Continuous passive motion in knee arthroplasty patients

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ABSTRACT
Introduction: Total knee arthroplasty (TKA) is a valid therapeutic option for patients with severe arthritis and physical disability. However, many TKA patients develop pain and functional impairment. In our study, we used a continuous passive motion (CPM) device for exercise starting 10 days after surgery. **Materials and Methods:** The study population consisted of 60 patients, who were randomized into 2 groups. Group I (GI: 30 patients, 23 females) underwent the standard treatment and group II (GII: 30 patients, 17 females) underwent the standard treatment plus CPM starting 10 days after surgery. We evaluated pain, range of motion (ROM), extension muscle strength, and function (WOMAC and TUG tests). **Results:** All compared parameters yielded no statistically significant differences. A greater trend toward improvement was observed in GII regarding some parameters: greater extension muscle strength and a baseline correlation between flexion strength and the TUG test. **Conclusions:** The use of CPM starting 10 days after surgery improved the extension muscle strength and produced better TUG test results, although without any statistically significant difference with the standard procedure. No adverse effects were observed.
Key words: Continuous passive motion; knee arthroplasty; functional assessment; knee.
Level of Evidence: I

Movilización pasiva continua en pacientes con artroplastia de rodilla

RESUMEN
Introducción: La artroplastia total de rodilla es el recurso terapéutico para pacientes con artrosis severa y gran incapacidad física. Sin embargo, muchos evolucionan con dolor y déficit funcional. En este estudio, se utiliza un tratamiento con movilización pasiva continua a partir de los 10 días de la cirugía. **Materiales y Métodos:** Se incluyó a 60 pacientes que fueron asignados, en forma aleatoria, a 2 grupos (30 en cada grupo). Al grupo 1 (G1, 23 mujeres) se le aplicó un protocolo de tratamiento convencional y, al grupo 2 (G2, 17 mujeres), el mismo programa y la adicción de un equipo de movimiento pasivo continuo a los 10 días de la intervención. Se evaluaron el dolor, la movilidad articular, la fuerza muscular y la función (WOMAC y prueba TUG). **Resultados:** No se observaron diferencias estadísticamente significativas en los parámetros estudiados, aunque sí una tendencia a la mejoría en el G2. En este grupo, la fuerza de extensión de la rodilla fue mayor y también hubo una correlación basal entre la fuerza y la prueba TUG. **Conclusiones:** El uso diferido de la movilización pasiva continua mejoró la fuerza de extensión de la rodilla y el rendimiento en la prueba TUG, aunque sin diferencias significativas entre ambos grupos. No se observaron efectos adversos.
Palabras clave: Movimiento pasivo continuo; artroplastia de rodilla; evaluación funcional; rodilla.
Nivel de Evidencia: I

INTRODUCTION

Knee osteoarthritis is a common orthopedic condition with an overall prevalence of symptomatic osteoarthritis ranging from 8.1% to 19%.[1-5] TKA is the treatment of choice in advanced osteoarthritis patients following failure of conservative treatments.[6] TKA aims at achieving joint alignment and stability with relief of pain and improvement in mobility and function. However, the procedure requires an extensive dissection of soft tissue around the knee, resulting in major aggression to the extensor mechanism and other periarticular structures. In addition,

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chronic degenerative changes and osteoarthritis-related malalignment and stiffness also affect the postoperative outcome.[7,8] Although a considerable number of patients indicate a significant and early pain relief, functional limitations may persist long after TKA, especially in cases where disability is measured using performance-based functional tests.[9-13] Some factors, such as postoperative muscle weakness,[10,13] hinders patients' general mobility and affects their ability to perform regular daily life activities.[14]

Early mobilization has become a key aspect in rehabilitation protocols following TKA in contrast to traditional protocols that recommended immobilization in extension to promote healing.[15] CPM is a postoperative movement method based on a mechanical device that moves the leg slowly and continuously through a controlled ROM.

Constant movement in flexion and extension without any weight-bearing associated with muscle activity causes sinusoidal oscillation in the intra-articular pressure, resulting in an articular pumping effect.[16] Although there are reports suggesting CPM patients may improve flexion, require fewer analgesics and less manipulation under anesthesia,[15,17,18] several randomized clinical studies have found no additional advantage for CPM compared to the traditional postoperative protocol based on joint mobilization and active exercises.[19-26]

One of the main factors that may account for the lack of clinical benefits observed with CPM therapy is associated with its application method, namely, time of institution and application procedure. In line with Salter's principles, most studies instituted CPM on postoperative day 1. During this stage, an intense inflammatory process occurs in the knee as a result of the TKA, characterized by the inflammatory cell response to remove damaged tissues and form granulation tissue to which fibroblast in the proliferation stage will adhere to produce the new connective tissue matrix.

