RESEARCH ARTICLE

Effect of Knee Orthosis and Kinesio Taping on Clinical and Neuromuscular Outcomes in Patients with Knee Osteoarthritis: A Randomized Clinical Trial

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Received: 15 May 2023 *Accepted: 20 July 2023*

Abstract

Objectives: Impaired proprioception and muscle weakness may not only be a consequence of knee osteoarthritis (OA) but also part of its pathogenesis. Thus, the enhancement of quadriceps strength and proprioceptive accuracy can play a pivotal role in the management of knee OA. This study aimed to investigate the effects of Kinesio tape and flexible knee orthosis in terms of clinical and neuromuscular outcomes in patients with knee OA.

Methods: This clinical trial was conducted on 56 patients with knee OA, randomly allocated to two groups: knee orthosis or Kinesio tape. The knee orthosis group wore a neoprene knee support for 4 weeks. For participants in the Kinesio tape group, tape was applied once a week, for 4 weeks. The primary outcomes were pain intensity and physical function evaluated through the visual analog scale and the Western Ontario and McMaster OA index. The secondary outcomes were concentric and isometric quadriceps strength, Joint Position Sense (JPS), Threshold to Detect Passive Motion (TTDPM), and force sense (FS), all measured by isokinetic dynamometry.

Results: All outcome measures were significantly improved in the orthosis group. The Kinesio tape group also demonstrated significant changes in all outcome measures except three proprioception components namely JPS (70° target), FS, and TTDPM. At the end of the fourth week, there were no significant between-group differences for measured parameters.

Conclusion: Wearing a flexible knee orthosis and/or Kinesio tape for 4 weeks significantly improved knee pain, physical function, and quadriceps strength. Although knee orthosis showed significant beneficial effects on various components of proprioception, there were no significant differences between the two groups at the end of the 4-week intervention.

Level of evidence: II

Keywords: Kinesio taping, Knee orthosis, Knee osteoarthritis, Muscle strength, Proprioception

Introduction

Osteoarthritis (OA) is the most prevalent chronic joint disease worldwide.[1] Although OA can occur in any synovial joint, large joints, such as knees, are more susceptible due to their weight-bearing nature and repeated movements. The most prominent risk factor for the development of OA is age.[2] For example, while the prevalence of knee OA in adults under 40 years of age is 4%-14%, this figure accounts for 19%-43% in adults over 40.[3] In addition to causing adverse consequences, such as considerable pain, decreased ability to perform basic activities of daily living (e.g., walking and climbing stairs),[4] and reduced quality of life for the affected person,[5] OA also imposes a considerable economic burden on society due to its chronic course and high medical expenses and hence constitutes one of the major public health problems of our time.[1]

Reports suggest that patients with knee OA are more likely to have neuromuscular impairments, including quadriceps

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THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

muscle weakness and proprioceptive inaccuracy.[6-8] Although the causal role of these neuromuscular deficits in the pathogenesis of knee OA is still not proven, they most certainly contribute to the accelerated progression of joint degeneration and patients getting stuck in a vicious cycle of cause and effect.[3,9]

Considering the three functions presumed for knee proprioception, namely protection against excessive movements, stabilization during static postures, and movement control and coordination,[10] it is possible that proprioceptive inaccuracy accelerates joint degeneration by impairing motor control and consequently sudden and excessive loading to the knee.[10] On the other hand, hindered recruitment of high-threshold motor units due to abnormal afferent feedback and inaccurate sensory information can lead to quadriceps muscle weakness,[11] which is known as a hallmark impairment of knee OA.[6]

Since muscle strength also plays a major role in joint stabilization and shock absorption, it is reasonable to assume that muscle weakness also leads to aberrant dynamic joint loading and progression of the disease.[12,13] Deficit in quadriceps strength, which is the primary dynamic stabilizer of the knee joint, can predict the level of functional disability.[14] Furthermore, proprioception accuracy and muscle strength are both important determinants of postural control,[15] the deterioration of which can compromise a person's ability to perform numerous activities of daily living (transfer and ambulation), thereby reducing the person's quality of life.[15-17]

Considering that impaired proprioception and muscle weakness may not only be a consequence of OA but also part of the pathogenesis of the degenerative joint disease,[18] the enhancement of quadriceps muscle strength and proprioceptive accuracy can play a pivotal role in the management of knee OA.[19] Since modifying these factors also affects clinical outcomes,[10,20] their improvement can be considered an important target in the design and evaluation of treatment regimens for patients with knee OA.

