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Effect of Mechanical Traction and Therapeutic Exercises in Treatment of Primary Knee Osteoarthritis

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SUMMARY

Background. Knee osteoarthritis is a degenerative disorder causing pain and disability. It is distinguishable by cartilage degeneration and joint space loss. Therapeutic exercises are an established treatment option for knee osteoarthritis. Mechanical knee traction is a novel method that allows for transient unloading of the knee joint.

Purpose. To compare between the effect of therapeutic exercises and therapeutic exercises preceded by mechanical traction in treatment of primary knee osteoarthritis.

Patients and methods. Forty patients were randomly distributed into two equal experimental groups. The exercise group received selected stretching and strengthening exercises. The traction and exercise group received mechanical knee joint traction followed by the same exercise program. Patients received this treatment for 12 sessions (3 sessions/week) for 4 weeks. They were assessed before and after treatment for knee pain severity, functional disability, isometric quadriceps and hamstring muscle strength, walking time and stairs ascending and descending time.

Results. Within groups comparison showed a significant improvement in all the measured variables in both groups ($p < 0.05$). Between groups, comparison showed a significant decrease in both knee pain severity and functional disability and a significant increase in isometric quadriceps and hamstring muscle strength in favor of the traction and exercise group ($p < 0.05$). However, no significant difference was found between groups in walking time and stairs ascending and descending time ($p > 0.05$).

Conclusions. Therapeutic exercises preceded by mechanical traction are more significantly effective than therapeutic exercises alone in treatment of primary knee osteoarthritis.

Study registration. This study was registered at ClinicalTrials.gov on March 2021 (NCT/04830748).

KEY WORDS

Knee pain; mechanical traction; primary knee osteoarthritis; quadriceps strength; therapeutic exercises.

INTRODUCTION

Knee osteoarthritis is a degenerative disorder causing pain and disability due to joint wear and tear, ageing and obesity (1). It is distinguishable by cartilage degeneration, joint space loss, bone sclerosis and osteophytes (2). In Egypt, knee osteoarthritis prevalence rate ranges from 7.8 to 9.3% (3). Patients with knee osteoarthritis present clinically with pain, crepitus, morning stiffness, abnormal joint loading and functional impairment (4, 5).

For knee osteoarthritis, therapeutic exercises are considered as an effective and safe intervention (6). Therapeutic exercises of low to moderate intensity does not accelerate the progression of knee osteoarthritis (7, 8). Therapeutic exercises are an established treatment option and upcoming studies are hardly going to change confidence in this fact (9, 10). Therapeutic exercises mainly improve aerobic fitness, hip and knee muscle strength and flexibility (11, 12). Therapeutic exercises were reported to

reduce knee pain, disability, improve functional performance, quality of life and spatiotemporal gait parameters (11, 12).
Traction was primarily introduced as surgical joint traction (13). Limitations during and after the application of the skeletal traction (14) lead to a research interest in non-surgical traction (15-20). Recent studies (21, 22) reported observations of suppression of articular cartilage degeneration after the application of non-surgical unloading.
Mechanical traction is a conservative technique based on the same concept of skeletal knee joint traction; it provides transient joint unloading. The application of mechanical traction is clinically promising with positive observations related to pain, disability, range of motion, functional performance and quality of life (16-20).
The addition of mechanical traction to therapeutic exercises was proposed to help gain the beneficial effects of both exercises (11, 12) and unloading techniques (21-23). There is a need for better description and reporting of these treatment methods to confirm the positive effects of the combined use of both techniques. Moreover, the effect of mechanical traction on quadriceps and hamstring muscle strength was not studied in the literature. Combined application of mechanical traction with therapeutic exercises was assumed to optimize muscle function by reversing the arthrogenic muscle inhibition (24-27). Hence making exercise performance easier and exercise gains faster (26).
The current study may provide a more conclusive insight in treatment of patients with primary knee osteoarthritis. This combined program might be beneficial within a short period of time and may be more efficient than therapeutic exercises alone (28). Therefore, the purpose of this current study was to compare between therapeutic exercises and therapeutic exercises preceded by mechanical traction in treatment of primary knee osteoarthritis.

