Does Transcutaneous Electrical Nerve Stimulation Improve the Physical Performance of People With Knee Osteoarthritis?

Pearl P.W. Law, MSc, Gladys L.Y. Cheing, PhD,† and Amy Y.Y. Tsui, MSc‡*

Background: According to a recent metaanalysis study, there is strong evidence to support the view that transcutaneous electrical nerve stimulation (TENS) is an effective treatment for managing osteoarthritis (OA) knee pain. However, there is limited evidence showing its effectiveness in improving physical function. This study examined whether TENS alone can improve physical function in terms of range of knee motion and the Timed-Up-and-Go Test.

Methods: Subjects were randomly allocated into 2 groups receiving TENS at 100 Hz or a placebo TENS. Outcome measures included: 1) visual analog scale for measuring the intensity of the present pain, 2) Timed-Up-and-Go Test, and 3) range of knee motion (ROM). Repeated-measures analysis of variance and Pearson correlation were used for data analyses.

Results: By day 10, TENS produced a significantly greater increase in maximum knee ROM than the placebo group ($P = 0.033$). TENS also significantly increased the pain-limited knee ROM across sessions, but the between-group difference was short of significance ($P = 0.067$). The decrease in time in performing the Timed-Up-and-Go Test was also not significantly different between the 2 groups. A moderate correlation was observed between the reduction in pain scores and the improvement in the Timed-Up-and-Go Test.

Conclusions: Our findings suggested that TENS did improve some of the physical parameters but over 10 days was unable to produce significant improvement in functional performance among people with knee OA. A larger-scale study with the assessment of other functional outcomes may be required to clarify if TENS could improve function in people with knee OA. Also, exercise can be considered to be an important adjunct treatment to TENS to improve function significantly.

Key Words: TENS, pain, knee osteoarthritis, OA

(*J Clin Rheumatol* 2004;10: 295–299)

From the *Physiotherapy Department, Chi Lin Care and Attention Home, Hong Kong; the †Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong; and ‡Queen Elizabeth Hospital, Hong Kong.

Reprints: Gladys L.Y. Cheing, PhD, Assistant Professor, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong. E-mail: rsgladys@polyu.edu.hk.

ISSN: 1076-1608/04/1006-0295

DOI: 10.1097/01.rhu.0000147047.77460.b0

There is a high prevalence of osteoarthritis (OA) among people over the age of 65.[1] It is estimated that approximately 15.8 million Americans have osteoarthritis.[2] In the United States, people with OA account for an estimated 7.3 million visits to physicians per year.[3] Of all visits to general practitioners, 15% to 30% may be either directly or indirectly attributed to OA.[4] The major signs and symptoms of knee OA are pain, stiffness, crepitation, instability, loss of function, joint enlargement, and impaired muscle strength.[5] Synovitis and angular deformities with subluxation may occur in an advanced stage.[6] People with OA knees have particular difficulties rising from a chair, climbing stairs, kneeling, standing, and walking.[7] The isometric peak torque of both the quadriceps and hamstrings of people with knee OA are weaker than those of elderly people of the same age.[8] In addition, gait velocity is slower, cadence is reduced, and stride length is shorter among people with knee OA. Their range of knee motion during nonweight-bearing movement or during walking is reduced.[8] This may be one of the reasons why people with knee OA encounter difficulties in rising from a chair, walking, or climbing stairs.

According to a recent metaanalysis performed by a Philadelphia Panel,[9] there is strong evidence that TENS is effective in managing OA knee pain; however, there is limited evidence to support its effectiveness in improving physical function. In fact, pain is one of the major factors restricting physical function. Pain, weakness, and physical dysfunction form a vicious cycle as the disease progresses. It is unclear if transcutaneous electrical nerve stimulation (TENS) produces an improvement in physical function parallel to pain reduction. A limited amount of research has been conducted in this area. Therefore, the objectives of this article are first, to examine whether TENS alone can improve knee range of motion (ROM) and performance in the Timed-Up-and-Go Test, and second, whether the reduction in knee pain by TENS correlates to an improvement in physical performance.

