The Effect of a Single Session of Transcutaneous Electrical Nerve Stimulation on Weight Bearing Asymmetry during Squatting in People with Knee Osteoarthritis

Diz Osteoartritli Kişilerde Tek Seans Transkutanöz Elektriksel Sinir Stimülasyonunun Çömelme Sırasında Ağırlık Aktarma Asimetrisine Etkisi

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Abstract

Objective: The aim of this study was to investigate the effect of a single session of Transcutaneous Electrical Nerve Stimulation (TENS) on weight bearing asymmetry (WBA) during squatting in people with knee osteoarthritis (OA).

Material-Method: Using a retrospective analysis of prospective study design, twenty five patients (6M/19F) with unilateral knee OA included in the study. Prospectively recorded data were obtained retrospectively from the physiotherapy evaluation forms of patients who received a single session of 40-minute TENS intervention to the affected knee. Knee pain intensity was assessed with Visual Analog Scale (VAS). WBA values during standing and squatting (30°, 60°, and 90° of knee flexion) were collected in 3 stages: before the TENS intervention (baseline); immediately after TENS intervention; and 24 hours after TENS intervention.

Results: Significant difference was found for WBA values at 30°of squatting after TENS intervention ($p<0.05$). Reported pain intensity both in immediately after and 24 hours after TENS interventions decreased significantly compared with baseline scores ($p<0.001$).

Conclusions: Single session of TENS intervention controls knee pain and people with knee OA can present squatting with improved inter-limb weight bearing distribution after TENS intervention.

Keywords: Knee Osteoarthritis, Pain, Squatting, Transcutaneous Electrical Nerve Stimulation, Weight Bearing Asymmetry

Özet

Amaç: Bu çalışmanın amacı tek seans transkutanöz elektriksel sinir stimülasyonunun (TENS) diz osteoartritli kişilerde çömelme sırasında ağırlık aktarma asimetrisine etkisi incelemekti.

Materyal-Method: Prospektif çalışma dizaynı ile retrospektif analizler kullanılarak yirmi beş diz osteoartritli hasta çalışmaya dahil edildi. Etkilenmiş dizine tek seans 40 dk TENS uygulanan kişilerin kaydedilen verilerine retrospektif olarak fizyoterapi değerlendirme formlarından ulaşıldı. Diz ağrısı şiddeti vizüel analog skalası (VAS) ile değerlendirildi. Ayakta duruş ve çömelmedeki (30°, 60° ve 90° diz fleksiyonu) ağırlık aktarma asimetrisi değerleri TENS uygulaması öncesi, TENS uygulamasından hemen sonra ve 24 saat sonra olmak üzere 3 aşamada toplandı.

Bulgular: 30° çömelmedeki ağırlık aktarma asimetrisi değerlerinde TENS uygulaması sonrası anlamlı fark bulundu ($p<0,05$). Uygulama öncesi skorları ile karşılaştırıldığında, TENS uygulamasından hemen sonra ve 24 saat sonraki ağrı şiddeti anlamlı olarak azaldı ($p<0,001$).

Sonuç: Tek seans TENS uygulaması diz ağrısını kontrol altına almakta ve diz osteoartriti olan kişiler TENS uygulaması sonrası çömelmeyi gelişmiş ağırlık aktarma simetrisi ile gerçekleştirebilmektedir.

Anahtar Kelimeler: Diz osteoartriti, Ağrı, Çömelme, Transkutanöz Elektriksel Sinir Stimülasyonu, Ağırlık Aktarma Asimetrisi

Introduction

Knee osteoarthritis (OA) has commonly been associated with a symptom of pain resulting in deteriorated physical performance and mobility during various functional tasks in daily living (1, 2). The common observed compensation strategy in functional tasks was an inter-limb weight bearing asymmetry (WBA) (3). WBA is thought to primarily arise from the pain of the affected side to reduce loading of the limb (4). Another explanation of WBA is limited force generation capacity of quadriceps femoris due to arthrogenic muscle inhibition which is typically seen in knee OA (5, 6).

