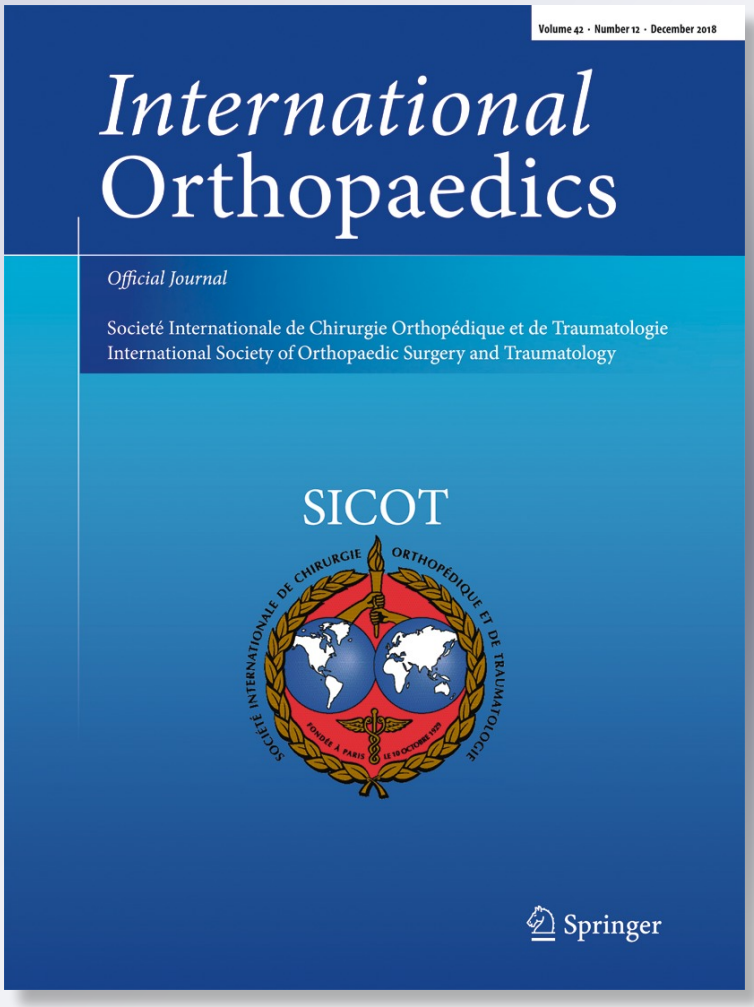
Mobilization with movement and kinesio taping in knee arthritis—evaluation and outcomes

Hülya Altmış, Deran Oskay, Bülent Elbasan, İrem Düzgün & Zeynep Tuna

International Orthopaedics

ISSN 0341-2695
Volume 42
Number 12

International Orthopaedics (SICOT)
(2018) 42:2807-2815
DOI 10.1007/s00264-018-3938-3



Springer

Your article is protected by copyright and all rights are held exclusively by SICOT aisbl. This e-offprint is for personal use only and shall not be self-archived in electronic repositories. If you wish to self-archive your article, please use the accepted manuscript version for posting on your own website. You may further deposit the accepted manuscript version in any repository, provided it is only made publicly available 12 months after official publication or later and provided acknowledgement is given to the original source of publication and a link is inserted to the published article on Springer's website. The link must be accompanied by the following text: "The final publication is available at link.springer.com".



Author's personal copy

International Orthopaedics (2018) 42:2807–2815
https://doi.org/10.1007/s00264-018-3938-3

ORIGINAL PAPER

Mobilization with movement and kinesio taping in knee arthritis—evaluation and outcomes

Hülya Altmış[1] · Deran Oskay[2] · Bülent Elbasan[2] · İrem Düzgün[3] · Zeynep Tuna[2]

Received: 20 December 2017 / Accepted: 5 April 2018 / Published online: 10 May 2018
© SICOT aisbl 2018

Abstract

Introduction The aim of this study was to investigate the acute effects of Mulligan mobilization with movement (MwM) and taping on function and pain intensity in patients with osteoarthritis (OA).

Materials and methods Female patients aged between 40 and 70 years with knee OA participated in the study. The patients were divided into three groups and each group received different interventions. Group 1 received MwM and taping according to Mulligan's concept. Group 2 received MwM and placebo taping with no recovery effect and group 3 received placebo taping. Functional tests including lifting, picking up, sit and stand-up, socket tests in addition to climbing up and down stairs, ten metres walk, and timed up and go (TUG) tests were performed before and after intervention. Pain during the test performances were assessed by a visual analog scale.

Results Performance in all tests improved significantly in the MwM + taping group, while only sit and stand-up, ten metres walk, and TUG test performances improved in the MwM + placebo taping group ($p < 0.05$). Pain intensity during the tests was also significantly better after intervention in those two groups ($p < 0.05$). Comparison between the groups showed that the pain intensity during all tests was less and functional test scores were better in sit and stand-up, ten metres walk, and walking down stairs in the MwM + taping group than the MwM + placebo taping group.

