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The effect of high frequency transcutaneous electrical nerve stimulation on knee joint proprioception

A cross-sectional study in healthy adults

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ABSTRACT

BACKGROUND: Proprioceptive information arises from mechanoreceptors situated in the muscles, joints, ligament- and cutaneous tissues. Together with the visual and vestibular system they all contribute to the ability of defining the position of the body and the position of the joints in relation to each other. There is a known deterioration in proprioception sense with greater age and various diseases and injuries, such as osteoarthritis (OA). High frequency TENS is a common treatment for pain relief in this patients. Previous investigations have evaluated the effect on proprioception sense by applying an electrical noise or high frequency TENS to the subject´s knee or lower limb. To our knowledge there are no studies on the possible effect of high frequency TENS on proprioception sense after the actual TENS treatment.

OBJECTIVE: The aim of this study was to evaluate the effect of 30 min high frequency TENS on the knee joint proprioception in healthy subjects.

RESEARCH QUESTION: How is the ability to reproduce an angle of 70^0 in the dominant knee joint, in relation to the collateral (control) knee joint before TENS, during TENS stimulation, immediately after and five minutes after a 30-minute High- TENS intervention?

METHODS: Ten subjects (five women), mean age 26 years (range 20-45) were included in the study. Inclusion criteria were that they consider themselves as healthy and that they had not undergone any surgery in the knee or hip in the past six months. High frequency TENS was applied bilaterally over the subject´s knee joint. To evaluate any effect on proprioception sense we used joint position sense (JPS). Multiple T-tests and Bonferroni correction was used to determine differences between the measurements.

RESULTS: There was no difference in JPS between control measures and during (p=013), immediately after (p=0.093) and 5 minutes after (p=0.333) the TENS intervention.

CONCLUSIONS: High frequency TENS seems to have no impact on proprioception sense in the knee joint as measured by JPS in healthy adults.

Key words: Joint position sense, TENS, electric stimulation therapy, physiotherapy

BACKGROUND

Proprioceptive information arises from mechanoreceptors situated in the muscles, joints, ligament- and cutaneous tissues. Together with the visual and vestibular system they all contribute to the ability of defining the position of the body in space and the position of the joints in relation to each other. It is important for the performance of daily tasks, to walk or just keeping your balance[1]. Muscle spindles provide the nervous system with information about muscle length and contraction velocity and contribute to the ability to distinguish joint movement (kinesthesia) and the position of the joints (joint position sense, JPS). The golgi tendon organ and peripheral receptors in joints, like the pacinian corpuscles, Ruffinis endings, ligament receptors and free nerve endings together with receptors in cutaneous tissue provide the cerebral cortex with important proprioceptive information. The receptors send information through afferent signals via the dorso lateral pathway regarding body position and they play an essential role for motor control and joint stability[2, 3].

The proprioceptive acuity can be influenced by several factors such as temperature, fatigue[4] and various diseases and injuries. There is also a prominent loss in proprioception sense with age[5, 6]. Defects in proprioception sense are shown in patients with Anterior cruciate ligament injury[7-9] diabetes[10, 11], Parkinson's- and Huntington's diseases[12]. Poorer proprioception sense is also known to be present in patients suffering from Osteoarthritis (OA)[13].

OA is a disease widespread throughout the world and is often a cause of pain and restricted movement in the joint. Among people in their seventies the prevalence of OA of the knee is high (40%) and a common reason for medical treatment[14, 15]. In addition to traditional physiotherapy such as physical training, transcutaneous electrical nerve stimulation (TENS) is commonly used by physiotherapists for pain relief in these patients[16, 17].

Electrical stimulation has been in therapeutic use, and practiced for alleviating pain through the ages. From electrical eels as long ago as 300B.C, to the battery in the 1800´s, which eventually resulted in the more advanced equipment we use today[18]. It is often used as a non-pharmacological option for alleviating chronic[19]and post- operative pain[20]. TENS can also be used for improvements in tactile sensitivity in MS patients[21]. TENS involves the application of electrical current to the skin and can be set to different frequencies, durations and intensities. This results in a large recruitment of sensory nerve fibers and mechanoreceptors[22]. Different types of TENS treatment are often referred to as Hi-TENS and Low-TENS. The high frequency TENS, is also referred to as conventional TENS, it is applied at frequencies in general from 40 - 120 Hz. It temporarily reduces the cutaneous (skin) perception for touch by increasing the sensory threshold in the area. The low frequency TENS is applied at frequencies from two – four HZ and generates muscle contractions[23].

