomized into two groups – "standard" (n=34) and "maneuver" (n=34). 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 quadriceps muscle contraction before every movement of the knee during the daily activities. Pain intensity, knee range of motion, 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 quadriceps muscle contraction is an important additional recommendation in short-term treatment and long-term prophylaxis of recurrent knee pain due to osteoarthritis. It is simple, quick, effective, and without side effects or complications. It requires no allocation of space, time, or resources. This "maneuver" protects the knee 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 knee stability and mobility.

Keywords: Exercise; Interferential current; Laser; Osteoarthritis; Physiotherapy; Preliminary quadriceps muscle contraction; Rehabilitation; Recurrent knee pain

Introduction

One of the overlooked facilitating factors for recurrent knee pain due to osteoarthritis 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 [1,5-8]. The central motor reaction (M3 long reflex) has the longest latency [1-8]. The corresponding central muscle reaction is fully controllable and effective, but it takes too much time before the periarticular muscle counteraction [1-8]. The inert structures (joints, cartilages, ligaments, tendons, insertions, meniscuses, bursas, synovial structures, and Hoffa's fat pad) are vulnerable during the muscle latency even in very short durations and low impacts [1-6]. The initiations of the movements have the highest injury potential on the inert structures because the periarticular muscles cannot counteract against the initial external forces due to muscle latency [1-6]. This periarticular muscle delay is happening thousands of times daily, leading to multiple repetitive micro-traumas of the knee inert tissues [1-6]. Aging and pain lead to increased muscle latency and to accelerated degeneration [1-6,9].

The only way to overtake the periarticular muscle latency and its consequences is the preliminary quadriceps muscle contraction before every movement of the knee, i.e. before standing, sitting, bending, kneeling, straightening, lifting or lowering of objects, walking, running, climbing down, or upon stairs, slopes, or vehicles [1]. This bracing "maneuver" could help to improve the reduced daily activities (including disturbed locomotion) due to pain, knee instability, and muscle imbalance [1,10-20]. The knee stability could be augmented by bracing quadriceps "maneuvers", producing pre-activation and co-activation of all periarticular muscles [1,21,22]. The periarticular muscle co-contraction is associated with a corresponding increase in knee stability, reducing the risk of injury, degeneration, and pain [1,21,22]. The preliminary quadriceps muscle contraction not only reduces pain during the initiation of movement but also afterward – until the completion of the knee movement [1]. This can be explained by co-contraction of all periarticular muscles, which provides greater protection before and during knee movements [1,21,22].

Common conservative approaches for recurrent knee pain due to osteoarthritis are exercises, physical factors and prophylactic recommendations [1,6,10-20,23-29]. The rationale for relaxation exercise of the shortened (static) knee muscles, is correction of muscle imbalance between them and their elongated (dynamic) antagonists, leading to decreased pain and increased range of motion [1,30,31]. The rationale for strengthening exercise of the elongated (dynamic) muscles, is correction of muscle imbalance, compensation of passive instability and improving of active knee control [1,10,17,25-27,30]. Uncorrected muscle imbalance leads to osteoarthritis due to abnormal mechanical loading and joint instability [1,30,31]. The rationale for physical factors is their short-term symptomatic (analgesic) effect [1,10-12,14,15,19,23,24,27,29,32]. Interferential current is the most promising analgesic electrical stimulation therapy in knee osteoarthritis [32]. Interferential current is more effective as a supplement to another intervention [33]. Interferential current and low level laser therapy have a short-term pain relief for knee osteoarthritis [23]. Interferential laser therapy is safe and effective in reducing knee pain [29]. The rationale for prophylactic recommendations is to reduce the accelerating factors of knee degeneration [1,6,10-12,14-16,18,19,24,28]. The only way to reduce the accelerating factor "periarticular muscle latency" seems the preliminary quadriceps muscle contraction [1].

The purpose was to study the effect of preliminary quadriceps muscle contraction on the short-term treatment and the long-term prophylaxis of recurrent knee pain due to osteoarthritis.