PATIENTS AND METHODS

Patients

Forty male and female patients with the diagnosis of primary knee osteoarthritis participated in this study. Patients were included if they had grade II or III primary knee osteoarthritis, their age ranged from 45 to 65 years with duration of illness ranged from 3 to 12 months. In patients with bilateral primary knee osteoarthritis, the more painful knee was chosen for the study. Patients were excluded if they had skin lesions or infections at the treatment site. All patients were assessed and treated in the outpatient clinic of the faculty of physical therapy in Cairo University.
Patients were randomly distributed into two equal experimental groups. The first experimental group consisted of 20 patients (18 females and 2 males) who received stretching and strengthening exercises of selected muscles of the thigh and leg. The second experimental group consisted of 20 patients (18 females and 2 males) who received continuous mechanical knee joint traction followed by the same exercise program of the first group. All patients were treated for 12 sessions, 3 times per week each other day for 4 weeks. An informed consent was obtained from each patient prior to the study. The ethics committee of the faculty of physical therapy in Cairo university gave its approval to the study (P.T.REC/012/002876 - date of approval: September 09, 2020). The study was conducted from May 2022 to December 2022

Assessment procedures

Clinical assessment included knee pain severity, functional disability, isometric quadriceps and hamstring muscle strength and functional performance. Assessment was done pre-treatment (2-3 days before the first treatment session) and post-treatment (2-3 days after the last treatment session).
Knee pain severity was measured by using the Arabic numerical pain rating scale (29) where 0 equals no pain and 10 equals the worst possible pain. The patient was instructed to choose only one number on this scale.
Knee functional disability was measured by using the Arabic version of the Western Ontario and McMaster Universities Osteoarthritis Index (30). It is a valid, reliable and specific patient reported index which consists of 24 items measuring pain, stiffness and physical function. Every item has five possible answers graded from 0 (none) to 4 (extreme). Total score is the sum of the 24 items, and it ranges from 0 (best) to 96 (worst) points. The patient was instructed to choose the best answer which describes the level of difficulty he faces during daily activities in each of the 24 items.
Isometric muscle strength was measured for knee muscles by using a hand-held dynamometer (model 12-0393 baseline push/pull dynamometer, USA). It is both a valid and reliable tool for measuring of isometric muscle strength (31). The isometric muscle force was shown in pounds and kilograms. Force was later converted to Newtons according to the work of Jaric (32).
Based on the work of Bohannon (31), isometric quadriceps muscle strength was measured from the sitting position with both hips and knees flexed 90°. The end

piece of the dynamometer was applied to the anterior surface of the distal leg just above the ankle joint, then the patient was instructed to extend his knee, contract quadriceps maximally and hold for 5 seconds before relaxation. Isometric hamstring muscle strength was measured from the same position with the end piece of the dynamometer applied to the posterior surface of the distal leg just above the ankle joint. The patient was instructed to flex his knee, contract hamstring maximally and hold for 5 seconds before relaxation. The patient performed three trials of 5 seconds each and had 30 seconds of rest between trials. In each trial, the registered force on the dynamometer was recorded and the dynamometer was readjusted to zero before the next trial. The mean of the three trials of each test was chosen for the purpose of data analysis.

Functional performance was measured by using the 40 meter fast paced walk test and the 12-step stair test based on the work of Stratford *et al.* (33). Both tests have high reliability with low measurement error. The first test measures the time needed to walk a 40 meters distance. The patient stood behind a predetermined start mark, then was instructed to walk as quickly as possible on the command "GO", but not to run. The patient walked a 20 meters distance along a leveled unobstructed indoor course departing at the start mark and then walked another 20 meters returning to it. The second test measures the time needed to ascend and descend a 12-step stair where step height equals 17 centimeters and step depth equals 30 centimeters. The patient stood behind a predetermined start mark, and then was instructed to ascend and descend the stair as quickly as possible on the command "GO". Safety was assured by holding the handrail during the task. Scores were calculated using a stopwatch mobile application as the time needed to complete each test. Three trials were done for each test with 5 minutes rest between trials and 10 minutes rest between tests. The mean of the three trials of each test was chosen for the purpose of data analysis.