There are several surgical and conservative interventions for knee OA. Conservative interventions are viewed as the first-line treatment for the management of OA and surgical interventions are typically reserved as the final option for severe cases.[21] Non-pharmacological interventions for patients with mild to moderate knee OA include the prescription of external joint stabilizers, such as Kinesio tape and flexible knee orthosis, with ample evidence supporting their immediate efficacy for relieving pain symptoms.[22-27]

Flexible knee orthoses are elastic non-adhesive supports that have several advantages over kinesio tape (elastic adhesive supports), including easier application and removal and higher cost-effectiveness because of reusability. However, there is a common concern among clinicians that the use of these orthoses may cause some side effects, such as weakening the surrounding muscles.[25,28] Despite the shortcomings of Kinesio tape, including non-reusability, which makes them quite expensive for prolonged use, as well as needing a physiotherapist to apply the tape, they can be indeed effective in improving muscular performance when used to facilitate muscle activation. However, the existing evidence regarding the effect of Kinesio tape on muscle strength is still unconvincing.[29] Although the enhancement of proprioception accuracy has been assumed as the underlying mechanism delivering the beneficial effects of both flexible knee orthosis and Kinesio tape,[30] there is no comprehensive investigation of their efficacy in terms of different aspects of proprioception and even comparison between them concerning clinical effects in the previous studies. Therefore, this study aimed to evaluate and compare the clinical and neuromuscular effects of Kinesio tape and flexible knee orthosis in patients with knee OA.

Materials and Methods

Study design

This parallel-group randomized clinical trial was conducted from October 2021 to April 2022 in the Faculty of Sport Sciences and Health of Shahid Beheshti University, Tehran, Iran. The study protocol was approved by the Research Ethics Committee at Iran University of Medical Sciences (IR.IUMS.REC.1399.1157) and followed the principles of the Helsinki Declaration. The trial was registered in the Iranian Registry of Clinical Trials (under registration number IRCT20200315046784N1). Reporting of the study followed the Consolidated Standards of Reporting Trials guidelines.

Participants

Using G-power software, with visual analog scale (VAS) and the Western Ontario and McMaster (WOMAC) OA index scores considered as the primary outcomes, the sample size was calculated to be 50 individuals (n=25 per group) with $\alpha = 0.05$, test power of 0.8, and effect size of 0.72 (based on means and standard deviations obtained from our pilot study). However, considering the possibility of dropout, ultimately 56 individuals (n=28 in each group) were recruited through outpatient clinics, healthcare center databases, and advertisements on social media. Radiographic images of participants were examined by an orthopedic surgeon, and all participants were also examined and checked for eligibility criteria by a physical therapist.

The inclusion criteria were the age range of 50-65 years, diagnosis of knee OA according to the American College of Rheumatology criteria with grade 2 or 3 radiographic severity according to the Kellgren and Lawrence (K-L) grading system, pain intensity of ≥ 4 on VAS, and ability to stand and walk without assistance. On the other hand, the exclusion criteria were intra-articular corticosteroid injection within the past 6 months, systemic rheumatic disease, history of surgery and/or any musculoskeletal injuries in the affected limb, diabetes mellitus, neurological disorders, history of wearing knee orthoses or applying Kinesio tape in the last 6 months, body mass index of > 36, and a history of skin allergy.