Transcutaneous electrical nerve stimulation (TENS) is one of the effective non-pharmacologic interventions widely used in the treatment of people with painfull knee OA (1, 7, 8). The study of Cheing et al. has revealed that even a single session of TENS treatment results in a significant reduction in knee pain (7). They have also observed that the analgesic effect of TENS lasted for 24 hours for some of the people with knee OA. Another impressive outcome of TENS intervention for pain management was the fact that TENS has a greater effect on movement-evoked pain rather than pain at rest (9). Moreover, people with knee OA were immediately able to increase their

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voluntary quadriceps activation after TENS application via increasing quadriceps motor neuron pool excitability (6).

There is strong evidence showing that TENS is an effective treatment approach in pain relief of knee with OA; however there is lacking evidence to reveal its effect on improving functional daily activities (10). Squatting, involved in many functional tasks in daily living, is one of the demanding movements of knee that requires optimum quadriceps strength (11).

Considering the reflection of TENS on pain inhibition and quadriceps motor neuron pool excitability, we hypothesized that TENS intervention would be a useful method to achieve squatting movement with more symmetrical inter-limb weight bearing distribution.

Therefore, the objective of the present study was to investigate the effect of a single session of TENS on WBA during squatting in people with knee OA.

Material-Methods

This study was a retrospective study including the data of patients with unilateral knee OA. Ethical approval was obtained from the Institutional Review Board at Dokuz Eylul University. All patients were informed about the assessments and intervention and they gave their informed consent. Using a retrospective analysis of prospective cohort study design, we reviewed patients' physiotherapy evaluation forms and the files recorded in the Balance Master System. Prospectively recorded data were obtained retrospectively from the assessments of patients who had been referred to Dokuz Eylul University, School of Physical Therapy and Rehabilitation for physiotherapy interventions with a diagnosis of unilateral knee OA. The data of patients who received only TENS intervention at the first session of the treatment and had records of squat tests in Balance Master System were included for statistical analysis.

The patients who were between the ages of 45-70 with unilateral knee OA were included in our study if they had documented radiological alterations in the knee joint of grade 2 or more according to Kellgren-Lawrence criteria, and had weight bearing knee pain of > 4 on a 10 cm Visual Analog Scale (VAS) on their affected knee. Patients were excluded if they had received knee surgery or an intra-articular injection within the past 6 months, had neurologic/lower extremity orthopedic problems, cognitive impairment, dementia, uncontrolled diabetes mellitus/uncontrolled hypertension or had received physiotherapy program in the last year. The ones who had indicated more than half the level of pain on the non-affected knee were also excluded.

Subjects received a single session of TENS intervention to the affected knee for 40 minutes, which Cheing et al.(7) had shown that this is optimal treatment duration for post-stimulation analgesia in knee OA patients. During that time, patients did not receive any other physiotherapy intervention except TENS. Dual channel TENS device (ET-3000, ZMI Electronics Ltd., IEM United Kingdom) with four rubber electrodes (4x6 cm) and electrode pads were used. The TENS intervention was applied in a conventional mode with a frequency of 100 Hz. The treatment intensity (mA) was set at a comfortable level as determined by the patients. The current was delivered across the joint through two channels. Each channel was connected to two electrodes. One channel was connected to an electrode superiorly in the lateral aspect of the knee and inferiorly in the medial aspect of the knee, and the second channel was connected to an electrode superiorly in the medial aspect of the knee and inferiorly in the lateral aspect of the knee.

Data were collected in four categories: patients' demographics, patients' medical information, measures of WBA while squatting from Balance Master System and knee pain intensity. Knee pain intensity and WBA values were collected in 3 stages: (1) before the TENS intervention (baseline), (2) immediately after TENS intervention and (3) 24 hours after TENS intervention. All measurements were conducted at Human Movement Analysis Laboratory of School of Physical Therapy and Rehabilitation.

Knee pain intensity: The intensity of knee pain was measured by using VAS. The scale consisted of a 10-cm horizontal line, with the left extreme indicating 'no pain' or 0 and right extreme indicating 'pain as bad as it could be (i.e. unbearable pain)' or 10. Patients rated the pain level with regard to weight bearing pain using this scale.