METHODS

Subjects

This was a double-blind, randomized, controlled trial. Thirty-nine subjects were recruited from 2 local physiotherapy clinics. They were randomly allocated into 2 groups:

those receiving TENS (n = 22) and those receiving a placebo TENS (n = 17). Randomization was carried out by physiotherapists who performed the treatment by drawing lots from the randomization envelope without replacement. The assessors and subjects were blind to the group allocation. All subjects were told that when the indicator light of the TENS was blinking, it meant the machine was working properly. They might or might not feel any tingling sensation during treatment because the intensity of the current was small. Demographic characteristics and visual analog scale (VAS) scores at the baseline were comparable among the groups (Table 1). Three people withdrew from the study: 1 from the treatment group and 2 from the placebo group. The first withdrawal was the result of an unstable medical condition (high blood pressure). The second one was because of social problems. The third one was an induced dropout because of consumption of analgesics on day 5.

Inclusion criteria were subjects with at least grade II osteoarthritic changes in x-ray according to Kellgren and Lawrence,[10] who were considered competent enough to complete the VAS, and for whom OA was the major cause of the present knee pain. Exclusion criteria were subjects with prior knee surgery, those who had received intraarticular corticosteroids within 4 weeks before the study, and those with any chronic or uncontrolled comorbid disease. People with a cardiac pacemaker or those who had received any TENS 1 month before the study were also excluded.

Instrumentation

Dual-channel TENS (ITO, Tokyo, model 120Z) was used in this study. Two pairs of rubber electrodes (4.5 × 3.8 cm^2) were placed over the acupuncture points of the knee (ST35, LE4, SP9, GB34). Acupuncture points were chosen because they were highly reproducible and convenient.[11] The stimulators delivered a current at 100 Hz with a pulse width of 200 μs. The duration of the stimulation was 40 minutes. Forty minutes was chosen because our previous study found that it is the optimal treatment duration for treating knee OA knee.[12] The intensity of the current was set at a comfortable level as determined by the subjects and ranged between 25 mA and 35 mA. The intensity of the current was increased at 5 minutes into the stimulation if subjects reported accommodation to the stimulation. New batteries were replaced for every 10 hours of operation.

The appearance of the placebo machine was identical to the real treatment unit, but the circuit was disconnected by an electrical technician. When the placebo machine was turned on, an indicator light would light up; however, there was no electrical output. Therapists pretended to step up the intensity of stimulation 5 minutes into the stimulation, as was being done with the other treatment groups. A new battery was also inserted after every 10 hours of operation.

TABLE 1. Demographic Characteristics of the Subjects

	TENS (n = 22)	Placebo (n = 17)	*P* Values*
Age (years)	74.7 ± 13.1	74.9 ± 11.2	0.948
Gender	21 F + 1 M	16 F + 1 M	
Body height (m)	1.5 ± 0.1	1.5 ± 0.1	0.880
Body weight (kg)	59.4 ± 10.0	64.2 ± 13.1	0.202
History of osteoarthritic knee (years)	6.5 ± 10.3	9.0 ± 8.0	0.376
Baseline VAS scores	5.2 ± 1.5	5.1 ± 2.2	0.972
Radiographic grading of osteoarthritis	2.6 ± 0.7	2.6 ± 0.7	0.648

Values are mean ± standard deviation.
*P values denote the comparisons between the 2 groups.
TENS indicates transcutaneous electrical nerve stimulation.

Experimental Procedures

After explaining the experimental procedures and the potential risks, informed consent was obtained. Demographic data, including the gender, age, body weight, body height, and history of knee pain, were recorded. Daily treatment was delivered 5 days a week for 2 consecutive weeks.

Assessments were performed at baseline, day 5, day 10, and at the 2-week follow-up session. Outcome measures included a VAS for recording the intensity of the pain, knee ROM (pain-limited ROM and maximum ROM), and Timed-Up-and-Go Test. The data obtained in the VAS were used to correlate to the physical outcomes.