All patients who volunteered to participate received a written and verbal description of the experiment and were asked to sign a written consent form before enrollment. The enrolled patients were randomly allocated to one of two groups: knee orthosis or Kinesio tape. Group allocation was performed by permuted block randomization in blocks of four with a 1:1 assignment ratio. For allocation concealment, randomization codes were kept in opaque, sealed, sequentially numbered envelopes by a researcher who was not involved in enrollment, evaluation, or intervention. All participants were asked to maintain their pre-existing conventional management program consisting of modifications of daily activities and performing low-impact aerobic exercise. Moreover, they were not allowed to take part in any new training program during the 4-week intervention period.

Intervention

Kinesio-taping

For participants assigned to the Kinesio taping group, therapeutic Kinesio tapes were applied in accordance with Kenzo Kase's principles of Kinesio tape application.[31] Three "I" strips were applied on the quadriceps femoris along the course of the rectus femoris, vastus lateralis, and vastus medialis muscles [Figure 1]. For rectus femoris, the strip was applied from 10 cm below the anterior superior iliac spine to the superior border of the patella with 50%-75% tension, the knee was flexed 45 degrees, and the rest of the strip was applied on the superior border of the patella without tension. For vastus lateralis, the strip was applied from under the larger trochanter to the lateral border of the patella with 50-75% tension, the knee was flexed 45 degrees, and the rest of the strip was applied towards the tibial tuberosity without tension. For vastus medialis, the strip was applied from the middle third of the medial side of the thigh to the medial border of the patella with 50%-75% tension, the knee was flexed 45 degrees, and the rest of the strip was applied towards the tibial tuberosity without tension. Tapes were applied once a week (totally, 4 times during the intervention period), each time, tapes were kept for 5 consecutive days, followed by a 2-day interval between applications.[32]

Figure 1. Kinesio tape application

Knee orthosis

Participants assigned to the knee orthosis group received a flexible neoprene knee support with an open-patella design [Figure 2]. This orthosis had dual side steel strips providing lateral stability while allowing a wide range of knee motion. The orthosis also had two adjustable straps for improved stability and comfort. The size of the knee orthosis was selected according to the knee circumference of the individual. Participants were asked to wear the orthosis for the whole day for four weeks.

Figure 2. Flexible neoprene knee orthosis

Outcome measures

The primary outcome measures were pain intensity and physical function. Pain intensity was measured by VAS. On this scale, pain is rated with scores ranging from 0 (no pain) to 10 (worst imaginable pain). Physical function was assessed using the WOMAC OA index. This 24-item questionnaire measures 3 subscales: stiffness (2 items), pain (5 items), and physical function (17 items). The total score of the questionnaire ranges from 0 to 96, with higher scores indicating poor health. The secondary outcome measures were concentric and isometric quadriceps strength, Joint Position Sense (JPS), Threshold to Detect Passive Motion (TTDPM), and force sense (FS), all measured by isokinetic dynamometry. For participants with bilateral OA symptoms, measurements were performed on the more symptomatic knee. For other participants, measurements were conducted on the involved side. Participants were evaluated twice: once at the baseline and another time at the end of the fourth week. All evaluations were administered in a random order and were performed without knee orthosis and/or Kinesio tape and by the examiner who was blinded to group allocation. However, because of the obvious nature of external knee supports, it was impossible to blind participants to the intervention.

Joint Position Sense

The joint Position Sense test measures a person's ability to actively reproduce a pre-determined target position. This test was performed using a Biodex System 4 isokinetic dynamometer with two target positions: 45° and 70° of knee flexion. To perform the test, the patient was asked to sit on the dynamometer chair while the hips and knees were flexed to 90°.

Initially, to familiarize the patient with the test procedure, the patient's leg was moved to the target angle at a rate of 2 degrees per second and kept at that position for 5 seconds to let them memorize the target angle, and then returned to the starting position (90° knee flexion). The patient was then asked to actively extend the leg to reproduce the target position and press the handheld stop button upon reaching the target position. The average deviation of the participant's reproduced angle from the pre-determined angle was recorded as the absolute error. Three trials were performed for each target angle. Blindfolds and headphones were used to remove the effect of visual and auditory clues.