Squat test and weight bearing asymmetry: WBA was assessed using a Weight Bearing Squat Test (WBST) of the Balance Master System (NeuroCom version 8.1 International, Inc., USA). The Balance Master System is a tool to provide quantitative assessment of balance ability and specific movement characteristics during functional activities. This system has been used in the previous studies (5, 11). All WBSTs were performed on a long force platform comprising of two force plates. Force sensors under the force plates measure the vertical forces exerted by the subjects' feet. This test quantifies the percentage of body weight borne by each leg with the patient standing in three different positions as standing at 0º (knees fully extended), 30º, 60º and 90º of knee flexion. Every subject was barefoot on a force platform in standing position. In a standing position, they placed feet symmetrically to the reference places on each force plate according to Balance Master System's instructions. The patients were instructed to look forward and stand erect and then squatting in three positions of knee flexion (30º, 60º and 90º). Prior to testing, movement pattern during the test was explained to the subjects and they practiced several trials to become familiar with the test.

WBA documents differences in the percentage of body weight borne by each limb during the WBST, expressed as a percentage. It was calculated using the following formula:

WBA: $|(A\%-NA\%) / (A\%+NA\%)| \times 100\%$

where A and NA represent affected and non-affected limb, respectively. This formula shows the absolute WBA, which indicates absolute differences between the limbs. The WBA value of 0% would represent perfectly symmetrical weight bearing between the affected and non-affected limb.

Statistical analyses were performed using the SPSS software version 15.0 (SPSS Inc., Chicago, IL, USA). According to Shapiro-Wilk test, most of the variables were not normally distributed. Therefore, non-parametric tests were deemed more adequate for this study. Medians and interquartile ranges (25th-75th percentile) were used for descriptive analyses. The Friedman test was used to examine time effects on WBA and pain (three assessments: before the TENS intervention, immediately after TENS intervention and 24 hours after TENS intervention). Significant results were then analyzed by post-hoc tests (Wilcoxon signed ranks test with Bonferroni correction). The significance level was set at 0.05, except for post-hoc analysis, in which the significance level was set at 0.017 (0.05/3) after Bonferroni correction.

Results

After the elimination process, retrospective analysis of 25 patients' files who received TENS interventions in their physiotherapy program fulfilled all aspects of the study (Figure 1). Baseline descriptive data of participants are summarized in Table 1.

Table 2 presents the results of changes in the WBA values before, immediately after and 24 hours after TENS intervention. The results revealed a significant difference over time for WBA values during the 30° of squatting ($p<0.05$). Multiple comparisons showed statistically significant differences between before TENS intervention and 24 hours after TENS intervention, and between immediately after TENS intervention and 24 hours after TENS intervention for 30° of squatting ($p<0.017$). During the 300 squatting, percentages of participants with less weight bearing on the affected side were 88% before the TENS intervention; 76% immediately after TENS intervention, and 72% at 24 hours after TENS intervention. The results of one session TENS intervention showed no significant changes in WBA values over 3 time periods during standing, 60° and 90° of squatting ($p>0.05$).

Table 3 presents the results of changes in the VAS scores. Over 3 time periods, reported pain levels decreased significantly compared with baseline scores ($p<0.001$). Multiple comparisons showed statistically significant differences between all time periods ($p<0.001$). Pain levels of 52% participants were lower than baseline levels even after 24 hours.

Figure 1. Flow diagram of the study

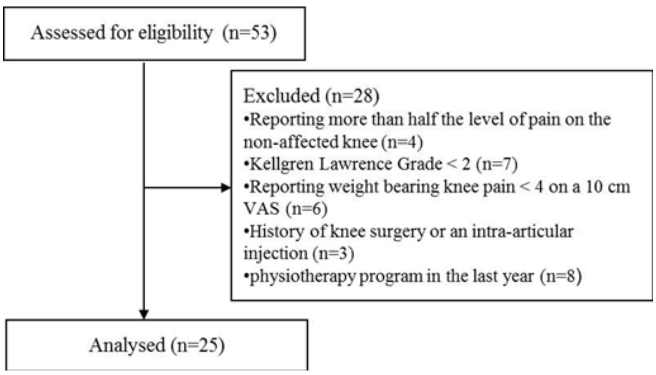

Table 1. Baseline descriptive data of participants (n=25)