Treatment procedures

All patients were treated individually under the direct supervision of the main investigator. The exercise group received therapeutic exercises in the form of stretching and strengthening exercises of selected muscles of the thigh and leg based on the recommendations of Rausch Osthoff *et al.* (34). Passive stretching exercises were done for the rectus femoris, hamstring, and calf muscles based on the work of Reid and McNair (35). Each exercise was done for three repetitions, with a hold of 30-60 seconds and a rest of 30-60 seconds between repetitions. Each repetition was performed slowly until a feeling of tightness was noticed. This group also received strengthening exercises of the quadriceps (terminal knee extension, knee extension and straight leg raise from supine) and hamstring muscles (hamstring curl from prone and standing positions and straight leg raise from prone) according to the work of Kus and Yeldan (36). These exercises are shown in **table I**. Each exercise was done for 3 sets, each set consisted of 10 repetitions with a rest of 2-3 minutes between sets. The given resistance was 50% of 1 repetition maximum of the patient. Each repetition was performed slowly with a hold for 5 seconds at the end position. Exercises were carried out within a tolerable level of pain. If joint swelling or unacceptable pain occurs, the exercise repetition or resistance was reduced.

The traction and exercise group received mechanical knee joint traction followed by the same exercises of the first group. Mechanical traction of the knee involved the use of a mechanical traction system that included pulleys, weights and a specially designed greave to apply traction to the knee joint. The protocol of using mechanical traction was based on the work of Khademi-Kalantari *et al.* (17). Mechanical traction was applied for 20 minutes continuously in the supine lying position with the affected knee flexed at 25-30° by a wedge placed under the thigh. The thigh was stabilized by a strap and the leg was held by the specially designed greave with the weight of traction hanging throughout the pulley system, as shown in **figure 1**. The initial traction force was set to 10% of the body weight. Traction force was increased each week by 1% of body weight if the patient could tolerate the duration of 20 minutes with the preset force. Traction force was maintained or reduced if intense pain or swelling occurred.

Figure 1. Application of continuous mechanical traction of the knee joint.

Table I. Description of stretching and strengthening exercises.

Exercise	Description
Hamstring muscle stretching	Done with the patient lying down on the back with the investigator holding the affected leg, keeping the affected knee fully extended and stabilizing the opposite extremity. The investigator flexed the hip slowly till a feeling of tightness was felt.
Rectus femoris muscle stretching	Done with the patient lying down on the back close to the edge of the treatment table with the non-affected leg flexed toward the patient's chest to stabilize the pelvis and spine while the affected leg was hanging outside the treatment table. The investigator pushed the affected limb downwards into hip hyperextension and then flexed the affected knee slowly till a feeling of tightness was felt.
Calf muscle stretching	Done with the patient lying down on the back. The investigator grasped the patient's heel and placed his forearm along the plantar surface of the foot while stabilizing the lower leg just above the ankle joint with his other hand. Then the investigator dorsiflexed the ankle slowly till a feeling of tightness was felt.
Terminal knee extension	Done with the patient in back lying position with the affected leg supported over some rolled-up towels and bent to about 30° of knee flexion. The sand weight was placed just above the ankle joint. The patient was instructed to straighten the affected knee by slowly lifting the heel off and hold for 5 seconds.
Knee extension	Done with the patient sitting over the edge of the treatment table with both legs off the ground and knees at 90° flexion. The sand weight was placed just above the ankle joint. The patient was instructed to straighten the affected knee by slowly lifting the foot as high as possible and hold for 5 seconds.
Straight leg raises from supine	Done with the patient in a back lying position with the affected leg straight. The sand weight was placed just above the ankle joint. The patient was instructed to raise the affected limb slowly off the treatment table while keeping the affected knee extended and hold for 5 seconds.
Hamstring curl from prone	Done with the patient in the prone lying position with the affected leg straight. The sand weight was placed just above the ankle joint. The patient was instructed to bend the affected knee slowly as much as he could and hold for 5 seconds.
Hamstring curl from standing	Done with the patient in a standing position with the thigh pressed against the treatment table to prevent hip flexion. The sand weight was placed just above the ankle joint. The patient was instructed to bend the affected knee slowly as much as he could and hold for 5 seconds.
Straight leg raises from prone	Done with the patient in the prone lying position with the affected leg straight. The sand weight was placed just above the ankle joint. The patient was instructed to raise the affected limb slowly off the treatment table while keeping the affected knee extended and hold for 5 seconds.