Materials and methods

During the enrolment process, 100 outpatients with recurrent knee pain due to osteoarthritis were assessed for eligibility. From them, 32 were excluded – 21 did not meet the inclusion criteria, and 11 declined to participate. The inclusion criteria were age over 18 years, anamnesis of more than one episode of knee pain in the past 2 years, lasting more than two weeks, resulting from knee osteoarthritis. The exclusion criteria were knee surgery, knee injury (sprains, strains, menisci injury, ligament injury, fractures, and dislocations), structural abnormalities, neurological complications, infections, acute inflammatory disorders, malignancies, as well as severe deficiencies – cardiovascular, respiratory, hepatic, metabolic, or renal.

The enrolled 68 outpatients (age 50.9 ± 15.4 years) were randomly allocated into two equal groups – "standard" (n=34) and "maneuver" (n=34). Both groups received prophylactic recommendations and were treated for two weeks with 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 preliminary quadriceps muscle contraction before every movement of the knee during daily activities, i.e. before standing, sitting, bending, kneeling, straightening, lifting or lowering of objects, walking, running, climbing down, or upon stairs, slopes, or vehicles.

Both groups received prophylactic recommendations to avoid the extreme range of motions, intensive overloading (including carrying heavyweights), over-warming or over-cooling (over-acclimatization), prolonged standing or sitting, tight compression with bandages, and overweight.

Both groups received a ten-minute interferential current once daily for 10 working days (excluding the weekends). Fixed frequency of 100 Hz was used – "Gate-theory" electro-analgesic protocol [34]. The same procedure was used for the next recurrences.

Both groups received a ten-minute low-intensity He-Ne laser, with wavelength 632.8 nm and frequency 900 Hz, once daily for 10 working days (excluding the weekends). The total energy for one procedure was 2.592 J. The same procedure was used for the next recurrences.

Both groups received supervised flexibility and strengthening exercises for 10 minutes once daily for 10 working days (excluding the weekends) [1,30,31,35]. The flexibility exercise included 5 minutes daily post-isometric muscle relaxation of the predominantly static muscles, which were prone to shortening, increased muscle tone, muscle spasm or rigidity – m.biceps femoris, m.semimembranosus, and m.semitendinosus [1,30,31,35]. The strengthening exercise included 5 minutes daily progressive resistance exercise of the predominantly dynamic muscles, which were prone to elongation, flabbiness, reduced tone, hypotrophy, or atrophy – m.vastus lateralis, m.vastus medialis, and m.vastus intermedius [1,30,31,35]. All patients were instructed to perform at home the same flexibility and strengthening exercise two times daily during the two-week rehabilitation course and three times daily after that.

The "maneuver group" was trained additionally to perform quadriceps muscle preliminary contraction (before any knee movement), incorporated in the daily activities, i.e. before standing, sitting, bending, kneeling, straightening, lifting or lowering of objects, walking, running, climbing down or upon stairs, slopes, or vehicles. The training process of this "maneuver" was easy, short, and effective for every outpatient. During the first "maneuver" attempt, the fingers of the hand were placed over the quadriceps muscle, 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 intensity of pain was measured 30 times by visual-analogue scale [36] twice daily (before and after the daily procedures) during the two-week course (20 times), and at the end of 10 consecutive years (10 times).

The knee mobility was recorded 12 times by standard goniometry [37] 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 average range of motion, the angular degrees were transformed into percentages from the normal range of motion. The average goniometric percentage of the knee was equal to the sum of the percentages in both directions [flexion (%) + extension (%)], divided by 2.

The strength of the knee muscles was recorded 12 times by manual muscle testing (MMT) [37] 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 average muscle strength, the grades of MMT were transformed into percentages from the normal muscle strength. The average MMT percentage was equal to the sum of the percentages of the knee muscles [flexors (%) + extensors (%)], divided by 2.

The success rate of performing the preliminary contraction of the quadriceps 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 quadriceps muscle contraction before every movement of the knee. For example, if the patient forgets to contract the quadriceps muscle before every second knee 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 the two-week rehabilitation courses were recorded for 10 consecutive years (10 times). 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 30 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 29 follow-ups ($P<0.05$), except the one at the beginning of the study ($P>0.05$) (Figure 1). In the "maneuver" group, the pain decreased significantly after the first day ($P<0.05$), while in the "standard" group – after the fifth day ($P<0.05$) (Figure 1). During the weekend the pain increased significantly in the "standard" group ($P<0.05$), while in the "maneuver" group – insignificantly ($P>0.05$) (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 after 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).