Sex, n (%)	
Men	6 (24)
Women	19 (76)
Painful side, n (%)	
Right	9 (36)
Left	16 (64)
Age, years	55.0 (48.5-64.0)
Height, cm	160.0 (156.5-163.0)
Body Weight, kg	80.0 (68.0-92.5)
BMI, kg/m2	31.3 (27.6-34.2)
Baseline VAS score, cm	7.0 (6.0-8.1)
Kellgren-Lawrence Grade, n (%)	
Grade II	16 (64)
Grade III	9 (36)

BMI, body mass index; VAS, visual analog scale
Values expressed as median (interquartile range) or number of patients (%)

Table 2. Changes in weight bearing asymmetry (WBA) values after transcutaneous electrical nerve stimulation (TENS) during standing and squatting

WBA (%)	Before TENS Median (IQR)	immediately after TENS Median (IQR)	24 hours later Median (IQR)	P-value
Standing	8.0 (2.0-14.0)	8.0 (3.0-15.0)	6.0 (4.0-14.0)	0.968
30º of squatting	14.0 (5.0-23.0)	10.0 (4.0-20.0)[a]	6.0 (4.0-13.0)[b]	0.007*
60º of squatting	16.0 (5.0-26)	8.0 (3.0-16.0)	8.0 (4.0-14.0)	0.073
90º of squatting	10.0 (4.0-22.0)	6.0 (2.0-18.0)	10.0 (2.0-16.0)	0.344

IQR, interquartile range
*Statistically significant at $p<0.05$ (Friedman test: p-value indicates the comparisons among before TENS, immediately after TENS and 24 hours later)
[a]30ºof squatting; 24 hours later versus immediately after TENS p= 0.005
[b]30ºof squatting; 24 hours later versus before TENS p= 0.006
[a-b](post-hoc Wilcoxon signed ranks test with Bonferroni correction resulting in a significance level of $p<0.017$)

Table 3. Changes in visual analog scale (VAS) scores after transcutaneous electrical nerve stimulation (TENS)

	Before TENS Median (IQR)	immediately after TENS Median (IQR)	24 hours later Median (IQR)	P-value
VAS score	7.0 (6.0-8.1)[a]	6.1 (5.1-7.5)[b]	5.0(4.1-6.7)[c]	<0.001*

IQR, interquartile range
*Statistically significant at p<0.001 (Friedman test: p-value indicates the comparisons among before TENS, immediately after TENS and 24 hours later)
[a] immediately after TENS versus before TENS p<0.001
[b] 24 hours later versus immediately after TENS p<0.001
[c] 24 hours later versus before TENS p<0.001
[a-c](post-hoc Wilcoxon signed ranks test with Bonferroni correction resulting in a significance level of p<0.017)

Discussion

One of the most common complaints of people with knee OA is considered to be pain which is especially aggravated by the movements of the knee. Movement-evocated pain may discourage these people from performing squat movement with symmetrical inter-limb weight bearing. The findings of the current study supported this statement by indicating higher asymmetry values at 30º and 60º of squatting before TENS intervention. As expected, people with knee OA demonstrated more symmetrical weight bearing distribution during squatting at 30º and 60º after intervention of TENS. Interestingly, significant differences were found between the WBA values measured at 24 hours later and before TENS intervention for only 30º of squatting.