RESULTS

For data analysis SPSS version 21.0 for windows was used. The level of significance was set as $p < 0.05$. Age, weight and height in addition to all the dependent variables of the study were shown to be normally distributed by using the Kolomogrov-Smirnov test of normality ($p > 0.05$). Unpaired t-test showed non-significant difference between groups for age, weight and height ($p > 0.05$), as shown in **table II**.

Unpaired t-test also showed non-significant difference between the pretreatment means of both groups regarding functional disability, isometric quadriceps strength, walking time and stairs time ($p > 0.05$). However, a significant difference was found between the pre-treatment means of both groups regarding knee pain severity and isometric hamstring strength ($p < 0.05$), as shown in **table III**.

Post-treatment within groups difference

Paired t-test showed significant difference between the pre-treatment and post-treatment means of all the dependent variables in the exercise group as well as in the traction and exercise group ($p < 0.05$), as shown in **table IV**.

Post-treatment between groups difference

Unpaired t-test showed significant difference between the post-treatment means of both groups regarding functional

Table II. Comparison between groups for age, weight, and height.

Variable	Exercise group Mean ± SD	Traction and exercise group Mean ± SD	t-value	P-value
Age (yars)	55.30 ± 5.95	56.90 ± 5.78	0.86	0.39
Weight (Kg)	91.40 ± 9.28	87.40 ± 10.96	1.25	0.22
Height (cm)	161 ± 5.60	165 ± 7.80	1.77	0.09

Table III. Pretreatment between groups difference.

Variable	Exercise group Mean ± SD	Traction and exercise group Mean ± SD	t-value	P-value
Knee pain severity	8.35 ± 1.09	9.05 ± 0.89	2.23	0.03*
Functional disability	75.10 ± 9.85	79.80 ± 11.09	1.43	0.16
Isometric quadriceps strength	93.45 ± 31.50	77.88 ± 35.79	1.46	0.15
Isometric hamstring strength	86.11 ± 25.96)	64.30 ± 29.50	2.48	0.02*
Walking time	52.60 ± 12.28	56.10 ± 14.31	0.83	0.41
Stairs time	31.80 ± 12.00	35.40 ± 15.61	0.82	0.42

*Significant difference.

Table IV. Within groups difference.

Variable	Pre-treatment Mean ± SD	Post-treatment Mean ± SD	t-value	P-value
Exercise group				
Knee pain severity	8.35 ± 1.09	6.75 ± 1.41	7.61	0.001*
Functional disability	75.10 ± 9.85	58.30 ± 10.24	12.52	0.001*
Isometric quadriceps strength	93.45 ± 31.50	110.36 ± 33.16	9.63	0.001*
Isometric hamstring strength	86.11 ± 25.96	101.90 ± 26.02	11.09	0.001*
Walking time	52.60 ± 12.28	44.90 ± 10.35	8.47	0.001*
Stairs time	31.80 ± 12.00	26.25 ± 9.28	6.46	0.001*
Traction and exercise group				
Knee pain severity	9.05 ± 0.89	4.05 ± 1.64	15.41	0.001*
Functional disability	79.80 ± 11.09	40.10 ± 11.32	14.64	0.001*
Isometric quadriceps strength	77.88 ± 35.79	135.06 ± 37.96	10.51	0.001*
Isometric hamstring strength	64.30 ± 29.50	106.80 ± 21.17	8.56	0.001*
Walking time	56.10 ± 14.31	39.35 ± 6.76	8.11	0.001*
Stairs time	35.40 ± 15.61	21.25 ± 10.47	7.90	0.001*