Conclusions MwM accompanied by taping improves pain during functional activities as well as the performance. MwM without taping may also improve pain intensity; however, it may be inadequate in increasing the performance.

Keywords Mobilization · Knee · Osteoarthritis · Taping

Introduction

Knee osteoarthritis (OA) is a degenerative disease characterized with progressive loss of cartilage in knee joint. The main complaints of the disease are pain and loss of function. Such complaints increase with the activities like walking and climbing up and decrease with resting. Pain restricts the daily life activities of the patients and effects the quality of life [1, 2].

The biomechanical alignment in the knee joint is the major determinant of load distribution. Even a minor change in this alignment may affect the load distribution considerably. Thus, minor positional changes that disturb the alignment of the articular surfaces, cartilage thickness, ligament, and capsule orientation or in the direction of muscle and tendon may in turn cause pain, stiffness, weakness, and limitation of movement [3]. OA, because of its degenerative course, develops biomechanical malalignment in the knee or vice versa.

Biomechanical correction strategies like exercise, taping, orthosis, and manual treatment techniques are used in the management of OA [4]. Among the manual techniques, mobilization with movement (MwM) developed by Brian Mulligan has been shown to be effective in pain relief and functional improvement [5]. The fundamental principle of MwM is to correct the biomechanical shift in the joint and to

The authors confirm that the work described has not been published before; that it is not under consideration for publication anywhere else; and that its publication has been approved by all co-authors, if any, as well as by the responsible authorities—tacitly or explicitly—at the institute where the work has been carried out.

✉ Zeynep Tuna
zeyneptuna6@yahoo.com

[1] Institute of Health Sciences, Gazi University, Ankara, Turkey

[2] Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Gazi University, Beşevler, 06500 Ankara, Turkey

[3] Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Hacettepe University, Ankara, Turkey

Author's personal copy

aim the pain-free movement [6]. Through mobilization, bone and/or joint are repositioned and pain-free functional movement is regained and then repeated. In addition, according to the Mulligan concept, internal rotation taping should accompany with the mobilization as taping will help to maintain the correcting effect of the prior mobilization. By this way, it may contribute to further pain relief and increase in the pain-free movement range [5, 6].

In the literature, Adams et al. reported an immediate reduction in pain in response to mobilization [7]. Also, Takasaki et al. showed acute effects of MwM on pain during function in patients with OA in their case series study [5]. Though, in this study, only pain during function was measured, not the test performance [5]. For those reasons, the aim of this study is to investigate the acute effects of MwM based on the Mulligan concept and internal rotation taping on pain and function in patients with knee OA.

Materials and methods

The ethical committee approval for the study design was obtained from the Clinical Research Ethical Committee of Gazi University in January 20, 2014, with the number 25901600-713. Informed consent was obtained from all individual participants included in the study.

Participants

The study included female patients that were diagnosed with bilateral OA according to the ACR criteria by a physician. They were at the stage 2 or 3 according to Kellgren-Lawrence radiographic grading criteria, and between the age range of 40 and 70 years [8]. The patients who had a rheumatologic disease with systemic involvement or arthroplasty history in lower extremity and who had received physiotherapy, steroid injection, or any surgery for lower extremity in the last 12 months were excluded from the study. In addition, patients with limited knee joint movements and with cardiovascular, neurological, and metabolic diseases were not included in the study.

Sample size was calculated by NCSS Pass 2008 software by using mean and standard deviation values. Patients were divided into 3 groups according to the treatment to be applied. Each of the 3 groups was estimated to include at least 20 patients (power = 0.95, alpha = 0.05).

The groups were determined by a simple random method. Treatment group was determined by taking the order of referral to the clinic. Patients in the first group (group 1 or MwM + taping group) were treated with MwM based on the Mulligan concept and internal rotation taping with recovery effect according to the Mulligan concept. Patients in the second group (group 2 or MwM + placebo taping group) were treated with MwM and internal rotation taping without any recovery effect. Patients in the third group (group 3 or placebo taping) received only placebo taping.

All the assessments were performed by the same physiotherapist and treatment was applied by another physiotherapist.

Assessment

Demographic and clinical information (age, height, body weight, body mass index (BMI), and OA stage determined according to Kellgren-Lawrence grading of patients) were recorded.

Functional tests

Lifting test The number of times that patient managed to lift a box weighing 8.5 kg from the floor to a table at a 73 cm height with both hands was recorded [9].

Picking up test Patients were asked to pick up an A4 size paper off the floor with one hand and were assigned points ranged between 0 and 3 based on the straining that the patient experienced. According to this assessment, 0 meant "flexible enough and easily carried out" and 3 referred to "unable to pick up the paper off the floor" or "manages by using support." [9].