The gate control theory is the most common theory used to explain the effectiveness of high frequency TENS in pain relief. The electrical stimulation of the skin evokes selective nerve action potentials in large diameter Aβ fibers that are transmitted to;

i. the inhibitory cells of the substantia gelatinosa (SG) in the dorsal horn,
ii. the posterior column fibers of the spinal cord, that forward toward the brain and
iii. the posterior column fibers of the spinal cord, that forward toward the brain and the first central transmission cells in the dorsal horn.

The SG cells also receive afference from “pain” fibers (Aδ-fibers and C-fibers), and is believed to modulate the synaptic transmission of nerve impulses from peripheral sensory and nociceptive fibers, to central cells. The gate control theory suggests that afference from large diameter sensory fibers facilitates the inhibitory cells of the SG that in turn block both sensory and nociceptive afference to the central transmission cells which in turn relay to higher central nervous centers. The central transmission cell is inhibited or in other words the “gate” is closed causing not only subjective pain relief but also some reduction in sensory afference to higher centers[22, 24, 25].

To evaluate proprioceptive deficiencies, different measurements are used. Kinesthesia, which is measured by the threshold to detection of passive motion (TDPM) and joint position sense (JPS) – which is the ability to reproduce a passive joint position, are commonly used[26]. The angle achieved in the JPS test is measured with a goniometer and it´s a method that has proved both reliable and valid according to previous studies in which the goniometer was compared to radiographic measurements of the knee joint. The reliability increases if measurements are made by the same therapist[27].

A previous study has shown that stimulation with stochastic resonance, ie, an alternating electric field, can improve proprioception in healthy subjects during the actual stimulation period[28]. An improvement in sensory motor function in diabetic and stroke patients using mechanical noise input has also been reported by others[29]. Moreover, former investigations shows that applying high frequency TENS or electrical noise to the lower limb or knee, seems to have a positive effect on balance control in healthy subjects[30, 31]. However to the best of our knowledge no study has systematically assessed the effect of high frequency TENS on perceived proprioceptive ability in the knee joint following a session of TENS treatment. The aim of this study was to evaluate the effect of 30 min high frequency TENS on the knee joint proprioception.

RESEARCH QUESTION

How is the ability to reproduce an angle of 70^0 in the dominant knee joint, in relation to the collateral (control) knee joint before TENS, during TENS stimulation, immediately after and five minutes after a 30-minute High - TENS intervention?

METHOD

Subjects

Ten subjects (five women) were included (mean age 26, range 20-45 years). Inclusion criteria were that they consider themselves as healthy and that they had not undergone any surgery in the knee or hip in the past 6 months. Subject that experienced symptoms, i.e. pain from the back, hip or knee, at the time for the test or in the past 6 months were excluded. Nine subjects assigned their right leg as their dominant leg (the preferred kicking leg) and this leg was used for measurements. The group studied consisted of healthy young volunteer subjects who were familiar with TENS and who were instructed that they may discontinue their participation at any time during data collection. All subjects were given a written informed consent and were recruited from the faculty of medicine, Lund University.

TENS-intervention

The high frequency TENS (80Hz) was delivered using a portable battery-powered TENS stimulator (CEFAR REHAB 2 PRO, CEFAR Medical AB, Lund, Sweden) with two self-adhesive TENS electrodes (oval 4x6 cm) placed bilaterally over the knee joint (see Fig 1, 2, 3).

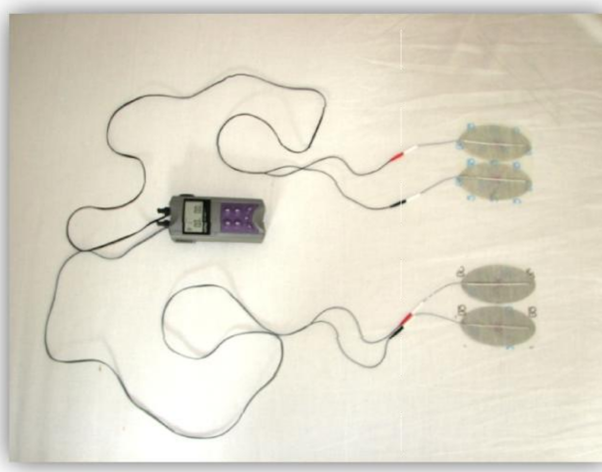

Figure 1. The portable battery-powered TENS stimulator with self-adhesive TENS electrodes.