Therefore, early movement may result in some damage to the initial scar tissue, increasing postoperative bleeding.[27-29] This reasoning is consistent with Maniar *et al*. findings, who reported that postoperative knee swelling in CPM patients persisted longer.[19] The application procedure also differs significantly between studies. CPM is applied almost exclusively during the hospital stay, in sessions ranging from 30 minutes[19] to 6 hours,[20,22,24,25] and for 1[19] to 8 days.[23] A study actually fixed the CPM device during the postoperative first night to hold the knee stationary at 90- degree position for 8 to19 hours and then continued with moving CPM for 5 hours per day until hospital discharge.[26] Only one of the reviewed studies continued CPM treatment after hospital discharge, for a total of 18 days.[21]

A possible alternative to these unsuccessful methods could be a delayed CPM application. This approach could potentially reduce postoperative bleeding, and so promote rapid inflammatory resolution, reducing pain and allowing for CPM during the proliferation stage of tissue repair. Therefore, the purpose of our study was to assess the short-term effects of a delayed CPM using an intense home-based program.

MATERIALS AND METHODS

Participants

This prospective randomized study included 60 patients, of both sexes, aged 55 to 75 years, with knee osteoarthritis, undergoing unilateral TKA. Exclusion criteria were: TKA due to inflammatory arthritis, infection, previous arthroplasty or bone tumors; history of corrective varus or valgus osteotomy of the affected or the contralateral leg; and history of other major orthopedic surgery in the affected or the contralateral leg or the spine. All study subjects signed a written informed consent form, and the study protocol was approved by both Institutional Ethics Committees.

Randomization and treatment allocation

Subjects were allocated in one of two groups. Randomization was run by one of the study researchers (RB) using a computer-generated code provided by the online randomization software www.randomizer.org.

GI patients were given a standardized exercise program aimed at improving joint mobility and strengthen the main muscles, including hip abductor muscles, knee extensor and flexor muscles, and ankle extensor muscles. The program was to be instituted as soon as pain permitted following hospital discharge. Patients were instructed to perform the exercises between 2 and 4 times per day, with 4 sets of 8-12 repetitions for each exercise.

GII patients were given the same exercise program plus a CPM program which started 10 days after hospital discharge and lasted for 2 weeks. An experienced physical therapist in the clinical application of the CPM device

trained the patients to correctly use the device at their homes. The CPM devise was used for 8 hours per day, 2 hours on 2 hours off (a total of 4 2-hour periods of daily use). The device was programmed to begin moving the knee to the maximum tolerated ROM for extension and flexion, without causing pain and keeping contact between the leg and the device support layer. As from day 2, patients should increase ROM by 5 degrees per day, following the same criteria. Exercise speed was 150 degrees per minute.

Surgical procedure

All replacement procedures were performed using a medial parapatellar approach. Anesthesia protocol was the same for both groups. All patients received spinal anesthesia plus periarticular injection or peripheral nerve block (sciatic, saphenous or femoral).

Sigma® (DePuy Orthopaedics, Warsaw, IN, USA) implants were used in all procedures. Postoperative suction drainage was applied for 24 hours. On postoperative day 1, the regimen allowed full weight-bearing and walking short distances using a walker. Non-steroidal anti-inflammatory drugs were prescribed to manage postoperative pain. No other analgesic therapy was administered.

Patients' assessments

Two physical therapists (LI and DB) were in charge of the patients' assessments, which took place within a week before surgery (T1), on postoperative day 30 (T2), and on postoperative day 90 (T3). T1 assessment recorded demographics and additional data on time of pain evolution and whether patients participated in any physical activity, and whether they underwent preoperative physiotherapy. The variables under study in all 3 assessments were: pain intensity, ROM in extension and flexion, muscle strength, and function.