When recording the intensity of the pain, subjects were asked to rate the intensity of the pain felt during walking before stimulation by making a mark on a 10-cm VAS line. Subsequent recordings of VAS were done on separate sheets of paper. This prevented the subjects from comparing the present VAS with the previous one.[13] A goniometer with a 1° increment was used to measure the range of knee motion in flexion and extension in the present study. The range of knee motion was measured as the patient reclined in a supine lying position. The axis of the goniometer was placed over the lateral epicondyle of the femur with the stationary arm pointing toward the greater trochanter. The movable arm was placed over the lateral border of the fibula and pointed toward the lateral malleolus. The pain-limited range of motion of the knee was recorded when the subjects actively flexed or extended their knees. The maximum knee range during passive movement was also measured.

The Timed-Up-and-Go Test is a simple test of basic physical functional mobility for frail elderly persons. It has been validated and has been shown to be a reliable measurement.[14] Subjects were required to stand up from a sitting position in an armchair with their arms resting on the arms of the chair. They wore their regular footwear and used their usual walk-

ing aids if necessary. They were asked to rise up from the chair, walked for a distance of 3 meters, turn around, and return to the same seat and sit down. The whole procedure was first demonstrated, then the actual test was recorded in terms of seconds.

Data Analysis

SPSS version 11 was used for this analysis and the significance level was set at 0.05. A repeated-measures analysis of variance to repeated comparisons; the Bonferroni correction was used to adjust the α level to 0.0125. A Pearson correlation was performed to examine the linear correlation of VAS scores on knee ROM and on the Timed-Up-and-Go Test.

RESULTS

Pain-Limited Knee Range of Motion

The results of pain-limited knee ROM for the 2 groups are summarized in Table 2. There was significant interaction between "group" and "treatment sessions" ($P = 0.001$), indicating that the change in pain-limited knee ROM across sessions varied in the 2 groups. For the within-group comparisons, the pain-limited knee ROM of the TENS group increased significantly from 104.5° on day 1 to 116.0° on day 5 and further increased to 122.2° by day 10 ($P < 0.001$). The within-group difference remained significant even when the Bonferroni correction was used to adjust the α level to 0.0125. The improvement in pain-limited knee ROM was maintained at least up to the 2-week follow-up session for the TENS group. The pain-limited knee ROM for the placebo group was not statistically significant across sessions ($P = 0.548$).

On day 10 and in the follow-up session, the between-group difference just fell short of significance with $P = 0.067$ and 0.060, respectively.

The Maximum Knee Range of Motion

The results of the maximum knee ROM for the 2 groups are summarized in Table 3. A significant interaction was found between "group" and "treatment sessions" ($P = 0.002$), indicating that the change in the maximum knee ROM across sessions was different in the 2 groups. The maximum knee ROM for the TENS group increased significantly from 121.6° on day 1 to 127.7° on the follow-up session ($P < 0.001$). Such a within-group difference remained significant even when the Bonferroni correction was used to adjust the α level to 0.0125. In contrast, no significant change was observed in the maximum knee ROM for the placebo group across sessions ($P = 0.177$).

For the between-group comparisons, a significant difference was recorded on day 10 ($P = 0.033$) and during the follow-up sessions ($P = 0.025$). The TENS group showed a greater increase in maximum knee range than did the placebo group.

The Influence of Transcutaneous Electrical Nerve Stimulation on the Timed-Up-and-Go Test

The results of the Timed-Up-and-Go Test for the 2 groups are summarized in Table 4. No significant interactions were found between "day" and "group" ($P = 0.330$), indicating that the time required for performing the Timed-Up-and-Go Test was similar across sessions for the 2 groups. The within-group difference for the 2 groups was significant across sessions ($P < 0.001$).

For the TENS group, the time required to complete the Timed-Up-and-Go Test was reduced significantly from 20.2 seconds on day 1 to 17.6 seconds on day 5, and then further to 16.5 seconds by day 10. The performance in the test was maintained from day 10 to the follow-up session. In the placebo group, the time to complete the Timed-Up-and-Go Test also improved significantly from 23.9 seconds on day 1 to 21.3 seconds on day 5, and further to 19.2 seconds by day 10. The time needed to complete the test was maintained from day 10 to the follow-up session. However, no significant between-group difference was found ($P = 0.246$).