To facilitate the angle measurements, the trial manager marked the lateral epicondyle of the femur as an approximation for the knee joint fulcrum for extension and flexion. Other anatomical landmarks were the greater trochanter of the femur and the lateral malleolus in each subject and lines were drawn between these marks. To prevent the reference lines from being displaced, the markings were made when the subject had a knee angle of approximately 70 degrees. This was done bilaterally and by the same trial manager to all participants. A marking of the medial epicondyle of the femur was also made for easier application of the electrodes at a later stage. The subjects were then told to lay prone on a treatment bench. A control test was performed on each subject in whom the trial manager set the knee joint on the participant's non-dominant side to 70°, the trial manager held the subjects non-dominant leg in 70^0 during the entire assessment periods . The subject was then blindfolded and asked to set their tested leg in the same position, whereupon the investigator measured the angle of the tested side's knee with a goniometer. Afterwards the joint was reset to its original position (0°). The trial manager then placed two electrodes over the knee bilaterally. To increase the precision of the electrodes, they had been marked with a cross that was placed over the mark on the epicondyle. The TENS unit was started and the subject was requested to state when the stimulation could be experienced, after which the intensity was doubled. When the right intensity was achieved, subjects were left with high frequency TENS on their knee for 30 minutes. The assessment procedure was repeated in the same way as the previous;

- 15 minutes into the intervention with the TENS unit on, referred to as during Tens (DT)
- immediately after TENS (AT), and
- five minutes after cessation of TENS (5AT).

Each subject was measured three times during the four occasions namely i) control, ii), DT iii) AT and iv) 5AT. The mean value of knee flexion for each occasion was calculated and used in the statistical analysis

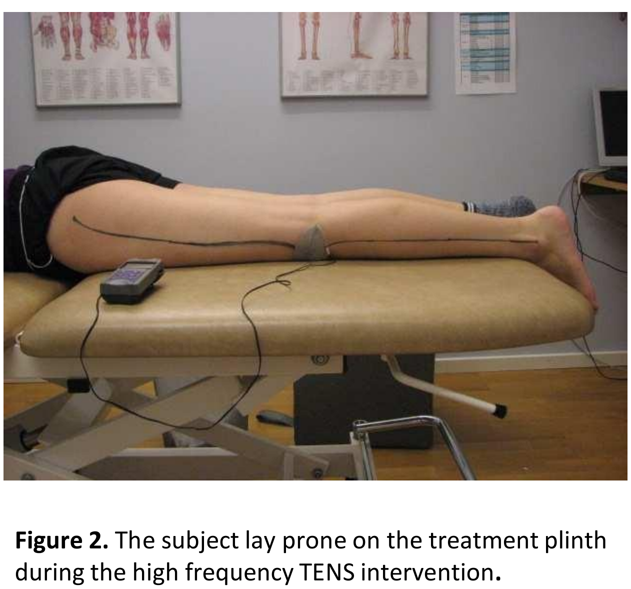

Figure 2. The subject lay prone on the treatment plinth during the high frequency TENS intervention.

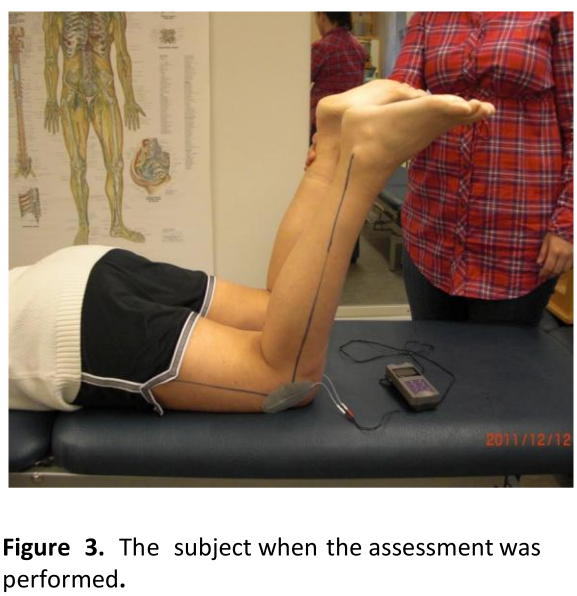

Figure 3. The subject when the assessment was performed.