Pain intensity was measured using the Visual Analogue Scale. Patients were trained to rate the level of pain on a 10 mm scale (ranged from 0 [no pain] to 10 [worst pain imaginable]), representing the mean intensity experienced during their daily activities, for every day the week before assessment. Both knee active flexion and extension ROMs were measured using a universal goniometer. Knee flexion ROM was measured with patients in a ventral decubitus position and the goniometer centered on the lateral epicondyle, with the proximal arm directed toward the greater trochanter, and the distal arm directed toward lateral malleolus. Patients were asked to actively flex the knee while the physical therapist assessed any potential compensations at hip level. Knee extension deficit was measured with patients in supine position. Patients were asked to place their heels on a firm cylinder and to relax the leg. The goniometer was placed in the same way as for the flexion ROM measurement and the deficit was recorded using negative values.[30]

The extension and flexion strength of both knees were measured using a hand-held dynamometer (Lafayette model 01165, Lafayette Instrument Co., Lafayette, IN, USA) with patients seated with a 90-degree hip angle and a 60-degree knee angle, and their arms crossed on the chest.[31] The foot was placed on a small bench to ensure the correct angle. The dynamometer was placed on the anterior aspect of the distal third of the lower leg to measure extension strength, and on the posterior aspect to measure flexion strength. Patients were asked to push as hard as possible for 6 seconds. Three repetitions were performed in each direction with a 30-second rest interval, and the average value was recorded.

Functional performance was assessed through a self-administered questionnaire and a physical functional performance test. The Likert version of the Western Ontario and McMaster Universities (WOMAC) index is a questionnaire made up of 24 items that evaluate pain and difficulties encountered in daily activity. Result values range from 0 (best health status) to 96 (worst health status).[32] Functional performance was established through the Timed Up and Go (TUG) test. TUG test begins with the patient sitting on 46 cm-high armchair. The patient then has to stand up, walk 3 m up to a line on the floor, turn, walk back to the chair, and sit down again. The test result is the time measured in seconds taken by the patient to complete the test.[33]

Statistical analysis

Two type of statistical analysis were conducted: t-tests on mean differences for independent samples or paired sample t-tests and factorial ANOVA for each group curve-data analysis (Statistica, Statsoft, USA).

RESULTS

Table 1 shows the study population demographics. All patients complied with the entire 3-stage assessment process. No complications associated with the procedures were reported. The home-based CPM protocol was well tolerated and patient compliance was excellent.

Table. Demographics

	Group 1	Group 2
N	30	30
Age (years)	69.76 ± 6.79	67.76 ± 6.03
Sex female	23	17
Evolution (years)	5.43 ± 3.68	4.91 ± 3.75

Values are expressed as mean and standard deviation.

T2 and T3 assessments yielded no statistically significant differences for pain intensity (P<0.001) and WOMAC index (P <0.001) between groups. Extension ROM showed no significant differences between groups at T2 and T3. Flexion ROM of the operated leg decreased for both groups at T2, GII patients having a less steep reduction (P<0.001). However, this disparity disappeared in T3 (Figure 1).