Correlation of Pain Outcomes With Physical Impairment and Function

Pearson correlations of the VAS scores and the physical impairment and function were calculated in the follow-up session. Physical impairment and function was examined in

TABLE 2. Pain-Limited Knee Range of Motion Recorded on Day 1, Day 5, Day 10, and the Follow-Up Session

	Day 1	Day 5	Day 10	Follow-Up	Within-Group *P* Values*
TENS	104.5 ± 17.48	116.00 ± 12.5	122.2 ± 12.6	121.1 ± 13.8	< 0.001
Placebo	110.9 ± 19.4	110.9 ± 19.5	112.2 ± 20.2	110.7 ± 21.4	0.548
Between-group *P* values	0.284	0.331	0.067	0.060	

Values are mean ± standard deviation.
There was significant interaction between "group" and "session" ($P = 0.001$).
*Within-group *P* values denote comparisons across sessions within each group.
TENS indicates transcutaneous electrical nerve stimulation.

TABLE 3. Maximum Knee Range of Motion Recorded on Day 1, Day 5, Day 10, and the Follow-Up Session

	Day 1	Day 5	Day 10	Follow-Up	Within-Group *P* Values*
TENS	121.6 ± 13.3	125.2 ± 13.4	129.4 ± 11.6	127.7 ± 13.4	< 0.001
Placebo	116.8 ± 18.8	116.4 ± 18.5	118.5 ± 19.1	115.1 ± 20.4	0.177
Between-group *P* values	0.353	0.094	0.033	0.025	

Values are mean ± standard deviation.

There was significant interaction between "group" and "session" ($P = 0.002$); hence, the analysis of "group" and "session" were carried out separately.

*Within-group *P* values denote comparisons within each group across sessions.

TENS indicates transcutaneous electrical nerve stimulation.

terms of limited knee ROM, maximum knee ROM, and the Timed-Up-and-Go Test. A weak-to-moderate correlation was noted between the percentage change in the VAS score with the pain-limited ROM ($r = -0.209$, $P = 0.350$), with the maximum knee ROM ($r = -0.262$, $P = 0.238$), and with the Timed-Up-and-Go Test ($r = 0.443$, $P = 0.039$) as shown in Table 5.

DISCUSSION

Most people with knee OA report pain when moving their knees. They usually cope with the disease by avoiding any movement that triggers knee pain. This may develop into joint stiffness over time. After repeated TENS treatments, the active TENS group, but not the placebo group, showed a significant increase in maximum knee ROM. The maximum knee ROM of the TENS group was still significantly greater than that of the placebo group at the 2-week follow-up session. Although TENS also produced a significant increase in the pain-limited knee ROM over time, the between-group difference just fell short of significance.

Pain, swelling of the joints, and stiffness are the common signs and symptoms of knee OA. High-frequency TENS is believed to increase the local blood supply.[15,16] Such an increase in local circulation may decrease the swelling around the joint, thus improving the freedom of movement within the joint. Sluka and Westlund[17] demonstrated that agents that decrease joint swelling could also decrease limb guarding. Grimmer[15] showed that high-frequency TENS (80 Hz) produced a significantly greater and faster relief for stiffness than a placebo ($P = 0.03$). It is possible that TENS reduces pain and swelling over the knee joint among people with knee OA, thus reducing limb guarding, and a greater maximum knee ROM can be accomplished. Most people believe that there is a vicious circle between pain and movement. Pain is an important factor restricting movement, but a limitation in movement may result in more pain. Theoretically, when pain decreases, muscle spasm decreases and joint mobility may increase. However, our findings demonstrated only a weak-to-moderate correlation between the pain outcomes and the physical data. The improvements in various treatment outcomes for people with knee OA could not be explained by a simple and linear relationship.