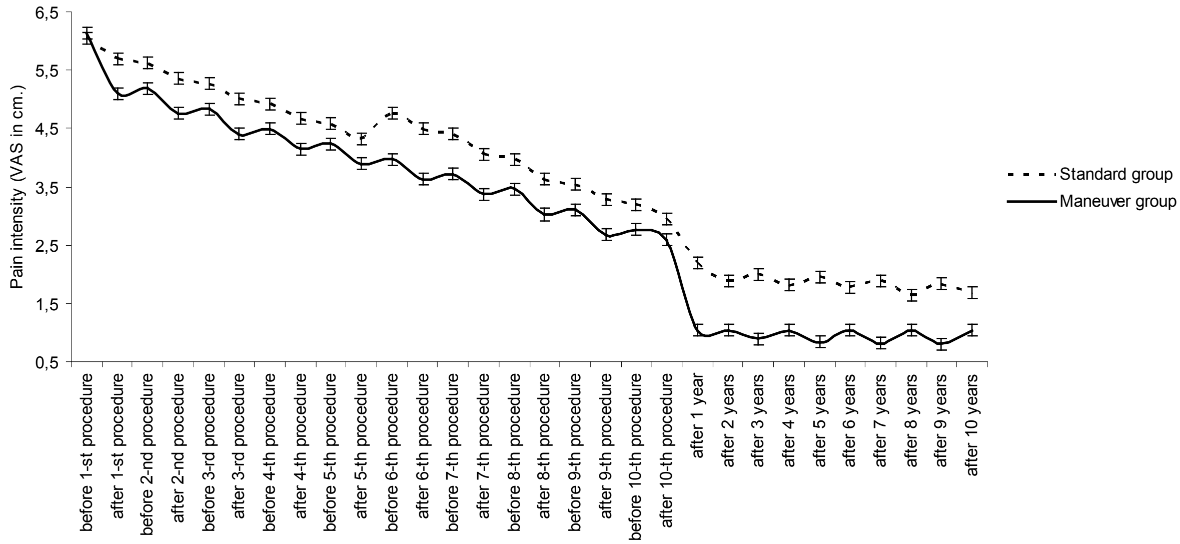

Figure 1: The pain intensity (VAS in cm.) in both groups ("standard" and "maneuver") recorded twice daily (before and after the daily procedures) during the two-week course, and at the end of 10 consecutive years.

Regarding the average goniometric percentage, 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 average goniometric percentage 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 average goniometric percentage 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 average goniometric percentage versus the "standard group" after two-weeks (P<0.05) and after the consecutive 10 years (P<0.05) (Figure 2). Within every group, the average goniometric percentage was comparable between the consecutive 10 years (P>0.05) (Figure 2).