Repeated sit-to-stand test With arms fixed up to the chest, the time of patient sitting and standing five times was recorded [9].

Socks test Patients were asked to put on socks normally and their performances were graded by 0–3 points. If the patient managed to reach their toes in a flexible manner and comfortably, then they were assigned "0" points, "1" point if they still managed to reach their toes but with strain, "2" points if they reached the malleolar level, and "3" points if they could not reach the malleolar level even with strain [9, 10].

Walking down stairs test The shortest time that the patient managed to walk 12 steps down the stairs was recorded [9].

Walking up stairs test The shortest time that the cases managed to walk up the stairs with 12 steps was recorded [9].

Ten-metre walking test The shortest time that the cases managed to walk the determined ten metre distance on a straight line was recorded [9].

Timed walking (TUG) test The shortest time that the patient got up from the chair where they sat, walk the predetermined three metres, and returned back to their seat was recorded [9, 11].

Pain A visual analog scale (VAS) was used to evaluate the pain during pre- and post-treatment functional tests.

Author's personal copy

Treatment protocol

MwM based on the Mulligan concept

Prior to intervention, in order to determine the direction of mobilization, direction of the glide that decreases the pain intensity was tested. The direction of pain-free movement was determined by applying lateral (Fig. 1), medial (Fig. 2), and rotational gliding force (Fig. 3) on tibia and anterior gliding force on head of fibula in supine position (Fig. 4). After determining the gliding direction, patients were asked to actively flex and extend the knee within the pain-free limit while the physiotherapist maintained the joint in the same position. Overpressure was applied at the last point of active motion. Ten repetitions were completed within three sets. Resting periods were given between the sets.

Internal rotation taping according to the Mulligan concept

Taping with recovery effect was administered by using a kinesiological tape through submaximal stretch following mobilization. During taping, patient was asked to stand up safely while holding a support. The patient then asked to bring the foot to internal rotation, knee to 5–10° flexion, and hip to external rotation while the foot was fixed on the floor. While the patient preserved the position, the physiotherapist applied the tape horizontally from 2 cm posterior of proximal head of fibula. Mobilization of the fibula head was performed horizontally towards medial direction (Fig. 5a). In the same direction with the mobilization, the tape was applied horizontal to the floor from the distal to patella so as not to prevent the movement of patella (Fig. 5b) and it continued diagonally through the medial of the knee (Fig. 5c) and wrapped around from the posterior of femur. The front view of the taping is shown in Fig. 5d.



Fig. 2 Medial gliding motion in MwM based on the Mulligan concept

Placebo taping

This taping also looks like internal rotation taping according to the Mulligan concept. However, it was applied without any mobilization and recovery effect.

Statistical analysis

One-way analysis of variance was conducted to evaluate whether there was significant differences among treatment groups for demographic characteristics.

One-way analysis of covariance was conducted to compare post-treatment scores among treatment groups after adjusting for pre-treatment scores. The independent variable treatment group included three levels: MwM + taping, MwM + placebo taping, and placebo taping. The dependent variables were the post-treatment scores of lifting, pick-up, repeated sit-to-stand, socks, walking down stairs, walking up stairs, ten metre walk, and timed up and go (TUG) tests, and the covariate variables were the pre-



Fig. 1 Lateral gliding motion in MwM based on the Mulligan concept



Fig. 3 Rotational gliding motion in MwM based on the Mulligan concept

Author's personal copy



Fig. 4 Proximal tibiofibular joint gliding motion in MwM based on the Mulligan concept

treatment scores of these tests. Preliminary analyses were made to evaluate homogenity of regression assumption.

Follow-up tests with Bonferroni adjustment were conducted to evaluate pairwise differences among the adjusted means for treatment groups. Effect sizes were reported to determine the clinical importance of the findings.

All calculations were carried out with SPSS 14.01 statistical software. $p < 0.05$ was considered to indicate statistical significance for all comparisons.

Results

The age, height, weight, and BMI results of the three groups were found as similar ($p > 0.05$) and were given in Table 1. Table 2 shows the distribution of disease grade according to the Kellgren-Lawrence system among the groups ($p > 0.05$).

The covariate, pre-treatment performance score of all functional tests, was significantly related to the post-treatment performance score ($p < 0.05$). There was also significant effect of the treatment group on post-treatment performance score of, excluding lifting and pick-up tests, all the functional test results after adjusting for the pre-treatment performance scores ($p < 0.05$) (Table 3).

In pairwise comparisons, excluding lifting and pick-up tests, all the functional test performance results of the MwM + taping group were found as better compared to the placebo taping group ($p < 0.05$). Also, sit-to-stand ($p = 0.02$), walking down the stairs ($p = 0.014$), and ten metres walking ($p = 0.017$) test performance results of the MwM + taping group were better compared to the MwM + placebo taping group. Only in walking down the stairs test, performance score of the MwM + placebo taping group was established as more successful compared to the placebo taping group ($p = 0.014$). Differences observed in other test performance scores were not found as statistically significant ($p > 0.05$) (Table 3).