Force sense

This test measures an individual's ability to actively reproduce a predetermined target force (submaximal voluntary isometric contraction). For this test, the target extension force was set to 30% of the patient's maximum voluntary isometric contraction (MVIC). Initially, to familiarize the patient with the movement, the individual was asked to perform an isometric knee extension to generate a target force indicated on the computer monitor (visual feedback) and hold the knee for 5 seconds to memorize the force. After 10 seconds of relaxation, the individual was asked to reproduce the target force without the visual feedback. The absolute difference between the pre-determined target force and the force reproduced by the patient was recorded as the force sense result.

Threshold to Detect Passive Motion

This test measures a person's ability to detect the initiation of passive joint movements. This test began at the starting position of 45° flexions. The knee was moved passively in the extension direction at a rate of 0.25°/s, and the individual was asked to press the handheld stop button as soon as they felt the movement. This test was performed in three trials, each with a random delay ranging from 0 to 20 s put at the start of the movement. The number of degrees at which the movement was detected in each trial was recorded, and the average of the three trials was used for data analysis.

Concentric isokinetic strength of quadriceps

This parameter was measured using an isokinetic dynamometer in the sitting position. For this measurement, restraining straps were applied on the waist, thigh, and thorax, and the axis of the rotation of the dynamometer was aligned with the axis of the rotation of the knee (lateral epicondyle of the femur). The pad of the lower leg attachment of the dynamometer was fixed at 5 cm above the lateral malleolus on the distal of the leg. The testing range of motion was set between 90 to 10 degrees of flexion and an angular velocity of 60°/s. The test was performed in five trials with 10-second rest intervals. Before starting the measurements, participants were asked to perform two submaximal trial repetitions to become familiar with the test procedure. For each person, the peak torque measured in Nm was considered their maximum concentric strength and was divided by their weight.

Isometric maximal voluntary contraction

This parameter was also measured using an isokinetic dynamometer in the sitting position with the hip and knee at 90° flexion. This test was performed in three trials with 3-minute rest intervals, and the peak isometric quadriceps maximum voluntary contraction (the best in all trials) was used for data analysis. During this test, participants received verbal encouragement from the examiner. Before starting, participants were asked to perform two submaximal trial repetitions to become familiar with the test procedure.

Statistical analysis

Data were analyzed in SPSS22 software. All the data were encoded to prevent bias in data analysis and blind the statistician. The normality of the distribution of the variables was evaluated using the Shapiro-Wilk test and residual plot assessment. The differences between pretest and posttest values were analyzed using paired t-test or Wilcoxon signed-rank test. The differences between the posttest results of the two groups at the end of week 4 were compared by the analysis of covariance (ANCOVA) with pretest results considered as the covariate. The significance level was set at 0.05 for all statistical tests. Hedges's g (the corrected Cohen's d) and $dpcc_2$ were calculated as effect sizes for differences between means in within-group and between-group designs, respectively.

Results

A total of 183 patients (105 women and 78 men) were screened from October 2021 to April 2022, and 56 of them were eligible and willing to participate in the study [Figure 3]. Comparison of demographic and clinical characteristics between the two groups showed no significant differences at the baseline [P>0.05; Tables 1 and 2]. Based on the results of ANCOVA, there was no difference between the two groups in terms of posttest-adjusted means of variables [Table 3]. Furthermore, $dpcc^2$ demonstrated low-grade efficacy for VAS, WOMAC, JPS, and FS. Furthermore, the width of the 95% confidence interval of $dppc^2$ indicated inconclusive findings for the above-mentioned variables. However, $dppc^2$ indicated a trivial effect for TTDPM, concentric, and isometric strength [Table 3].

Table 2 presents the results of paired t-test or Wilcoxon signed-rank test and mean changes within each group. In the orthosis group, all measured parameters showed statistically significant improvements. In the Kinesio tape group, significant changes were observed in all measured parameters except three proprioception components, namely JPS (70° target), FS, and TTDPM. Hedges's g for VAS, WOMAC, and JPS (45° target) in both orthosis and Kinesio tape groups demonstrated large size efficacy (effect size ≥0.8). Hedges's g for JPS (70° target), FS, and TTDPM indicated medium-size efficacy (0.5≤ effect size ≤0.79) in the knee orthosis group, and trivial effect (effect size ≤0.19) for JPS (70° target) and small effectiveness (0.2≤ effect size ≤0.49) for FS and TTDPM in the Kinesio tape group. Furthermore, Hedges's g for concentric muscle strength indicated a trivial effect in the orthosis group, and small effectiveness in the Kinesio tape group. For isometric strength, Hedges's g showed small effectiveness in both orthosis and Kinesio tape groups [Tables 2].