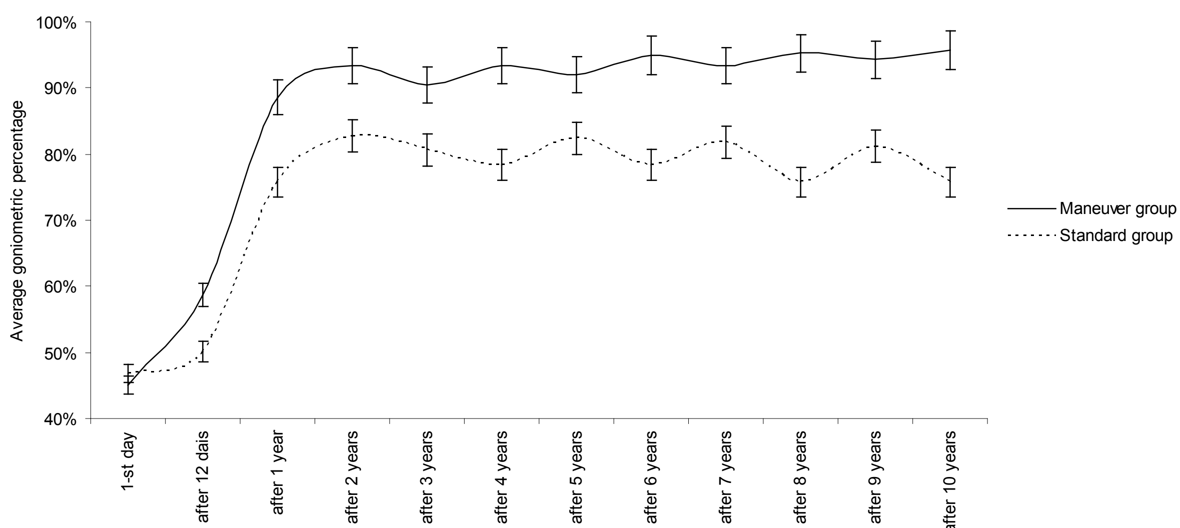

Figure 2: The average goniometric percentage in both groups ("standard" and "maneuver") recorded before and after the two-week course, and at the end of 10 consecutive years.

Regarding the average MMT percentage, 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 average MMT percentage 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 average MMT percentage 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 average MMT percentage versus the "standard group" after two-weeks (P<0.05) and after the consecutive 10 years (P<0.05) (Figure 3). Within every group, the average MMT percentage was comparable between the consecutive 10 years (P>0.05) (Figure 3).

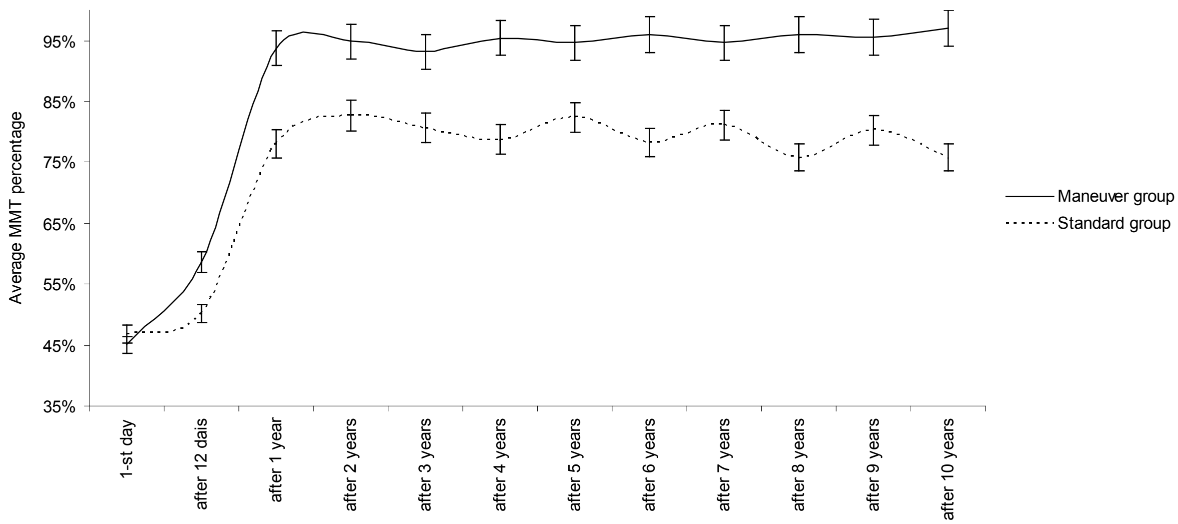

Figure 3: The average MMT percentage in both groups ("standard" and "maneuver") recorded before and after the two-week course, and at the end of 10 consecutive years.

Pearson's product-moment correlation analysis established significant correlations between the following pairs of variables: average goniometric percentage versus the pain intensity (P<0.05), average goniometric percentage versus average MMT percentage (P<0.05), the pain intensity versus average MMT percentage (P<0.05), the pain intensity versus "maneuver" success rate (P<0.05), average MMT percentage versus "maneuver" success rate (P<0.05), and average goniometric percentage versus "maneuver" success rate (P<0.05).

The regression post-hoc analysis found that as the degree of success of the "maneuver" increased, the intensity of pain significantly decreased (P<0.05) by the following formula:

Pain intensity VAS (cm.) = 6.12 - (4.86 * maneuver success rate)

According to this real formula, if the "maneuver" success rate increases from 0% to 100%, the pain intensity decreases from 6.12 to 1.26 (VAS cm.).