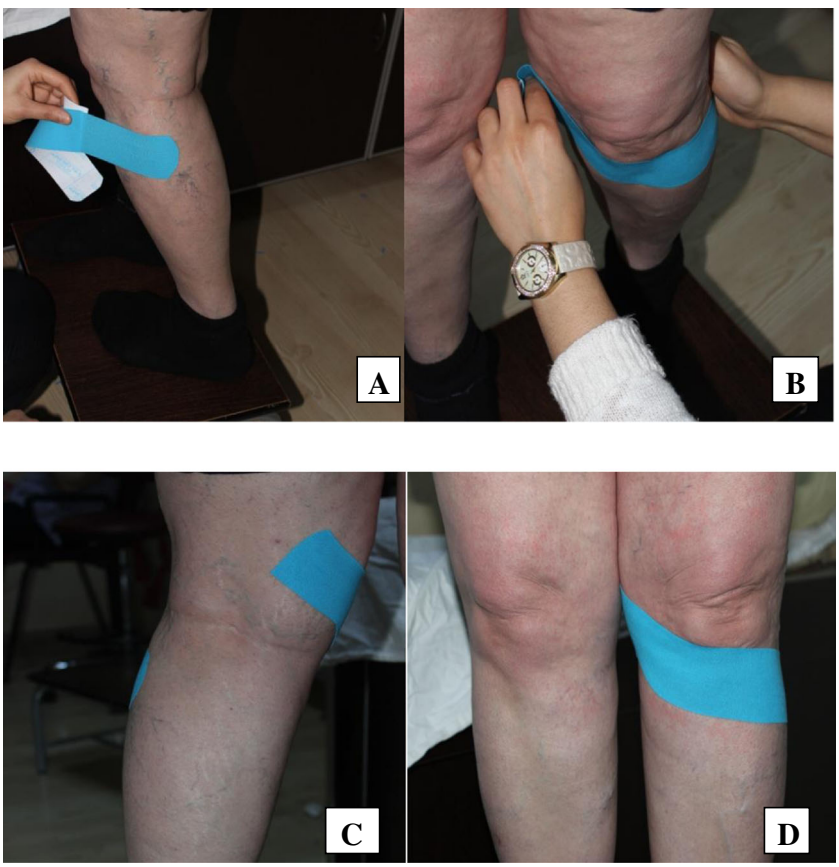


Fig. 5 Stages of internal rotation taping based on the Mulligan concept. **a** Sticking of the tape from the posterior. **b** Passing the tape diagonally from the front of the knee. **c** Sticking of the tape to the posterior of the medial condyle of the femur. **d** Frontal view of taping

Author's personal copy

Table 1 Comparison of the demographic characteristics of groups

	MwM + taping group (n = 20) Mean ± SD (min–max)	MwM + placebo taping group (n = 20) Mean ± SD (min–max)	Placebo taping group (n = 20) Mean ± SD (min–max)	*p*
Age	57.9 ± 7.36 (40–68)	59.05 ± 7.7 (46–70)	59 ± 7.21 (46–70)	0.859
Height	1.58 ± 0.04 (1.5–1.7)	1.57 ± 0.04 (1.5–1.63)	1.6 ± 0.05 (1.5–1.7)	0.173
Body weight	77.3 ± 9.02 (63–98)	77.6 ± 6.84 (68–90)	82.05 ± 11.11 (68–108)	0.194
BMI	30.6 ± 3.29 (24.2–36.9)	31.48 ± 3.38 (26.7–37.5)	32.09 ± 5.17 (26.6–44.4)	0.506

n number of cases, *SD* standard deviation, *Min* minimum data, *Max* maximum data, *p* inter-group significance level, *BMI* body mass index

The covariate, pre-treatment pain score of all functional tests, was significantly related to the post-treatment pain score ($p < 0.05$). There was also significant effect of treatment group on post-treatment pain score of all the functional test results after adjusting for the pre-treatment pain score ($p < 0.05$) (Table 4).

Pairwise comparisons of change observed in pain levels of groups during the tests are given in Table 4. In pairwise comparisons, while the pain of the MwM + taping group in all functional tests was lower compared to the placebo taping group ($p < 0.05$), it was found as similar to the MwM + placebo taping group ($p > 0.05$). In addition, the decrease in pain in the MwM + placebo taping group during all functional tests was established as higher compared to the placebo taping group ($p < 0.05$) (Table 4).

Discussion

This study is the first one in the literature that assessed the acute effects of the MwM technique with taping on pain and function in knee OA. The most striking result of the study was that MwM in combination with taping improved not only pain but also performance in the chosen activities. Besides, only mobilization also contributed to pain relief during performance. However, this effect was limited as only mobilization did not improve functional performance significantly.