Discussion

This study investigated the clinical and neuromuscular effects of two types of external joint stabilizers (Kinesio tape and flexible knee orthosis) that are commonly prescribed to reduce pain and inflammation and improve functional capacities for conservative management of knee OA.[23,25,26,33]

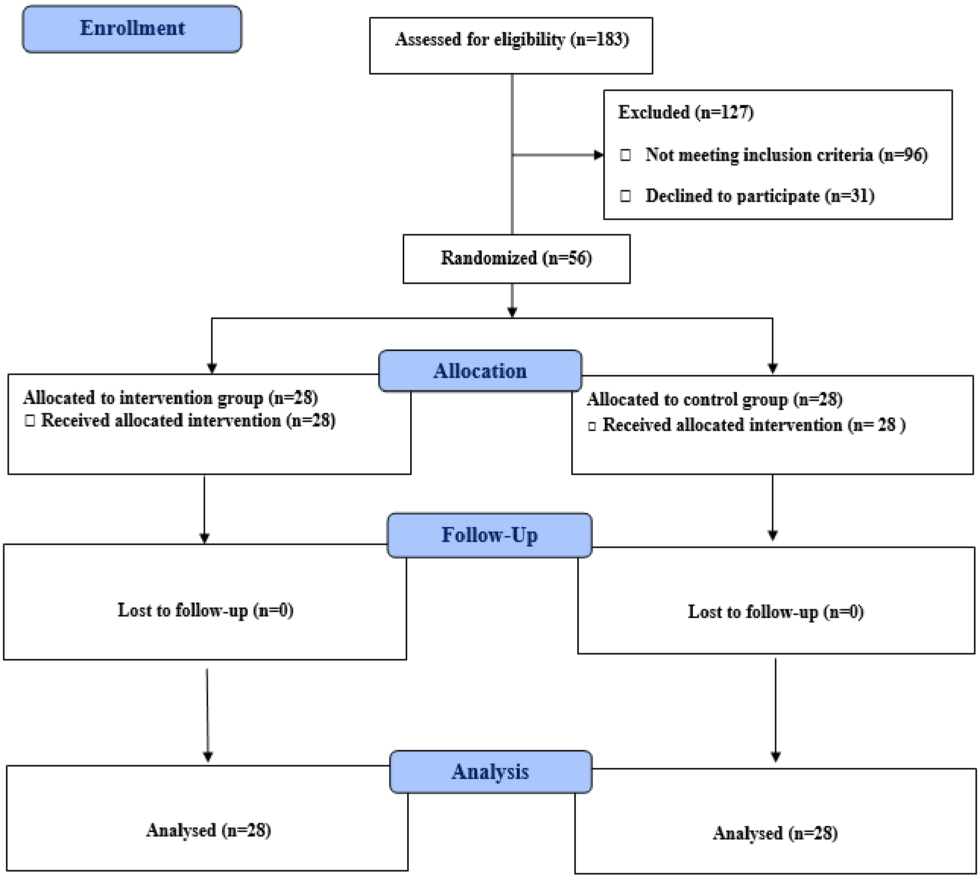

Figure 3. Flow diagram of participants' screening, allocation, and assessment

Table 1. Baseline demographic characteristics of participants in the knee orthosis and Kinesio-tape groups

	Knee orthosis group (n=28)	Kinesio-tape group (n=28)	P-value
Gender (male/female)	17/11	11/17	0.181
Age (years)	55.7±5.3	54.4±3.2	0.269
Height (cm)	168.3±8.8	164.5±8.1	0.095
Weight (Kg)	81.3±9.7	76.5±9.8	0.067
Body mass index (kg/m^2)	24.4±3.04	23.2±2.7	0.135
Kellgren & Lawrence severity stage (grade 2/grade 3)	16/12	18/10	0.785