The regression post-hoc analysis found that as the degree of success of the "maneuver" increased, the average goniometric percentage significantly decreased (P<0.05) by the following formula:

Average goniometric percentage = 44% + (46% * maneuver success rate)

According to this real formula, if the "maneuver" success rate increases from 0% to 100%, the average goniometric percentage increases from 44% to 90%.

The regression post-hoc analysis found that as the degree of success of the "maneuver" increased, the average MMT percentage significantly decreased (P<0.05) by the following formula:

Average MMT percentage = 41% + (44% * maneuver success rate) (P<0.05).

According to this real formula, if the "maneuver" success rate increases from 0% to 100%, the average MMT percentage increases from 41% to 94%.

The three-dimensional multiple linear regression between the "maneuver" success rate, the average goniometric percentage, and the average MMT percentage (P<0.05) is presented in Figure 4:

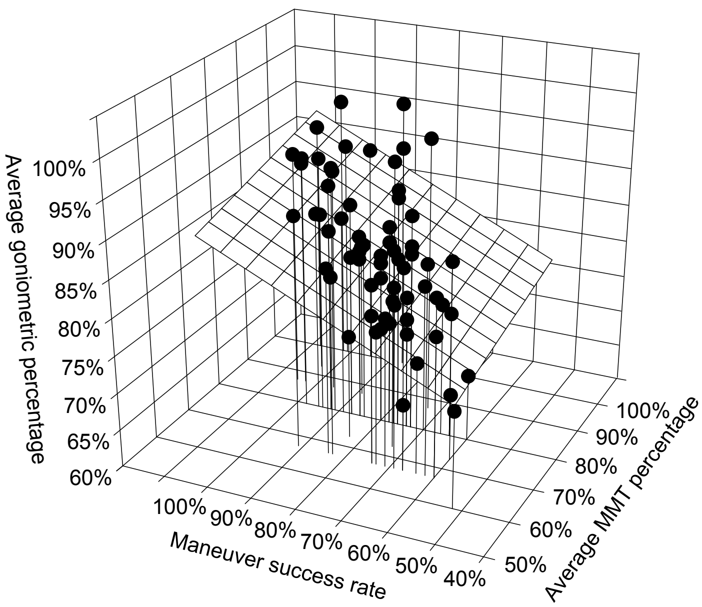

Figure 4: The three-dimensional multiple linear regression between the "maneuver" success rate, the average goniometric percentage, and the average MMT percentage.

Discussion

The lower pain (after the two-week rehabilitation course versus before it in both groups) could be explained by short-term analgesic effect of the natural healing process, physiotherapy, exercise, and prophylactic recommendations. The lower pain in the "maneuver" group versus the "standard" group after two weeks could be explained by a supplementary short-term analgesic effect of the "maneuver" over those of the natural healing process, physiotherapy, exercise, and prophylactic recommendations. A probable reason for this supplementary effect is the "maneuver" protection by overtaking the latency between the initial external forces on the knee and the internal counter forces of the periarticular muscles. Another possible explanation is the co-contraction of all periarticular muscles, leading to increased knee stability as a result of this bracing "maneuver". The analgesic effect of the "maneuver" was also proven by the significant correlation between the "maneuver" success rate and the intensity of pain. The analgesic effect of the "maneuver" could also be explained by a higher increase of knee mobility in the "maneuver" group versus the "standard" group. Since pain reflexively inhibited range of motion, increased range of motion indirectly reduced pain. This was evidenced by the significant correlation between the "maneuver" success rate and the knee range of motion. The analgesic effect of the "maneuver" could also be explained by increased muscle strength through frequent preliminary quadriceps muscle contractions, incorporated in the daily activities. They were triggering frequent co-contractions of all periarticular muscles, increasing their strength. Since pain reflexively inhibited muscle strength, increased muscle strength indirectly reduced pain. This was evidenced by the significant correlation between the "maneuver" success rate and the muscle strength.

In the "maneuver" group the pain decreased significantly after the first day, while in the "standard" group - after the fifth day. Therefore, preliminary quadriceps muscle contraction reduced pain at the moment of its application. All patients in the "maneuver" group reported an immediate pain reduction while using this bracing "maneuver" before standing, sitting, bending, kneeling, straightening, lifting or lowering of objects, walking, running, climbing down, or upon stairs, slopes, or vehicles. The same activities were reported to be more painful and restricted without this "maneuver".