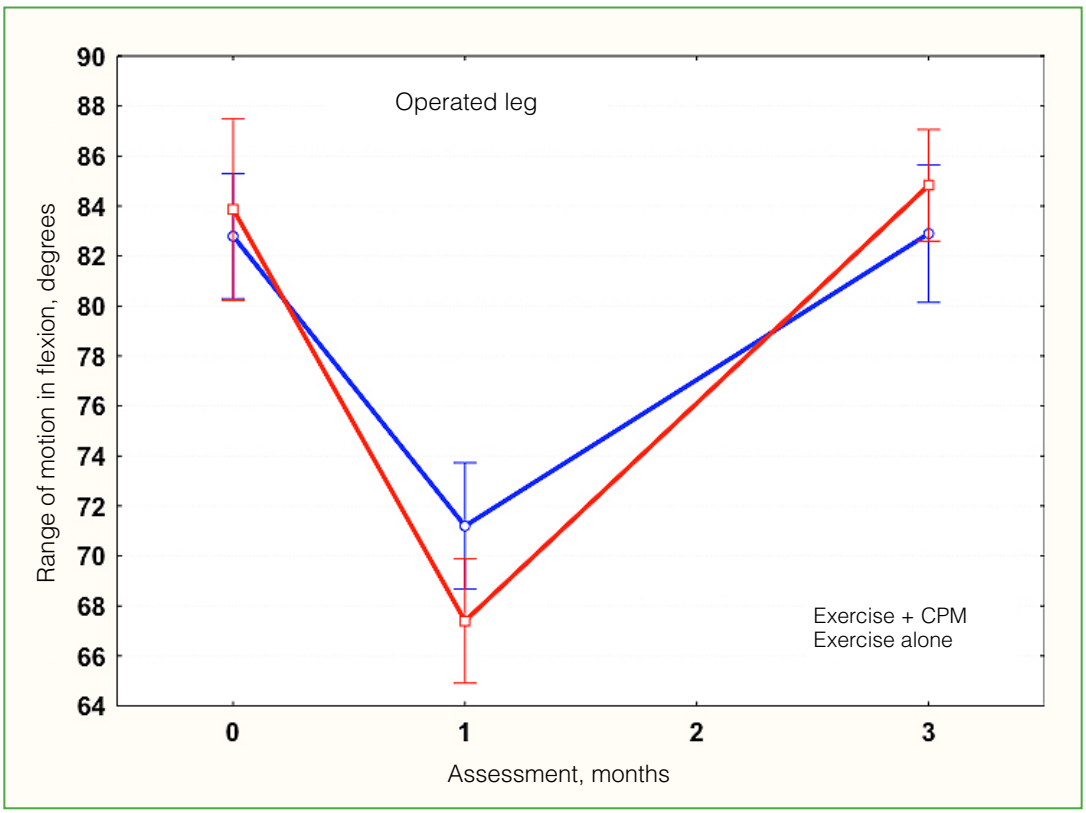

Figure 1. Operated leg range of motion in flexion (expressed in degrees).

In both groups, the extension strength of the operated knee decreased in T2 and increased in T3. GII patients had a clear tendency, although not statistically significant, toward a less strength loss at T2, maintaining this potential difference at T3 (Figure 2).

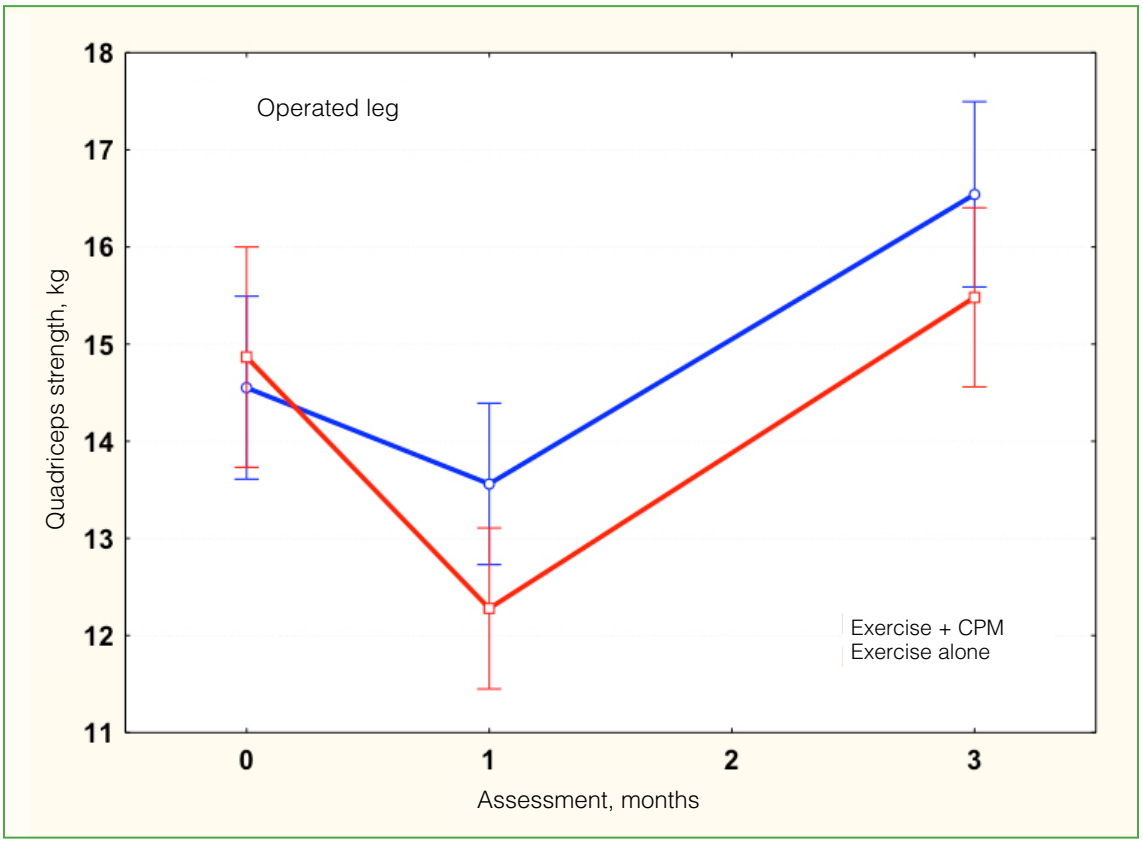

Figure 2. Operated leg extension strength (expressed in kilograms).