We found significant improvement in maximum knee ROM, but not in pain-limited knee ROM or the Time-Up-and-Go tests. It is well documented that the functional performance of people with OA knee is reduced.[18,19] Their walking speed is slower than that of normal aged-matched people.[19] If pain is elicited during the weight-bearing phase, people with knee OA may walk with a limping gait. If TENS could reduce knee pain, theoretically, it could improve walking performance. Our findings demonstrated a medium correlation between the VAS score and the Timed-Up-and-Go

TABLE 4. The Timed-Up-and-Go Test Recorded on Day 1, Day 5, Day 10, and the Follow-Up Session

	Day 1	Day 5	Day 10	Follow-Up
TENS	20.2 ± 7.9	17.6 ± 7.3	16.5 ± 7.8	15.5 ± 6.4
Placebo	23.9 ± 15.6	21.3 ± 11.8	19.2 ± 11.6	20.0 ± 11.6

Values are mean ± standard deviation.

There was no significant interaction between "group" and "session" ($P = 0.330$). That means that the changes in the Timed-Up-and-Go Test over time were similar in both groups. The overall within-group difference is significant ($P < 0.001$), but the between-group difference was insignificant ($P = 0.246$).

TENS indicates transcutaneous electrical nerve stimulation.

TABLE 5. Correlation Between the Percentage Change in the VAS Scores and the Physical Measurements in the Follow-Up Session

	Pain-Limited Knee Range of Motion	Maximum Knee Range of Motion	Timed-Up-and-Go Test
Pearson correlation (r)	−0.209	−0.262	0.443
Significance (2-tailed)	0.350	0.238	0.039

Test (r = 0.443). However, pain is not the only factor that limits functional performance among these subjects. Other factors such as the patient's confidence, their dynamic standing balance ability, muscle strength of lower limbs, and ability to use walking aids may also influence their performance in the Timed-Up-and-Go Test.

Theoretically, pain may discourage people with OA knee from performing exercises, which may result in a reduction in joint mobility over time. If the application of TENS controls knee pain and improves knee ROM, people with knee OA will be able to tolerate more quadriceps exercise in a greater knee ROM. However, our results only found a weak correlation between VAS scores and range of knee motion (r = −0.209 for pain-limited knee ROM and −0.262 for maximum knee ROM). That means pain reduction by TENS may not necessarily result in a corresponding gain in knee ROM. If so, exercise training to the quadriceps muscle is indicated. Stronger quadriceps muscles could provide better protection of the knee joint.[20] It reduces excessive stress and strain on the lax joint capsule where the nociceptors are located and reduces knee pain during movement. A previous study has shown that a muscle training program can effectively decrease pain and improve balance and walking speed[21] for people with knee OA. Therefore, it is indicated that an effective rehabilitation program should consist of both TENS and an adjunct exercise program.

In the present study, a placebo group was included as a control group. We did not request subjects to make a guess which group they were allocated; it was unclear how well the subjects were blinded. This could be a limitation of the present study. Also, as a result of the small sample size, the between-group difference in the pain-limited knee ROM just fell short of significance on day10 and the follow-up session. A larger-scale study with the assessment of other functional outcomes is required to clarify if TENS could improve functional performance in people with knee OA.

The present protocol for TENS showed little effect on physical function as measured in the Timed-Up-and-Go Test. However, previous studies have shown that TENS is effective in pain reduction. Because the cost of a TENS unit is economic and it is a safe modality that patients can use it at home, it is still felt to be a good choice of treatment in the management of knee OA. However, TENS alone appears to have little effect on function. Future studies are needed to evaluate if the addition of quadriceps strengthening exercises to TENS application would produce better overall treatment outcomes for knee OA.

CONCLUSIONS

Our findings demonstrated that 2 weeks of repeated applications of TENS significantly increased the maximum passive knee range of motion. However, it did not significantly increase pain-limited knee range or improve the performance of Timed-Up-and-Go Test. There was only a weak-to-moderate correlation between the VAS pain scores and various physical outcome measures. The present protocol of TENS appears to have little effect on physical functions as measured in the Timed-Up-and-Go Test. Quadriceps strengthening exercises can be considered as an adjunct treatment to TENS, which may be a better rehabilitation strategy in reducing pain and improving function for people with knee OA.