Table 2. Mean±SD and changes in the dependent variables over 4 weeks (95% confidence interval) for the knee orthosis and Kinesio-tape groups

	Knee orthosis group at the baseline	Knee orthosis group at the end of 4th week	Before to after intervention (95% CI)	P-value Knee orthosis group	Hedges' g Knee orthosis group	Kinesio-tape group at the baseline	Kinesio-tape group at the end of 4th week	Before to after intervention (95% CI)	P-value Kinesio-tape group	Hedges' g Kinesio-tape group	P-value Baseline comparison of two groups
VAS (cm)	5.6±1.42	0.78±0.91	4.82 (4.25-5.39)	<0.001	3.97	5.83±1.66	1.32±1.33	4.51 (3.73-5.3)	<0.001	2.95	0.66
WOMAC (0 to 96)	38.89±15.07	15.57±9.29	23.32 (17.72-28.91)	<0.001	1.83	32.46±10.93	13±8.77	19.46 (14.81-24.11)	<0.001	1.93	0.108
KJPS (°) target 45°	5.26±2.28	3.35±1.75	1.90 (1.11-2.69)	<0.001	0.92	4.85±2.14	3.41±1.71	1.43 (0.33-2.52)	0.01	0.72	0.488
KJPS (°) target 70°	3.85±2.15	2.67±1.86	1.17 (0.11-2.23)	0.039	0.57	3.67±2.34	3.33±1.88	0.34 (-0.66-1.35)	0.949	0.16	0.555
TTDPM (°)	2.02±1.15	1.5±0.74	0.52 (-0.005-1.04)	0.022	0.52	1.83±1.19	1.51±0.96	0.32 (-0.06-0.7)	0.118	0.29	0.279
KFS (N)	9.76±9.32	5.85±5.14	3.91 (0.95-6.86)	0.032	0.51	7.36±6.01	4.96±4.52	2.39 (-0.69-5.47)	0.106	0.44	0.555
Concentric knee extension strength (Nm/Kg)	1.31±0.57	1.39±0.61	0.08 (-0.002-0.16)	0.043	-0.14	1.23±0.5	1.38±0.43	0.14 (-0.017-0.14)	0.028	-0.28	0.61
Isometric knee extension strength (Nm)	119.2±43.21	133.61±44.43	14.4 (-7.23-21.57)	<0.001	-0.32	107.53±40.92	117.45±39.23	9.91 (-3.03-16.79)	0.006	-0.24	0.304

VAS: Visual analog scale; WOMAC: Western Ontario and McMaster index; KJPS: Knee joint position sense; TTDPM: Threshold to detect passive motion; KFS: Knee force sense

Table 3. Summary of the analysis of covariance for dependent variables

	F	P-value	d_{ppc2} (95% CI)
VAS (cm)	1.88	0.17	0.22 (-0.44 to 0.90)
WOMAC (0 to 96)	0.75	0.38	0.34 (-0.27 to 0.95)
KJPS (°) target 45°	0.08	0.77	0.23 (-0.41 to 0.89)
KJPS (°) target 70°	2.28	0.13	0.40 (-0.27 to 1.08)
TTDPM (°)	0.23	0.63	0.19 (-0.42 to 0.81)
KFS (N)	0.47	0.49	0.23 (-0.42 to 0.88)
Concentric knee extension strength (Nm/Kg)	0.51	0.47	0.10 (-0.18 to 0.39)
Isometric knee extension strength (Nm)	1.36	0.24	-0.10 (-0.33 to 0.12)

VAS: Visual analog scale; WOMAC: Western Ontario and McMaster index; KJPS: Knee joint position sense; TTDPM: Threshold to detect passive motion; KFS: Knee force sense; $dppc^2$: Effect size for pretest-posttest comparison design

Our findings demonstrated that Kinesio tape and flexible knee orthosis were both effective in improving pain, self-reported physical function, and isometric and concentric muscle strength. No significant difference was found between the two groups in terms of changes in pain, self-reported physical function, and isometric and concentric strength. The study also examined the effect of these two types of external joint stabilizers on multiple proprioception components. While both groups showed significantly enhanced JPS in reproducing the 45° flexion, the knee orthosis group also exhibited improvements in FS, TTDPM, and reproducing the 70° flexion, though the differences between groups were not statistically significant.