Both groups increased the flexion strength of the operated leg at T2 and T3, with the difference only being statistically significant at T3 (ANOVA, P0.02) (Figure 3).

Unexpectedly, TUG test results were higher at T1 and, in general, in GII. T2 values for the TUG test were significantly high in both groups, but the increase was only statistically significant in GII (P>0.004). T3 values for the TUG test clearly decreased in both groups and were lower than T1 values, but there was a greater tendency toward improvement in GII (Figure 4).

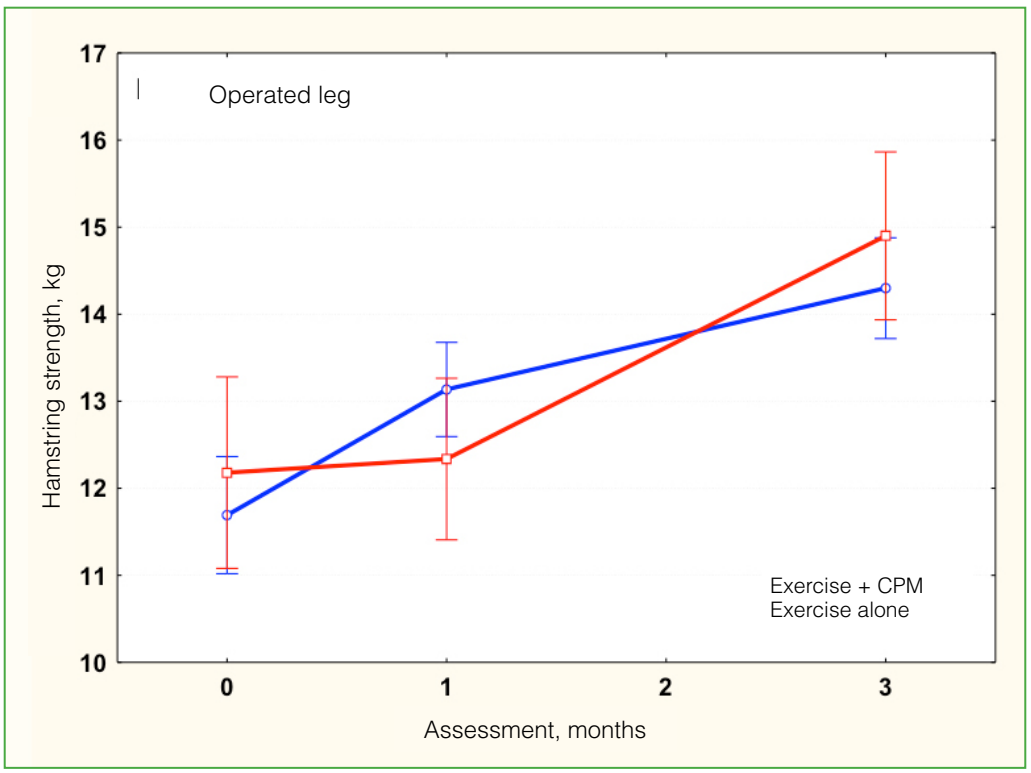

Figure 3. Operated leg flexion strength (expressed in kilograms).