WBA during various functional tasks in relation to knee OA has been well documented in the previous studies (4, 5, 12). Recently, Cristiansen et al. have demonstrated in their study that people with knee OA loaded their affected limb meanly at 87% of the non-affected limb during a Five Times Sit-to-Stand Test (12). In addition, Lim et al. have showed that elderly women with knee OA bore less weight on their affected side than other side with significant differences. They used the same test and equipment as ours to measure WBA during squatting movement. Their results proved the asymmetrical weight bearing during squatting at 30º and 60º. They presented their results only indicating percentage of the subjects with less weight bearing on the affected side during squatting (65.4% and 73.1% of subjects bore less weight on affected side at 30º and 60º squat, respectively) (5). 88% of the participants in our study performed 30º of squatting with WBA and 92% of them behaved the same for 60º of squatting before any intervention. As seen from Table II, there was an increase in asymmetry values from standing to 60º of squatting. It might be a consequence of exacerbating pain and increasing need for quadriceps muscle contraction by further flexing knee. Unfortunately we only asked the patients how much they felt the pain during weight bearing activities; we did not asked specifically for the 30º, 60º and 90º of squatting. The findings at standing indicated that participants tended to load their limbs more symmetrically compared with 30º and 60º of squatting. It might be due to the requirements of standing which are low-demand and do not challenge the individual compared with squatting does (11).

Why is it important to study ‘asymmetrical weight bearing during squatting movement’? Because WBA potentially increases risk for further injuries and falls (13). Squatting is a task that places greater demand on the individual better suited for identifying inter-limb weight bearing asymmetries compared with less demanding activities. Minimizing the WBA during squatting movement involving in most of the daily function may help preserve the healthy condition of the unaffected side (3).

In the current study TENS was thought to be a possible treatment approach to reduce pain based on evidence reported in Philadelphia Panel and thus, to minimize asymmetrical weight bearing during squatting movement in people with knee OA (14). People reported various durations for the lasting effect of post stimulation analgesia and some of them did not return the pre-stimulation levels even after 24 hours of TENS stimulation (7). We found that knee pain significantly dropped below the baseline values immediately after 40-minutes of TENS intervention. Moreover, 52% of the participants in the present study did not return baseline pain scores even after 24 hours over intervention. Cheing et al. have found similar results but they did not give a ratio for the people with knee OA who did experience the 24-hours lasting effect of post stimulation analgesia of TENS application (7). High frequency TENS has been shown to increase release of endogenous opioids in the cerebrospinal fluid of human subjects (15).

TENS also has been reported to influence pre- and post-synaptic inhibitory reflex mechanisms of motor neurons related with affected joint (16). Quadriceps muscle activity of affected knee joint is considered to be reduced by this reflex inhibition (arthrogenic muscle inhibition). If TENS intervention reduces the knee pain by reducing stimulation of nociceptive afferents, reflex inhibition of quadriceps muscle could be suppressed (17). Unfortunately we did not measure the quadriceps muscle activity of the affected knee to reveal this mechanism but the findings of the current study support this idea by indicating attenuated inter-limb WBA during squatting after TENS intervention (Table 2).

The results showed that people with knee OA were immediately able to reduce inter-limb WBA at 30º, 60º and 90º of squatting after TENS intervention compared to baseline values but the results were not statistically significant. It is interesting to note that there was a significant difference between WBA values measured before and 24 hours later TENS intervention for 30º of squatting. We cannot explain this result by pain relief since the findings indicated that pain reduced both immediately after and 24 hours after TENS intervention compared with pain at before TENS intervention (Table 3). Moreover, there was a statistically significant reduction of pain just immediately after TENS intervention compared with baseline pain intensity (Table 3).

However, Pietrosimone et al. have reported that people with knee OA immediately increased voluntary quadriceps activation after TENS application irrespective of pain modulation mechanisms (18). It has also been suggested that regardless of pain reduction, functional activities could be influenced by TENS application (17). From another aspect, Shirazi et al. showed that one session of conventional TENS application has immediately positive impact on proprioception sense in the knee joint in people with knee OA (19). The position sense of the affected knee joint of participants in the current study would have been improved with the application of TENS, and this improvement might help to reduce WBA during squatting.

Conclusion

Our results suggest that TENS intervention which is a common pain management strategy used in people with knee OA is not a useful approach only for pain relief, it also has favorable effects on physical function. Our findings showed that a single session of TENS intervention did reduce knee pain in people with knee OA and it also led to the reduction of WBA during squatting movement. Although there is significant evidence on the effectiveness of TENS on pain reduction, studies that have investigated the effect of TENS on physical function are lacking. Hence, further studies should be conducted to verify effectiveness of TENS on improvement of physical functions of people with knee OA.

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