Statistics

For the descriptives, means and standard deviations are given. All calculations were performed using IBM SPSS Statistics 19. To assess for differences between the measurements we used multiple paired T-tests, Wilcoxon signed rank test and applied the Bonferroni correction. P-values less than or equal to 0.05 were considered statistically significant. To assess the variability of the measures we used the percentual coefficient of variation (%CV) using the formula *(SD/mean) X 100%.*

RESULTS

The means and standard deviations of the knee angles are given in Table 1. There was no difference in JPS between measures, during (p=0.13), immediately after (p=0.093) and 5 minutes after (p=0.333) the TENS intervention, compared to the control measurements (see Table 2 and Figure 4 and 6). A p-value of 0.038 was found between the control measures and measures during TENS intervention, but after correcting for multiple pair-wise comparison, there was no difference (p=0.13). No difference was found when we compared the differences between actual measurements and the reference angle 70^0 for the four measurement occasions (Control/DT p=0.303, control/ATp=0.380. and control/5AT p=0.062. Using the %CV we found a slight decrease in the variability of the DT, AT and 5AT measures (6.5%, 7,3% and 6.5% respectively) compared to the control (8.6%).

Table 1. The means and standard deviations of the knee joint angles in degrees for the dominant leg from the four measurement periods i.e. Control, during TENS, just after and 5 min after TENS are given for each subject. N=10)

Subject	Control *Mean ±SD*	During TENS *Mean ±SD*	After TENS *Mean ±SD*	After 5 min *Mean ±SD*
1	62.75 ±3.95	67.00 ±3.60	69.67 ±3.80	69.00 ±2.60
2	73.75 ±0.50	74.33 ±3.20	80.00 ±3.00	79.67 ±1.20
3	67.25 ±1.50	68.67 ±1.20	67.70 ±4.00	64.33 ±1.50
4	60.00 ±3.65	70.67 ±1.20	72.67 ±2.10	71.33 ±2.50
5	73.75 ±1.71	81.00 ±10	75.33 ±1.20	73.67 ±1.20
6	76.50 ±1.00	73.67 ±2.50	71.33 ±0.60	70.67 ±0.60
7	65.50 ±1.91	65.33 ±7.00	64.33 ±1.20	64.67 ±3.20
8	64.00 ±1.15	71.33 ±2.30	78.67 ±3.50	75.67 ±1.20
9	76.50 ±1.00	75.67 ±5.10	79.00 ±10	70.67 ±0.60
10	70.50 ±0.58	76.33 ±3.50	69.33 ±2.50	71.67 ±1.20
Mean total ±SD	69.05 5.96	72.40 4.74	72.80 5.30	71.14 4.63

Table 2: Differences (degrees) between control, during, immediately after and 5 minutes after TENS.

	Subjects (N=10)	Control measures	
	Mean (SE)	*Mean diff (95% CI)*	*p-value (Bf)*
Control	69.05 (1.88)	-	
DT	72.40 (1.50)	-3.35 (-6.47, -0.23)	0.038 (0.13)
AT	72.80 (1.68)	-3.75 (-8.28 ,0 .77)	0.093
5AT	71.14 (1.47)	-2.09 (-6.69, 2.52)	0.333

Control=measures before TENS, DT=during TENS measure, AT=immediately after, 5AT=measures 5minutes after TENS. (SE) Standard error mean, Mean difference and 95% confidence interval of the difference, (Bf)= Bonferroni correction.