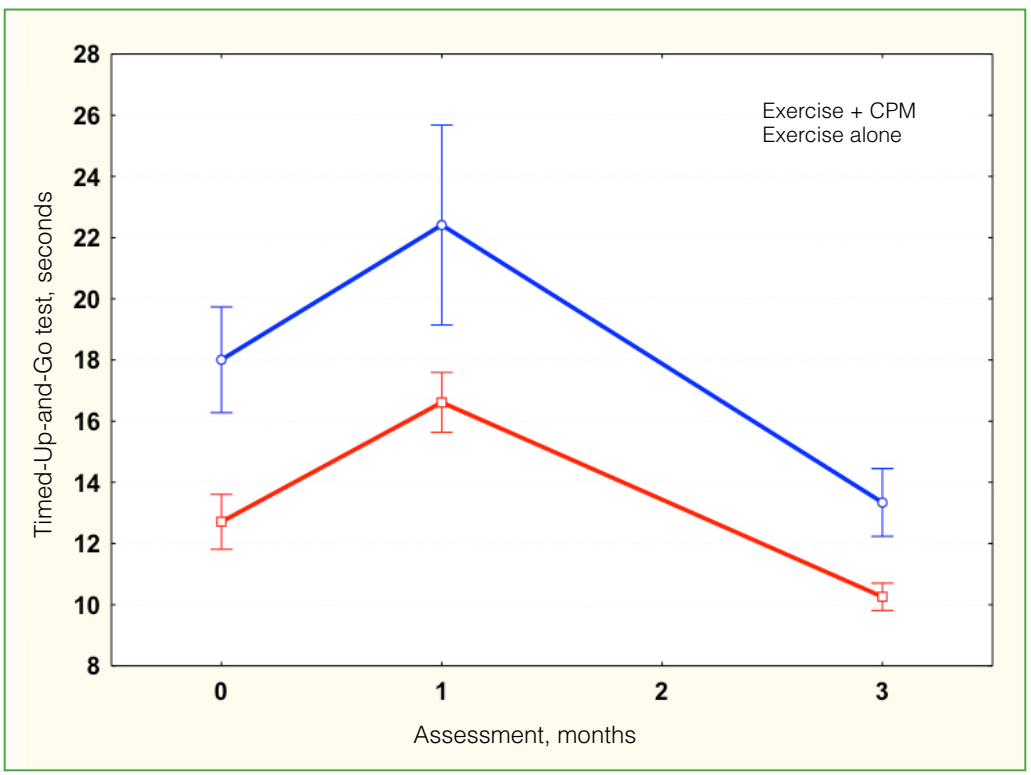

Figure 4. Group I and group II results for the Timed-Up-and-Go test (expressed in seconds).

There was no correlation between GI results for either knee extension strength and the TUG test. In contrast, all assessment stages showed a consistent correlation between GII results for the extension strength of the operated knee and the TUG test (P<0.001). According to secondary analyses, GII patients who achieve a 23.5 kg extension strength for either knee by day 90 (T3) are to achieve less than 12 seconds in the TUG test (Figure 5). There was also a correlation between flexion strength of the operated knee and the TUG test at T1, which was not present at T2 and reappeared at T3 but only in GII (Figure 6). Interestingly, a similar tendency was observed in the contralateral leg.