According to our results, combined use of MwM with true or placebo taping, pain during performance improved more than only placebo taping. This result indicates that the effect of mobilization in pain relief has superiority. Adams et al. also reported that manual treatment had mechanical, neurophysiological, and physiological effects in knee OA. They showed an immediate reduction in pain, activation of pain inhibition mechanisms, decrease in inflammatory mediators, and improvement in function after joint mobilization [7]. In a similar study, Moss et al. found an immediate relief in pain following the application of mobilization in patients with knee OA. Parallel to our initial hypothesis, they explained this pain relief by the stimulation of mechanoreceptors and inhibition of pain in the cortical system [12]. Similarly, Sambajon et al. showed that prostaglandin E2 which is an inflammatory and stimulates peripheral nociceptors in blood decreased by 70% within 24 hours after mobilization [13]. Also, in a systematic review on MwM, 25 studies that conducted applications to various joints were analyzed. As a result, MwM results in an immediate decrease in pain and improvement in function in various musculoskeletal system problems [6].

Table 2 Disease grade KL according to group

Treatment group	Kellgren-Lawrence grade	
	Grade 2	Grade 3
MwM + taping	%60	%40
MwM + placebo taping	%45	%55
Placebo taping	%40	%60

Pain relief during functions may partly be explained by central sensitization mechanism of pain. Changes occurring in OA are not limited to only joint and the peripheral tissues but central mechanisms are also affected. In OA, central inhibition mechanisms are shown to be weakened and pain threshold to decrease [14]. Positional faults are corrected by restoring biomechanical normality of joint through MwM. By correcting the positional errors in the joint by MwM and its repetition, pain-free active motion is then relearned by the patient. This pain-free movement is thought to contribute to pain desensitization especially at earlier stages of the disease. In addition to mobilization, taping is also assumed to contribute to the pain relief with its effects on blood circulation [15].

MwM and internal rotation taping was observed to be effective in improving the performance in all tests, excluding lifting and pick-up tests. However, the positive contribution of the combined use of MwM and placebo taping was limited to certain tests. Pain-free movement gained by MwM becomes more effective in improving performance when taping is accompanied. Repeating the pain-free movement is shown to be effective only in walking and sit-to-stand test performances; however, it seems to be insufficient in improving performance in high loading activities. This result was thought to result from biomechanical factors, because forces affecting knee joints in different positions and during activities may vary [16–18]. For

Author's personal copy

Table 3 Comparison of pre-intervention and post-intervention performance in functional tests within the groups

Effect	Mean ± SD	Estimated marginal mean ± SE	*F*	df		*p*	Partial eta squared
Lifting (pre-treatment)			30.86	1		0.000	0.355
Treatment group			1.25	2		0.249	0.043
Error				56			
Pairwise comparisons							
MwM + taping (1)	16.65 ± 3.18	16.25 ± 0.53			(1) vs. (2)	0.573	
MwM + placebo taping (2)	15.15 ± 2.43	15.26 ± 0.53			(1) vs. (3)	0.482	
Placebo taping (3)	14.90 ± 3.01	15.18 ± 0.53			(2) vs. (3)	1000	
Picking up (pre-treatment)			351.08	1		0.000	0.862
Treatment group			2.95	2		0.060	0.095
Error				56			
Pairwise comparisons							
MwM + taping (1)	1.05 ± 0.83	1.28 ± 0.06			(1) vs. (2)	0.243	
MwM + placebo taping (2)	1.45 ± 0.69	1.43 ± 0.06			(1) vs. (3)	0.069	
Placebo taping (3)	1.70 ± 0.66	1.49 ± 0.06			(2) vs. (3)	1000	
Repeated sit-to-stand (pre-treatment)			192.60	1		0.000	0.775
Treatment group			10.28	2		0.000	0.269
Error				56			
Pairwise comparisons							
MwM + taping (1)	12.43 ± 2.27	13.01 ± 0.22			(1) vs. (2)	0.020	
MwM + placebo taping (2)	14.45 ± 1.65	13.88 ± 0.22			(1) vs. (3)	0.000	
Placebo taping (3)	14.39 ± 1.99	14.37 ± 0.22			(2) vs. (3)	0.336	
Socks (pre-treatment)			249.42	1		0.000	0.817
Treatment group			4.05	2		0.023	0.126
Error				56			
Pairwise comparisons							
MwM + taping (1)	1.35 ± 0.67	1.56 ± 0.071			(1) vs. (2)	0.272	
MwM + placebo taping (2)	1.75 ± 0.79	1.74 ± 0.069			(1) vs. (3)	0.019	
Placebo taping (3)	2.05 ± 0.69	1.85 ± 0.070			(2) vs. (3)	0.729	
Walking down stairs (pre-treatment)			662.98	1		0.000	0.922
Treatment group			16.71	2		0.000	0.374
Error				56			
Pairwise comparisons							
MwM + taping (1)	11.80 ± 3.42	13.09 ± 0.19			(1) vs. (2)	0.014	
MwM + placebo taping (2)	14.63 ± 2.22	13.87 ± 0.18			(1) vs. (3)	0.000	
Placebo taping (3)	15.13 ± 2.69	14.60 ± 0.18			(2) vs. (3)	0.015	
Walking up stairs (pre-treatment)			764.77	1		0.000	0.932
Treatment group			8.65	2		0.001	0.236
Error				56			
Pairwise comparisons							
MwM + taping (1)	11.63 ± 3.47	13.15 ± 0.19			(1) vs. (2)	0.055	
MwM + placebo taping (2)	14.50 ± 2.96	13.79 ± 0.18			(1) vs. (3)	0.000	
Placebo taping (3)	15.07 ± 2.45	14.25 ± 0.18			(2) vs. (3)	0.216	
10-m (pre-treatment)			120.09	1		0.000	0.682
Treatment group			6.68	2		0.003	0.193
Error				56			
Pairwise comparisons							
MwM + taping (1)	12.54 ± 2.67	13.31 ± 0.29			(1) vs. (2)	0.017	
MwM + placebo taping (2)	14.69 ± 1.56	14.49 ± 0.29			(1) vs. (3)	0.003	
Placebo taping (3)	15.33 ± 2.34	14.76 ± 0.29			(2) vs. (3)	1000	
TUG (pre-treatment)			695.49	1		0.000	
Treatment group			3.85	2		0.027	
Error				56			
Pairwise comparisons							
MwM + taping (1)	10.55 ± 2.86	11.47 ± 0.151	11.47		(1) vs. (2)	0.772	
MwM + placebo taping (2)	12.20 ± 2.20	11.71 ± 0.148	11.71		(1) vs. (3)	0.024	0.925
Placebo taping (3)	12.49 ± 2.00	12.06 ± 0.148	12.06		(2) vs. (3)	0.313	0.121