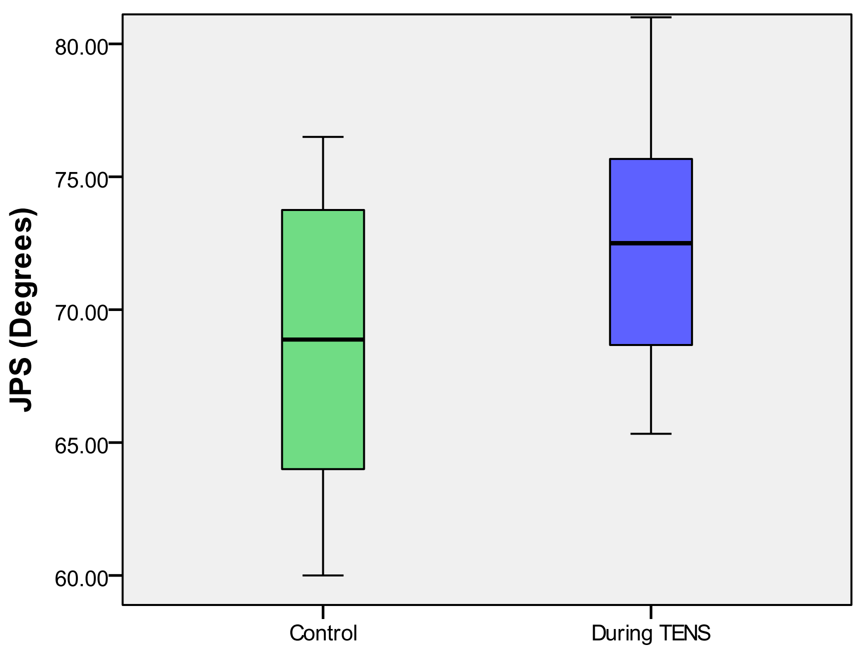

Figure 4 : Difference between control and measures during TENS intervention. JPS = Joint position sense, the box includes the first to the third quartile and the median value is indicated by the black line trough the box.

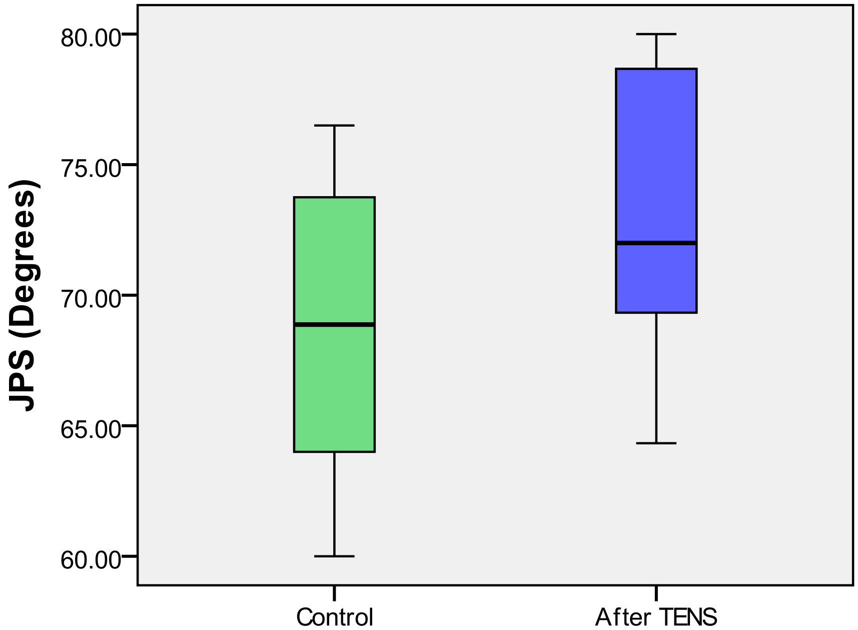

Figure 5. Difference between control and measures immediately after TENS intervention.JPS = Joint position sense, The box includes the first to the third quartile and the median value is indicated by the black line through the box.

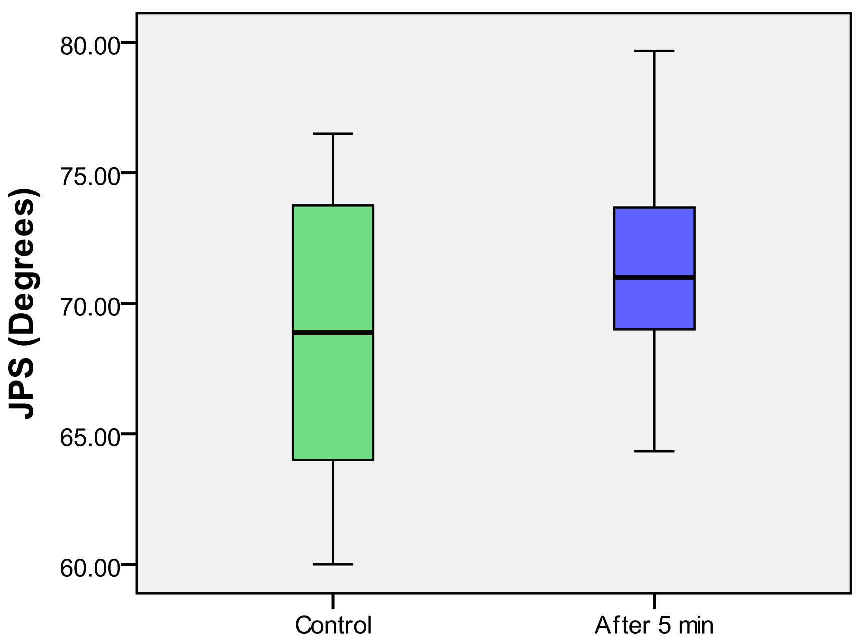

Figure 5: Difference between control and measures 5 minutes after TENS intervention. JPS = Joint position sense, The box includes the first to the third quartile and the median value is indicated by the black line trough the box. N=10