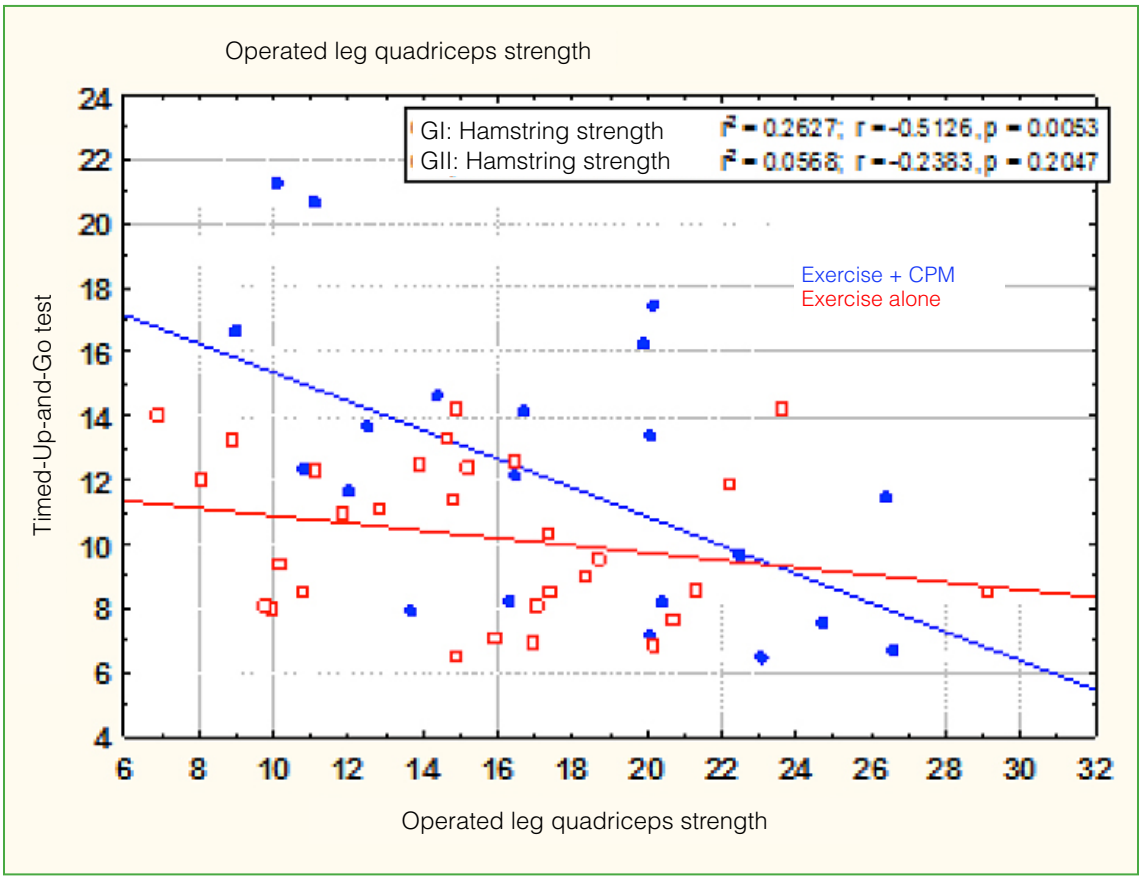

Figure 5. Group I and group II correlation chart between Timed-Up-and-Go test and quadriceps strength on postoperative day 90.

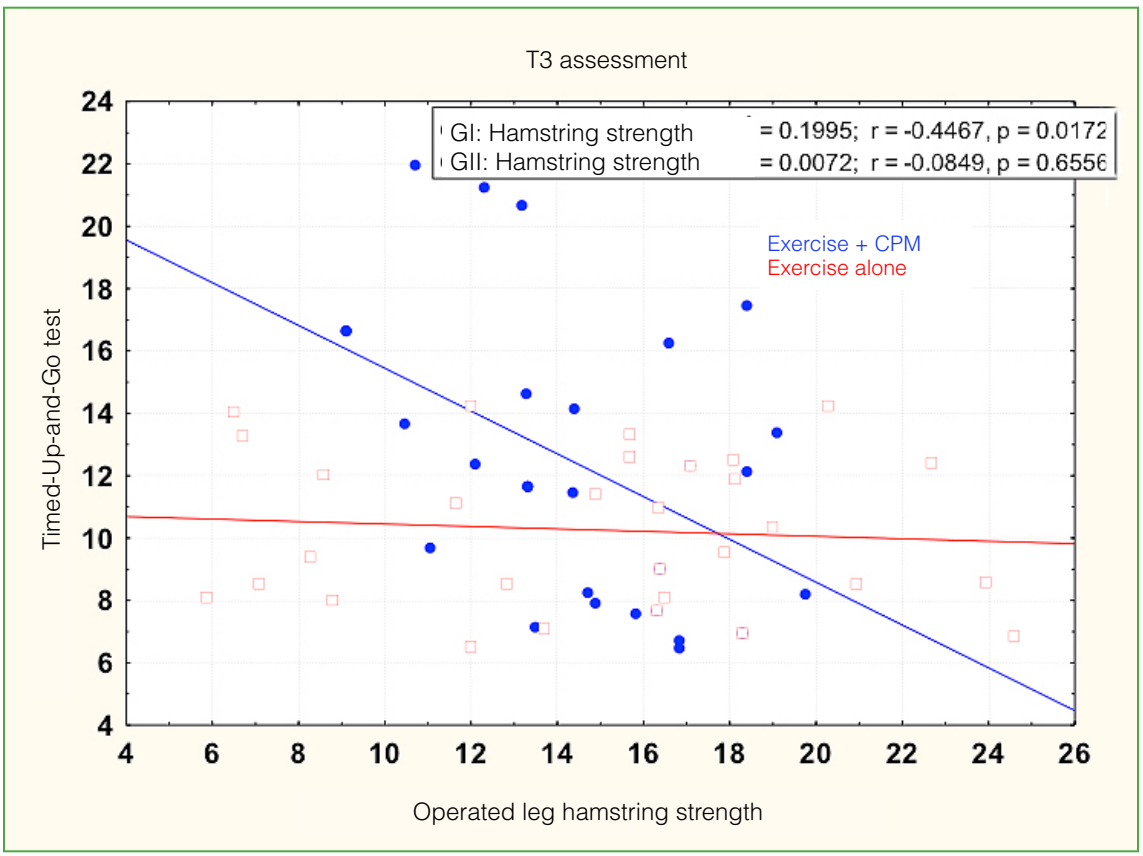

Figure 6. Group I and group II correlation chart between Timed-Up-and-Go test and hamstring strength on postoperative day 90.