An improvement in pain and self-reported physical function following the use of Kinesio tape or flexible knee orthosis is not a new or unexpected result. Indeed, both of these external joint stabilizers can be expected to have an analgesic effect on knee OA.[23,26,27] However, we observed that the two stabilizers had roughly similar impacts on pain and physical function at the end of the treatment period, which can be considered a new finding. While many previous studies have shown the effectiveness of Kinesio tape and knee orthosis in targeted pain reduction in the immediate term,[26,27,29,34] our findings suggest that in addition to having temporary pain-relieving effects, these external joint stabilizers have long-term impacts on pain and self-reported physical function, which makes them a good option for inclusion in knee OA intervention programs. It should however be noted that some studies in the literature, such as Wageck et al.,[35] have reported that Kinesio taping has no beneficial effect on pain and self-reported physical function in patients with knee OA. Regardless of the Kinesio taping technique used by Wageck et al.,[35] the taping period in that study was 4 days, which might not have been long enough to produce real benefits for these patients. Furthermore, we measured pain intensity using VAS, which is more subjective than the algometry that Wageck et al.[35] have used to measure pressure pain threshold.

It has been speculated that mild compression provided by orthosis not only alleviates pain by reducing muscle co-contraction and thus joint contact forces but also improves functional capacity by enhancing the person's perception of knee stability.[33,36] Orthoses can also reduce pain by providing warmth to the skin, which can alleviate spasms and enhance local blood flow.[33] Pain reduction effects of Kinesio tape have been frequently attributed to the impact of skin convolutions provided by the tape on the unloading of underlying tissues and reduction of nociceptive stimuli.[31] However, some have suggested that improvements in local blood circulation and lymphatic drainage also play a role in this regard.[31] Moreover, one of the most commonly proposed mechanisms for both of these external joint stabilizers is afferent cutaneous stimulation, which reduces the transmission of pain signals and enhances proprioception.[37]

There are many reports in the literature about the presence of proprioception deficits in OA patients compared to age-matched healthy controls.[6,8,9] Additionally, several studies have been conducted on the effect of Kinesio tape or knee orthosis on JPS as a component of proprioception.[37-39] However, no study has investigated the effect of these external knee stabilizers on other proprioception components, such as kinesthesia (movement detection) or sensation of force in OA knee patients. In the present study, we examined three components of proprioception and also used two target joint positions (one at 45° and the other at 70° of knee flexion) in knee JPS evaluations, as previous studies have shown that these joint positions are better markers for detecting alterations in proprioceptive accuracy.[40] Although the differences between the two groups were statistically insignificant, the intra-group changes in JPS, FS, and TTDPM in the knee orthosis group and JPS for 45° knee flexion in the Kinesio tape group were found to be statistically significant. Since JPS, KFS, and TTDPM constitute different aspects of knee proprioception, they may stimulate different receptors.[10] It is believed that motion sense tests, especially at slow angular velocities, strongly stimulate articular receptors and also stimulate cutaneous and muscle receptors to a lesser extent.[3] It seems that in FS, potent inputs derived from tendon organs are activated by active muscle contraction that provides information about muscle tension.[41] Since the changes in FS and TTDPM in the Kinesio tape group were not significant, it appears that Kinesio tape may only be effective in increasing afferent sensory inputs from cutaneous mechanoreceptors.[31] In contrast, orthoses also stimulate ligaments, joint capsules, and muscle mechanoreceptors by pressurizing structures around the joint, and these receptors tend to contribute more to proprioception than cutaneous mechanoreceptors.[42] As stated above, JPS changes in the Kinesio tape group were significant only when the target position was 45° knee flexion. Considering that 45° and 70° knee flexions are both in the midrange of joint motion, muscle spindles are expected to be discharged in these motions.[41] Theoretically, since the quadriceps muscle has a shorter length in 45° knee flexion than in 70° knee flexion, it is unreasonable to assume that muscle spindles have been effective in JPS in the 45° knee flexion but not in the 70° knee flexion (i.e., the position in which the muscle has a longer length). A possible explanation for this finding could be that Kinesio tape has only provided stimulation for cutaneous mechanoreceptors.