DISCUSSION

In this study, no significant difference was found in JPS between control measurements and during, immediately after and five minutes after TENS treatment respectively. These findings indicate that High frequency TENS has no influence on proprioception sense as measured by JPS in healthy adults.

However, we did find a statistically significant difference between the TENS session and control measures (p=0.038). Since the possibility to reject the nullhypothesis incorrectly increases with the number of comparisons made, the Bonferroni correction was used[38] and we got a p-value of 0.13, suggesting that there was no difference.

The outcomes in this investigation are in line with previous studies, in which no effect on proprioception sense has been found when random electrical noise was applied to the knee in a non-weight bearing position. These studies, however, found a significant difference in JPS when the subjects were set in a weight bearing position[28, 32].

Several investigations have reported improvements in balance control when an electrical or mechanical noise was applied[29, 31, 33, 34]. Moreover, Dickstein et al showed that an intervention of High frequency TENS to the lower leg had a positive effect on postural sway, suggesting that the electrical input contributes to a decrease in the mechanoreceptor threshold, responsible for proprioceptive detection (i.e improved proprioception sense)[30]. None of the previous investigations had examined the possible effect on proprioception sense after the electrical intervention. In the present study we didn`t find any differences in proprioceptive acuity. There can be several explanations for these contrarious results. Dickstein used high frequency TENS, at an intensity of the detection threshold. In this investigation we applied high frequency TENS at an intensity twice the threshold of the detection value. We chose this frequency and intensity because it is a common stimulation level for pain treatment in patients with osteoarthritis. OA patients are known to have proprioceptive deficiencies[13]

That there is an individual optimal frequency level for affecting the proprioceptive detection is well known[35] and it is possible that the stimulation level we used didn´t affect the proprioceptive sense as measured by JPS.

Proprioception can be measured in several different ways. The most common way in previous investigations is to make an indirect assessment of the proprioception sense by measuring postural sway on a specific platform [29-31, 33, 34]. In this study we used JPS as a measure of proprioception. This measure has been shown not to be as reliable as for example kinesthesia, as measured by the threshold to detection of passive motion (TDPM)[36]Former studies has also shown that there is no correlation between the different ways to measure JPS as well as between JPS and kinesthesia, indicating that it measures different aspects of proprioception sense[37]. This may indicate that high frequency TENS appear not to affect proprioception sense as measured by JPS. That we did not find any impact on proprioception sense in this study, however, does not rule out the possibility of detecting such influence in future investigations, using different measuring devices to assess proprioception. Moreover, there wasn´t any reliability or validity tests done of the trial managers measuring method, consequently there is a possibility that the results in this study could be due to measurement error.

No power analysis was made in this investigation, and consequently there is a possibility that a significant difference between these measurements could have been found, had it been applied to a larger population group. However, we did discover that there was a decrease in variation for measures performed *during, immediately after* and *five min after* TENS, but at this stage we cannot say if it is of any clinical importance.

Moreover, our subjects consisted of a group of ten healthy individuals with, to our knowledge, intact proprioceptive sense. Future investigations are needed to elucidate whether high frequency TENS has an impact on proprioceptive sense when applied to larger population groups and patients with known proprioceptive deficits such as OA and ACL injuries.

CONCLUSION

Our thesis was to determine if TENS may affect proprioception sense in the knee joint. However, since there was no significant difference between control measures, during TENS treatment and after treatment, high frequency TENS seems to have no impact on proprioception sense in the knee joint as measured by JPS in healthy adults. Further investigations in larger populations and with a well defined RCT design are however needed in patients with known proprioceptive deficiencies.

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Abbreviations

TENS - Transcutaneous Electric Nerve Stimulation
TDPM – Threshold to Detection of Passive Motion
JPS – Joint Position Sense
SG – Substantia Gelatinosa
DT – 15 minutes in to the TENS intervention
AT – immediately after the TENS intervention
5AT – five minutes after the TENS intervention