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 two-day period, could be explained by the analgesic effect of the preliminary quadriceps muscle contraction. The difference in pain between the groups over the weekend proved the short-term analgesic effect of physiotherapy. The pain increased significantly in the "standard" group for two days without physiotherapy. Therefore, physiotherapy added a short-term analgesic effect over those of the natural healing process, exercise, and prophylactic recommendations.

No differentiation could be established between the interferential current and the laser regarding their short-term symptomatic (analgesic) effect. They had no primary pathogenetic effect (on the range of motion and muscle strength). These physiotherapeutic 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 had to be inversely proportional if any physio-prophylactic effect was found.

The lower pain (after one year versus after two weeks in both groups) could be explained by the long-term analgesic effect of the natural healing process, exercise, and prophylactic recommendations. Physiotherapeutic factors 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 a supplementary long-term analgesic effect of the "maneuver" over those of the natural healing process, exercise, and prophylactic recommendations. This was proven also by the significant correlation between the “maneuver” success rate and the intensity of pain.

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. Physiotherapeutic factors and prophylactic recommendations had no short-term mobility effect. The higher range of motion of the “maneuver” group versus the “standard” group could be explained by a supplementary short-term mobility effect of the “maneuver” over those of the natural healing process and exercise. This was evidenced by the significant correlation between the “maneuver” success rate and the knee range of motion. The higher short-term mobility in the “maneuver” group versus the “standard” group could also be explained by the more successful reduction of pain in the “maneuver” group, allowing a greater and painless short-term mobility.

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. Physiotherapeutic factors and prophylactic recommendations had no long-term mobility effect. The higher mobility of the “maneuver” group versus the “standard” group for 10 consecutive years could be explained by a supplementary long-term mobility effect of the “maneuver” over those of the natural healing process and exercise. This was evidenced by the significant correlation between the “maneuver” success rate and the knee range of motion. The better long-term mobility in the “maneuver” group versus the “standard” group could also be explained by the more successful pain reduction in the “maneuver” group, allowing greater and painless long-term mobility.

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. Physiotherapeutic factors and prophylactic recommendations had no short-term strengthening effect. The higher short-term strength of the “maneuver” group versus the “standard” group could be explained by a supplementary short-term strengthening effect of the “maneuver” over those of the natural healing process and exercise. This was evidenced 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 also be explained by the more successful pain reduction in the “maneuver” group, allowing greater and painless muscle contractions, leading to higher short-term knee stability.

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. Physiotherapeutic factors and prophylactic recommendations had no long-term strengthening effect. The higher muscle strength of the “maneuver” group versus the “standard” group for 10 consecutive years could be explained by a supplementary long-term strengthening effect of the “maneuver” over those of the natural healing process and exercise. This was evidenced by the significant correlation between the “maneuver” success rate and the muscle strength. The higher long-term muscle strength in the “maneuver” group versus the “standard” group could also be explained by the more successful long-term pain reduction in the “maneuver” group, allowing greater and painless muscle contractions, leading to higher long-term knee stability.

The preliminary quadriceps muscle contractions trigger co-contractions of the knee muscles before loads of external forces on the joint. This protects the knee by avoiding the repetitive micro-injuries during the muscle latency, which is inevitable in usual daily activities. Another protecting factor is the increased muscle strength of all periarticular muscles, as a result of this bracing “maneuver”, leading to lesser pain with higher knee stability and mobility. Thus, it reduces the risks of injuries and degeneration. This “maneuver” reduces pain by increasing knee stability, muscle strength, and range of motion. It is short, simple, effective, and without side effects or complications. It does not require dedicating resources, time, or space, and not only does not interrupt the daily activities, but makes them easier, faster, and painless.

Conclusion

The preliminary quadriceps muscle contraction is an appropriate addition to the prophylactic advices for short-term treatment and long-term prophylaxis of recurrent pain due to knee osteoarthritis. It improves daily activities involving the knee (including locomotion) by increased knee stability, range of motion, and muscle strength, leading to reduced pain. This bracing “maneuver” could be useful in optimizing the treatment and prevention of recurrent knee pain due to osteoarthritis. It could save a lot of suffering, pain, and other negative emotions for many people at risk for a recurrent knee disability, and could reduce the number of lost working days due to knee osteoarthritis.

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