REFERENCES

1. Badley EM, Tennant A. Changing profile of joint disorders with age: findings from a postal survey of the population of Calderdale, West Yorkshire, United Kingdom. *Ann Rheum Dis*. 1992;51:366–371.
2. Lawrence RC, Hochberg MC, Kelsely JL. Estimates of the prevalence of selected arthritic and musculoskeletal diseases in the United States. *J Rheumatol*. 1989;16:427–441.
3. Yelin EH, Felts WR. A summary of the impact of musculoskeletal conditions in the United States. *Arthritis Rheum*. 1990;33:750–755.
4. Bradley JD, Brandt KD, Katz BP, et al. Comparison of an anti-inflammatory dose of ibuprofen, an analgesic dose of ibuprofen, and acetaminophen in the treatment of patients with osteoarthritis of the knee. *N Engl J Med*. 1991;325:87–91.
5. Altman RD. Osteoarthritis: aggravating factors and therapeutic measures. *Postgrad Med*. 1986;80:150–163.
6. Martin DF. Pathomechanics of knee osteoarthritis. *Med Sci Sports Exerc*. 1994;26:1429–1434.
7. Cooke TDV, Dwosh IL. Clinical features of osteoarthritis in the elderly. *Clin Rheum Dis*. 1986;12:155–172.
8. Cheing GLY, Hui-Chan CWY. The motor dysfunction of patients with osteoarthritic knee in a Chinese population. *Arthritis Care Res*. 2001; 45:62–68.
9. Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for knee pain. *Phys Ther*. 2001;81:1675–1700.
10. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthritis. *Ann Rheum Dis*. 1957;16:494–502.
11. Smith CR, Lewith GT, Manchin D. TNS and osteoarthritic pain: preliminary study to establish a controlled method of assessing transcutaneous nerve stimulation as a treatment for the pain caused by osteoarthritis of the knee. *Physiotherapy*. 1983;69:266–268.
12. Cheing GLY, Tsui AYY, Lo SK, et al. Optimal stimulation duration of TENS in the management of osteoarthritic knee pain. *J Rehab Med*. 2003;35:62–68.
13. Carlsson AM. Assessment of chronic pain. I. Aspects of the reliability and validity of the visual analogue scale. *Pain*. 1983;16:87–101.
14. Podsiadlo D, Richardson S. The Timed 'Up-and-Go': a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991; 39:142–148.
15. Grimmer K. A controlled double-blind study comparing the effects of strong burst mode TENS and high rate TENS on painful osteoarthritic knees. *Aust J Physiother*. 1992;38:49–56.
16. Wolf AW, Benson DR, Shoji H, et al. Current concepts in synovial fluid analysis. *Clin Orthop*. 1978;134:261–265.
17. Sluka KA, Westlund KN. Inflammation-induced release of excitatory amino acids is prevented by spinal administration of a $GABA_A$ and not by a $GABA_B$ receptor antagonist in rats. *J Pharmacol Exp Ther*. 1994;270:76–82.
18. Fisher NM, Gresham G, Pendergast DR. Effects of a quantitative progressive rehabilitation program applied unilaterally to the osteoarthritic knee. *Arch Phys Med Rehabil*. 1993;74:1319–1326.
19. Lankhorst GJ, Van de Stadt RJ, Van der Korst JK, et al. Relationship of isometric knee extension torque and functional variables in osteoarthrosis of the knee. *Scand J Rehabil Med*. 1982;14:7–10.
20. Gerber LH. Exercise and arthritis. *Bull Rheum Dis*. 1990;39:1–9.
21. Rogind H, Bibow-Nielsen B, Jensen B, et al. The effects of physical training program on patients with osteoarthritis of the knees. *Arch Phys Med Rehabil*. 1998;79:1421–1427.