*Significant difference.

disability and isometric quadriceps strength in favor of the traction and exercise group ($p < 0.05$). However, this test showed non-significant difference between post-treatment means regarding walking time and stairs ascending and descending time ($p > 0.05$), as shown in **table V**.

Unpaired t-test also showed significant difference between the mean differences of both groups regarding knee pain severity and isometric hamstring strength in favor of the traction and exercise group ($p < 0.05$), as shown in **table VI**.

Table V. Between groups difference for functional disability, isometric quadriceps strength, walking time and stairs ascending and descending time.

Variable	Exercise group Mean ±SD	Traction and exercise group Mean ± SD	t-value	P-value
Functional disability	58.30 ± 10.24	40.10 ± 11.32	5.33	0.001*
Isometric quadriceps strength	110.36 ± 33.16	135.06 ± 37.96	2.19	0.04*
Walking time	44.90 ± 10.35	39.35 ± 6.76	2.01	0.06
Stairs time	26.25 ± 9.28	21.25 ± 10.47	1.60	0.12

*Significant difference.

Table VI. Between groups difference for knee pain severity and isometric hamstring strength.

Variable	Exercise group Mean difference ± SD	Traction & exercise group Mean difference ± SD	t-value	P-value
Knee pain severity	1.60 ± 0.94	5.00 ± 1.45	8.79	0.001*
Isometric hamstring strength	15.79 ± 6.37	42.49 ± 22.20	5.17	0.001*

*Significant difference.

DISCUSSION

In our study there was a significant reduction of knee pain severity, functional disability and improvement of functional performance in the exercise group. These findings are in agreement with some previous investigations (11, 12, 36-40). Pain reduction through therapeutic exercises might be attributed to the reduction of external stress falling on the articular surface of the joint through the improvement of aerobic fitness, hip and knee muscles strength and flexibility (11, 12). This might be also related to stimulation of mechanoreceptors located in the joint capsule and ligaments, blocking the activation of pain pathways (41).

The reduction of functional disability and improvement of functional performance by therapeutic exercises might be related to an increase of thigh strength, decrease of knee extension impairment, and improvement in proprioception (12). Strengthening of the quadriceps and hamstring muscles increases joint stability, reduces excessive joint stress and increases physical activity (37). Stronger muscles are associated with lower knee pain, easier performance of activities of daily living and greater levels of mobility (42). Furthermore, stretching exercises increase the flexibility of the hip flexors, quadriceps, hamstring and calf muscles (38). More flexible muscles increase range of motion, peak passive torque and force generating capacity (35). Moreover, more flexible muscles allow for better functional performance and improvement in spatiotemporal gait parameters such as step length and speed (38, 39).

There was also a significant increase of isometric quadriceps and hamstring muscle strength in the exercise group. This result coincides with the findings of earlier studies (35-37). The increase of isometric quadriceps and hamstring muscle strength through therapeutic exercises might be related to improvement in different muscles contractile properties, *e.g.*, force-generating capacity, shortening velocity, force-velocity relationship, peak power, muscle mass, maximum fiber recruitment, fiber number and size (43).

In the traction and exercise group, there was also a significant reduction of knee pain severity, functional disability and improvement of functional performance. These findings are in agreement with earlier studies (16-20).