DISCUSSION

Most studies that assess the effects of immediate CPM following a TKA have failed to report any additional benefits as compared to a standard physical therapy program. This study puts forward a new CPM protocol consisting of an intense and entirely home-base 10-day program, without any CPM exercise being performed during the hospital stay. Our results show that adding said protocol to the rehabilitation regimen is associated with significant improvement in the TUG test and in the knee extension and flexion strength, with no additional benefits in terms of pain, ROM, and WOMAC index.

The final stage of knee osteoarthritis is identifiable by pain unresponsive to treatment and limited ROM. Limitation of daily life activities due to pain is the main factor determining a TKA indication. Increasing ROM and providing pain relief are the main objectives of CPM following TKA. However, as reported by other authors, our results evidence no significant differences between our program and a standard exercise program. This fact may be accounted for by the changes taking place in the subchondral bone tissue and the articular cartilage. As osteoarthritis progresses, the increased load conveyed to the subchondral bone triggers a bone remodeling process associated with an angiogenesis phenomenon. The new vessels and associated sensory nerves go through vascular channels into the cartilage, thus providing to this otherwise aneural tissue the ability to experience algesia and peripheral sensitization.[34,35] Therefore, this hypersensitive tissue resection may be the key contributing factor in postoperative pain relief. In addition, advances provided by navigation-assisted surgery in terms of soft tissue balancing and prosthetic alignment procedures may account for the lack of additional benefits observed with CPM. Further studies are warranted to compare the effects of this protocol in patients with different levels of preoperative mobility limitation in order to improve the indication criteria for CPM following a TKA.

Objective function assessment in TKA patients is a measurement of huge clinical importance. There are two types of tools to measure this parameter: self-administered questionnaires and functional performance tests. Functional scales have been reported to fail in detecting actual functional deficits following a TKA, mostly because the results are heavily influenced by pain perception.[10] In contrast, functional tests have been shown to have a direct and consistent relationship with quadriceps strength, small correlation with pain and self-reported scales,[10,36,37] and a significant predictive value.[38] Therefore, function assessment in TKA patients should include both methods. To the best of our knowledge, only a few studies have included functional performance tests as a method to measure the outcome. In 3 studies, CPM was applied in the early recovery and no improvements were reported.[19,22,23] As it has already been stated, the immediate use of a CPM device after surgery increases postoperative bleeding and may perpetuate swelling.

Therefore, early CPM may actually extend, rather than revert, the arthrogenic muscle inhibition, which is a known cause for knee extension weakness, both preoperatively and postoperatively.[39-41] In our study, the knee extension strength decreased at T2, for both groups, but there was a tendency toward a less strength loss in CPM patients which was also observed at T3.

Delayed CPM may provide time for the knee to adjust, which could favor the subsequent edema resorption with no additional stress on the joint and soft tissues. Consistent with this line of reasoning, only GII results for both knees' extension strength correlated with the TUG test results at T2 and T3, revealing an effect of CPM on the contralateral leg.[40,41] Herbold *et al*. also used the TUG test, but the population study consisted only of patients with poor postoperative knee ROM (between 45 and 75 degrees), and CPM was instituted on postoperative day 5, so no direct comparisons could be made.[42] Further studies are warranted to establish final conclusions on the effects of CPM on functional performance.

The limitations of this study include: first, the study population size could have affected the strength of the results. Further studies should assess the effects of this protocol in a larger number of patients to confirm the results of this study. A second limitation might have been the study follow-up period. The follow-up period was established based on several reports suggesting that CPM only has short-term effects. In the event that further studies confirm the CPM effect on functional performance, CPM indication could be justified in patients who desire a faster resumption of daily life activities. Finally, this study failed to assess the impact of certain factors, such as body mass index and preoperative valgus angle, on the final outcomes.

CONCLUSIONS

We present a new CPM protocol consisting of an intense home-based program starting on day 10 after TKA. Our results show that applying CPM as an adjunct to a standard physical therapy program increased knee extension strength and improved TUG test values.

These results may be attributed to the CPM effect on the postoperative edema resorption and the reduction in arthrogenic muscle inhibition. Further studies are warranted to assess this protocol in a larger number of patients to confirm the results of this study.

Conflict of interests: Authors claim they do not have any conflict of interests.

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