Author's personal copy

Table 4 Comparison of pre-intervention and post-intervention pain levels during functional tests within the groups

Effect	Mean ± SD	Estimated marginal mean ± SE	*F*	df		p	Partial eta squared
Lifting (pre-treatment)			340.80	1		0.000	0.859
Treatment group			24.41	2		0.000	0.485
Error				56			
Pairwise comparisons							
MwM + taping (1)	26.40 ± 18.51	27.94 ± 1.60			(1) vs. (2)	0.186	
MwM + placebo taping (2)	36.15 ± 19.26	32.28 ± 1.61			(1) vs. (3)	0.000	
Placebo taping (3)	41.50 ± 18.69	43.83 ± 1.60			(2) vs. (3)	0.000	
Picking up (pre-treatment)			274.17	1		0.000	0.830
Treatment group			23.28	2		0.000	0.454
Error				56			
Pairwise comparisons							
MwM + taping (1)	23.45 ± 19.07	22.89 ± 1.58			(1) vs. (2)	1000	
MwM + placebo taping (2)	25.05 ± 14.98	21.71 ± 1.59			(1) vs. (3)	0.000	
Placebo taping (3)	31.80 ± 16.76	35.70 ± 1.60			(2) vs. (3)	0.000	
Repeated sit-to-stand (pre-treatment)			187.49	1		0.000	0.770
Treatment group			24.80	2		0.000	0.470
Error				56			
Pairwise comparisons							
MwM + taping (1)	23.75 ± 18.77	24.48 ± 1.89			(1) vs. (2)	0.182	
MwM + placebo taping (2)	34.55 ± 17.23	29.67 ± 1.93			(1) vs. (3)	0.000	
Placebo taping (3)	38.80 ± 16.52	42.95 ± 1.92			(2) vs. (3)	0.000	
Socks (pre-treatment)			251.92	1		0.000	0.818
Treatment group			27.00	2		0.000	0.491
Error				56			
Pairwise comparisons							
MwM + taping (1)	26.85 ± 21.73	30.42 ± 1.94			(1) vs. (2)	0.272	
MwM + placebo taping (2)	37.10 ± 17.25	35.14 ± 1.93			(1) vs. (3)	0.000	
Placebo taping (3)	51.30 ± 20.78	49.69 ± 1.93			(2) vs. (3)	0.000	
Walking down stairs (pre-treatment)			108.24	1		0.000	0.659
Treatment group			33.22	2		0.000	0.543
Error				56			
Pairwise comparisons							
MwM + taping (1)	32.20 ± 16.85	34.46 ± 2.12			(1) vs. (2)	0.526	
MwM + placebo taping (2)	41.45 ± 14.61	38.60 ± 2.12			(1) vs. (3)	0.000	
Placebo taping (3)	56.65 ± 16.39	57.24 ± 2.11			(2) vs. (3)	0.000	
Walking up stairs (pre-treatment)			179.49	1		0.000	0.762
Treatment group			33.04	2		0.000	0.541
Error				56			
Pairwise comparisons							
MwM + taping (1)	27.55 ± 18.65	31.26 ± 1.83			(1) vs. (2)	0.829	
MwM + placebo taping (2)	38.05 ± 14.14	34.14 ± 1.83			(1) vs. (3)	0.000	
Placebo taping (3)	50.35 ± 16.27	50.55 ± 1.81			(2) vs. (3)	0.000	
10-m (pre-treatment)			239.47	1		0.000	0.810
Treatment group			23.52	2		0.000	0.457
Error				56			
Pairwise comparisons							
MwM + taping (1)	19.60 ± 14.65	21.04 ± 1.60			(1) vs. (2)	1000	
MwM + placebo taping (2)	26.65 ± 15.65	21.20 ± 1.64			(1) vs. (3)	0.000	
Placebo taping (3)	30.80 ± 18.31	34.80 ± 1.62			(2) vs. (3)	0.000	
TUG (pre-treatment)			257.14	1		0.000	0.821
Treatment group			25.92	2		0.000	0.481
Error				56			
Pairwise comparisons							
MwM + taping (1)	18.45 ± 14.56	18.28 ± 1.46			(1) vs. (2)	0.648	
MwM + placebo taping (2)	21.85 ± 14.73	20.87 ± 1.47			(1) vs. (3)	0.000	
Placebo taping (3)	31.15 ± 16.67	32.31 ± 1.47			(2) vs. (3)	0.000	