Pain reduction through mechanical traction might be attributed to the reduction of intraarticular stress falling on the knee through increasing knee joint space and unloading of articular cartilage (44-46). This in turn increases microcirculation and synovial fluid movement (44), increases the delivery of nutrients and facilitates cartilage regeneration (47), reduces secondary inflammation and halts cartilage degeneration (21, 22). Pain reduction might also be related to the reduction of the subchondral and intraarticular joint pressure which in turn may reduce the pressure on the damaged tissues, pain receptors and free nerve endings (41). Pain reduction might also be attributed to increased soft tissue extensibility through breaking of intraarticular adhesions and stretching of the periarticular soft tissues (15).

The reduction of functional disability and improvement of functional performance through mechanical traction is based primarily on the reduction of pain, stiffness and the improvement of physical function (30). Traction was reported to be clinically significant in the reduction of pain both at rest and during movement (16-20). Moreover, mechanical traction was reported to ease the sensation of morning stiffness and restore joint resiliency (15). Furthermore, mechanical traction was reported to improve physical function as reported in the six-minute walking test (17) and the timed up and go test (20).

There was also a significant increase of isometric quadriceps and hamstring muscle strength in the traction and exercise group. The increase of isometric quadriceps and hamstring muscle strength through mechanical traction is primarily attributed to the reduction of knee pain (24-27). Quadriceps muscle is considered a very important muscle among patients with knee osteoarthritis, knee pain is mainly linked to quadriceps weakness and reduced quadriceps cross-sectional area (48, 49). It was reported that experimental pain induction to the knee joint was correlated with immediate reduction of quadriceps muscle activation (25) and impaired quadriceps force steadiness (26). Thus, a reduction of pain would allow for a reduction of arthrogenic muscle inhibition (24), normalization of activation patterns (25) and force control ability of quadriceps and hamstring muscles (27).

Between groups comparison showed that traction and therapeutic exercises were more effective than therapeutic exercises alone in reduction of knee pain severity and functional disability and in increasing isometric quadriceps and hamstring muscle strength. This may be attributed to the combined positive effects of both therapeutic exercises (11, 12, 35-43) and mechanical traction (16-22, 44-47). Moreover, the application of traction before exercises may have provided an opportunity for greater pain reduction, greater normalization of quadriceps and hamstring activation patterns before exercise performance (25) opening a window for easier performance (26) and a greater force control during exercises (27). This may be related to greater distractive forces imposed on the joint during traction (46) opposite to greater compressive and shear forces falling on the joint during exercises (50). Furthermore, the application of traction before exercises may have provided greater improvement in patient's motivation, confidence and self-efficacy during exercise performance.

On the other hand, there was no significant difference between groups in functional performance (walking time and stairs ascending and descending time). This means that the use of mechanical traction did not provide any significant additional effect on functional performance when combined with therapeutic exercises. This may be attributed to inability of the used mechanical traction parameters (force, duration and total number of sessions) to induce a significant difference between groups.

This study has three main limitations. The first limitation is the small number of participants. The second limitation is the absence of a control group while the third is the lack of follow up of patient's improvement after the end of the study.

CONCLUSIONS

Therapeutic exercises preceded by mechanical traction are more effective than therapeutic exercises alone in the reduction of both knee pain severity and functional disability and in increasing isometric quadriceps and hamstring muscle strength. This is mainly attributed to the combined positive effects of both types of treatment encompassing joint gapping, unloading of articular cartilage, reduction of intraarticular stress, decreased pressure on free nerve endings, blocking of pain pathways, reduction of morning stiffness, reduction of arthrogenic muscle inhibition, normalization of muscle activation patterns, increased soft tissue extensibility and increased muscle strength. However, both treatments are equally effective in the reduction of walking time and stairs ascending and descending time. This may be related to inability of the used mechanical traction parameters to induce a significant difference between groups.

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None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

MRR: project administration, investigation, writing – original draft. IME, KAH: writing – review & editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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