There is evidence in the literature suggesting that proprioceptive input is overridden by nociceptive input and that impaired proprioceptive accuracy is associated with knee pain.[3,10,19] However, pain alleviation may not necessarily lead to the enhancement of proprioceptive acuity. We also observed that while both groups experienced pain reduction, only the knee orthosis group showed significant changes in different components of proprioception.

On the other hand, normal sensory inputs are needed to achieve optimal muscle activity.[43] If quadriceps muscle weakness results from hindered high-threshold motor unit recruitment as hypothesized by Konishi et al.,[44] it is possible that Kinesio tape or even knee orthosis can increase input to gamma motor neurons through tactile stimulation, subsequently promoting adequate I_α afferent activity and therefore recruitment of high-threshold motor units, ultimately leading to the enhancement of muscle activity.[11] The observed improvement in isokinetic (concentric) and isometric quadriceps muscle strength in both groups may at least be partially explained by this hypothesis.

The literature contains contradictory reports on the effect of Kinesio tape on quadriceps torque production. For example, while Anadukumar et al.[32] reported an improvement in isokinetic quadriceps torque production 30 min after Kinesio tape application, Wageck et al.[35] and Rahlf et al.[29] reported that the application of Kinesio tape for respectively 4 days and 3 days had no effect on concentric quadriceps muscle strength and maximum voluntary isometric contraction of quadriceps muscles. Furthermore, in cases where quadriceps weakness is due to pain and prolonged disuse, torque production capacity can improve with a decrease in pain. Because it has been suggested that pain acts as a confounding factor in the assessment of muscle strength, as patients may refuse to perform maximum voluntary muscle contraction in the presence of pain.[45] Nevertheless, since several routine daily activities are performed using submaximal muscle forces, measuring submaximal force production may provide a more comprehensive image of a person's neuromuscular performance than maximum contraction.[46] This is why we also measured force accuracy, the results of which were discussed above.

An interesting finding of this study was the improved muscle strength observed in the knee orthosis group, which contradicts the popular belief that orthoses adversely affect muscle performance. This finding is consistent with the results of a study by Callaghan et al.,[28] who reported an increase in quadriceps MVIC after 12 weeks of wearing flexible knee support in patients with patellofemoral joint OA. Flexible knee orthosis can enhance the patient's perception of knee stability, thereby encouraging higher levels of activity and walking, which may result in improved quadriceps muscle strength.[33,36] Moreover, a flexible knee orthosis cannot fully restrict knee movements as like full immobility provided by a rigid orthosis.[25]

Limitations

The absence of a control group that receives no intervention makes it hard to draw a firm conclusion regarding the efficacy of these external knee supports. Furthermore, since the participants in the present study were K-L grade 2 and 3 patients in the narrow age range of 50 to 65 years, the findings may not be generalizable to knee OA patients with K-L grade > 3 or over 65 years of age.

Conclusion

According to our results, a flexible knee orthosis and/or Kinesio tape delivered for 4 weeks significantly improved pain, physical function, and quadriceps muscle strength. Furthermore, the results of the present study demonstrated that knee orthosis had significant beneficial effects on various components of proprioception. However, there were no significant differences between the two groups at the end of the 4-week intervention. According to our results, using external knee support can be recommended for patients with mild to moderate knee OA.

Acknowledgement

The authors would like to thank all participants for their valuable contributions.

Conflict of interest: None

Funding: The authors would like to appreciate the Iran University of Medical Sciences for the partial financial support of this study (grant number: 17095)

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