Author's personal copy

example, while tibiofemoral joint predominantly bears compressive load in knee joint, patellofemoral joint plays a role in the extensor mechanism in transferring quadriceps force to tibia [16, 19]. The load on both tibiofemoral and patellofemoral joints increases along with the increase in knee flexion degree. Since walking down and up the stairs in alternative steps causes both loading in flexion and load transfer on a single leg, more loads are imposed on the knee [18]. Only MwM application was insufficient in improving performance in the activities that require more force transfer such as walking up and down stairs and wearing socks, because those activities require more flexion and rotation angles of the knee [18, 19].

We showed that pain-free movement gained by MwM and experienced by repetitions imposed positive effects on pain in acute period even without being supported by taping. Physiological changes that a chronic painful condition in a peripheral joint caused on central level may underlie this effect. Since the patient experienced pain-free movement by regaining the biomechanical normality of the joint by MwM, desensitization of pain pathways may occur at the central level. If the effect is maintained with internal rotation taping, it may be effective in such activities as walking and sit-to-stand. However, it cannot be efficient in improving performance in activities only like stairing that impose more load on knees. However, internal rotation taping supported the internal rotation formed along with the flexion in the knees [20, 21]. Thus, pain-free movement effect maintained also in activities containing more flexion of the knee.

One of the strengths of our study was the homogeneity of groups regarding clinical characteristics of participants, because it is now well-known that age, gender, BMI, and OA grade may affect the treatment outcome [22, 23]. Therefore, our results reflect the outcomes without any potential interference effect as all groups were clinically similar.

Apart from those biomechanical reasons we explained above, there still may be other parameters that would contribute to our results. For instance, it is known that quadriceps muscle weakness and proprioceptive impairment significantly restrict function of the knee [24–27]. Our most significant limitation is the lack of strength and proprioception measurements.

In summary, altering the perception of pain by MwM and providing pain-free movement may increase the active and voluntary participation of the patient in treatment. Also, patient's performance in exercises may be supported by taping after MwM to increase workout.

Compliance with ethical standards

Informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

1. Felson DT, Lawrence RC, Dieppe PA, Hirsch R, Helmick CG, Jordan JM, … & Sowers M (2000) Osteoarthritis: new insights. Part 1: the disease and its risk factors. Ann Intern Med 133(8): 635–646
2. Van Dijk GM, Dekker J, Veenhof C, Van Den Ende CH (2006) Course of functional status and pain in osteoarthritis of the hip or knee: a systematic review of the literature. Arthritis Care Res 55(5): 779–785
3. Mulligan BR (2004) Manual therapy:"nags", "snags", "mwms" Etc. Optp. 5th Ed. Wellington: NZ
4. Page CJ, Hinman RS, Bennell KL (2011) Physiotherapy management of knee osteoarthritis. Int J Rheum Dis 14(2):145–151
5. Takasaki H, Hall T, Jull G (2013) Immediate and short-term effects of Mulligan's mobilization with movement on knee pain and disability associated with knee osteoarthritis—a prospective case series. Physiother Theory Pract 29(2):87–95
6. Hing W, Bigelow R, Bremner T (2009) Mulligan's mobilization with movement: a systematic review. J Manual Manip Ther 17(2):39E–66E
7. Adams T, Band-Entrup D, Kuhn S, Legere L, Mace K, Paggi A, Penney M (2013) Physical therapy management of knee osteoarthritis in the middle-aged athlete. Sports Med Arthrosc Rev 21(1): 2–10
8. Emrani PS, Katz JN, Kessler CL, Reichmann WM, Wright EA, McAlindon TE, Losina E (2008) Joint space narrowing and Kellgren–Lawrence progression in knee osteoarthritis: an analytic literature synthesis. Osteoarthr Cartil 16(8):873–882
9. Liikavainio T, Lyytinen T, Tyrväinen E, Sipilä S, Arokoski JP (2008) Physical function and properties of quadriceps femoris muscle in men with knee osteoarthritis. Arch Phys Med Rehabil 89(11): 2185–2194
10. Strand LI, Wie SL (1999) The sock test for evaluating activity limitation in patients with musculoskeletal pain. Phys Ther 79(2): 136–145
11. Tunay VB, Baltacı G, Atay AÖ (2010) Diz osteoartritinde hastanede ve evde uygulanan propriyoseptif ve kuvvetlendirme egzersiz programlar. Acta Orthop Traumatol Turc 44(4):270–277
12. Moss P, Sluka K, Wright A (2007) The initial effects of knee joint mobilization on osteoarthritic hyperalgesia. Man Ther 12(2): 109–118
13. Sambajon VV, Cillo JE, Gassner RJ, Buckley MJ (2003) The effects of mechanical strain on synovial fibroblasts. J Oral Maxillofac Surg 61(6):707–712
14. Finan PH, Buenaver LF, Bounds SC, Hussain S, Park RJ, Haque UJ, … & Smith MT (2013) Discordance between pain and radiographic severity in knee osteoarthritis: findings from quantitative sensory testing of central sensitization. Arthritis Rheumatol 65(2): 363–372
15. Windisch C, Brodt S, Röhner E, Matziolis G (2017) Effects of Kinesio taping compared to arterio-venous Impulse System™ on limb swelling and skin temperature after total knee arthroplasty. Int Orthop 41(2):301–307
16. Burstein H, Wright A, Timothy M (1993) Biomechanics. In: Insall JN (ed) Surgery of the knee, 2nd edn. Churchill Livingstone, New York, pp 43–54

Author's personal copy

17. Heck DA, Murray DG (1990) Biomechanics of the knee. In: Evarts CM (ed) Surgery of the musculoskeletal system, 2nd edn. Churchill Livingstone, New York, pp 3243–3251
18. Clarke ED, Scott WD, Insall JN (2001) Anatomy. In: Insall JN, Scott WD (eds) Surgery of the knee, 3rd edn. Churchill Livingstone, Philadelphia, pp 13–77
19. Öztürk L, Aktan ZA, Varol T (1997) Alt Ekstremite Kasları, İşlevsel Anatomi. Saray Kitabevleri, İzmir, pp 192–194
20. de Vos BC, Runhaar J, Bierma-Zeinstra SM (2014) Effectiveness of a tailor-made weight loss intervention in primary care. Eur J Nutr 53(1):95–104
21. Mounach A, Nouijai A, Ghozlani I, Ghazi M, Achemlal L, Bezza A, El Maghraoui A (2008) Risk factors for knee osteoarthritis in Morocco. A case control study. Clin Rheumatol 27(3):323–326
22. Howe A, Campbell A, Ng L, Hall T, Hopper D (2015) Effects of two different knee tape procedures on lower-limb kinematics and kinetics in recreational runners. Scand J Med Sci Sports 25(4): 517–524
23. Hendry D, Campbell A, Ng L, Grisbrook TL, Hopper DM (2015) Effect of Mulligan's and Kinesio knee taping on adolescent ballet dancers knee and hip biomechanics during landing. Scand J Med Sci Sports 25(6):888–896
24. Kacar C, Gilgil E, Urhan S, Arıkan V, Dündar Ü, Öksüz MC, … & Apaydın A (2005) The prevalence of symptomatic knee and distal interphalangeal joint osteoarthritis in the urban population of Antalya, Turkey. Rheumatol Int 25(3):201–204
25. Kappetijn O, van Trijffel E, Lucas C (2014) Efficacy of passive extension mobilization in addition to exercise in the osteoarthritic knee: an observational parallel-group study. Knee 21(3):703–709
26. Draper DO, VanPatten J (2010) Shortwave diathermy and joint mobilizations for postsurgical restoration of knee motion. Athletic Ther Today 15(1):39–41
27. Chaisson CE, Gale DR, Gale E, Kazis L, Skinner K, Felson DT (2000) Detecting radiographic knee osteoarthritis: what combination of views is optimal? Rheumatology 39(11):1218–1221