

Short Communication

Effectiveness of TENS on Quadriceps Muscular Endurance during Weight Bearing Exercise

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Abstract

Purpose: To examine the effectiveness of TENS use on quadriceps muscular endurance during weight bearing exercise for apparently-healthy populations.

Methods: Fifteen male and fifteen female volunteers provided informed consent prior to participation. In Session 1, participants height, body mass, and one repetition maximum (1-RM) for non-dominant quadriceps was assessed using a knee extension machine. In Session 2, participant's baseline maximum repetitions of non-dominant knee extensions at 40% of 1-RM were obtained. Participants were randomly selected into three groups: EXP: TENS unit with TENS activation; CON: no TENS unit with no TENS activation; PLA: TENS unit with no TENS activation. In Session 3, EXP, CON, and PLA participants performed maximum repetitions of non-dominant leg at 40% of 1-RM on the knee extension machine. Analysis of covariance (ANCOVA) was used to compare the change in repetitions from Session 2 and Session 3 between each treatment group, while controlling for baseline repetitions.

Results: No significant differences were found between groups in number of repetitions achieved at baseline ($p=0.703$). The EXP group performed significantly more repetitions compared to the CON group ($p=0.001$) and PLA group ($p=0.011$) when controlling for baseline repetitions.

Conclusion: Use of TENS during weight-bearing quadriceps muscular endurance activity significantly improves the number of repetitions performed by apparently-healthy populations.

Keywords

- TENS
- Muscular endurance
- Quadriceps
- Ergogenic aid

ABBREVIATIONS

TENS: Transcutaneous Electrical Nerve Stimulation; 1-RM: One Repetition Maximum; ANOVA: Analysis of Variance; ANCOVA: Analysis of Covariance

INTRODUCTION

Transcutaneous Electrical Nerve Stimulation (TENS) is a form of peripheral nerve stimulation used in healthcare to treat acute (e.g., post-surgery) and chronic (e.g., previous injuries invoking daily aches) pain. Put simply, the main functionality of TENS is to manage pain from a particular region of the body with the overall goal of improving quality of life [1]. In clinical and therapeutic settings, TENS treatment has been relatively successful within the clinical realm for pain management, however, there is scant data within the literature investigating the efficacy and ergogenicity of TENS utilization for weight bearing, muscular endurance exercise [2-4].

In 2003, Rakel and Frantz conducted a study examining 33

post-abdominal surgery patients with the aim of testing the effectiveness of TENS as a supplement to pharmacologic analgesia on pain with movement and at rest. Researchers concluded that TENS used to supplement pharmacologic analgesia was effective in decreasing pain intensity during walking and deep breathing maneuvers and that use of a TENS unit improved the distance and speed subjects could walk post-operatively [2]. In 2010, Hererro and associates were one of the first researchers to use TENS for athletic performance enhancement. Hererro and colleagues [3] focused upon TENS and its influence on muscular strength and anaerobic performance benefits amongst 28 subjects. Results of the study indicated that TENS utilization improved muscular strength performance within the experimental group, but not the control group. There was, however, no benefit from TENS on anaerobic performance between the two groups [3]. Most recently, in 2014, Rakel and colleagues explored the use of TENS to manage pain with the goal of expediting knee recovery in 317 post-operative knee arthroplasty patients. Within the previously-mentioned study, as a supplement to the standardized

pharmacologic analgesic pain management during rehabilitation exercises, the researchers randomly assigned the 317 study participants into three groups that received: 1) TENS, 2) Placebo-TENS, and 3) No TENS. Rakeland associates [4] concluded that TENS is beneficial to reduce movement pain when used alongside with pharmacologic analgesia.

In sum, previous literature revealed that TENS treatment is effective in managing pain, increasing joint range of motion, increasing muscular strength and enhancing low-intensity activities in post-operative patients [2-4]. To date, there is no scientific data investigating the combination of muscular endurance weight bearing exercise and the use of TENS as an ergogenic tool to manage the pain associated with muscular fatigue within an apparently-healthy population.

Against this backdrop, the purpose of this study is to determine the effectiveness of TENS on quadriceps muscular endurance during weight bearing exercise in apparently-healthy, active individuals. The first hypothesis is that individuals utilizing TENS will display a statistical difference in the number of repetitions performed between Sessions 2 and 3 when compared to both the control and placebo group. The second hypothesis is that the placebo group will not display a statistical difference between the number of repetitions performed in Sessions 2 and 3 when compared to the control group.

MATERIAL AND METHODS

Upon approval from the University's Institutional Review Board, 30 subjects (15 male, 15 female) were recruited to participate in the study. Descriptive characteristics of subjects are displayed in Table 1. Informed consent was obtained from each subject prior to participation. To be eligible for participation, subjects were required to not have any previous knowledge of and exposure to TENS. The reason for said requirement was to recruit participants that did not know anything about TENS, especially, how the TENS unit feels upon activation. If subjects recognized how TENS sensed upon activation, this would influence the results for those randomly selected into the Placebo group. Moreover, participants were also required to be familiar with a gym environment and answer "NO" to all seven questions listed in the Physical Activity Readiness - Questionnaire (PAR-Q).

Session One

The purpose of Session 1 was to obtain subject's non-dominant knee extension one repetition maximum (1-RM). Participants warmed up for 5 minutes on a stationary cycle ergometer, stretched, and then proceeded to perform the 1-RM knee extension protocol. The 1-RM assessment was completed and results recorded.

Session Two

The purpose of Session 2 was to obtain subject's baseline, non-dominant maximum knee extension repetitions. Researchers used 40% of the participant's 1-RM obtained in Session 1. Participants warmed up for 5 minutes on a stationary cycle ergometer prior to performing the muscular endurance assessment. Researchers instructed participants to perform as many repetitions as possible, ensuring that the knee angle attained 170°-180° with

Table 1: Descriptive Measurements of Study Participants (N = 30; 15 males; 15 females).

Variables	Control Mean±SD	Placebo Mean±SD	Experimental Mean±SD
Age (yrs)	22.3±4.3	21.0±1.8	21.6±1.8
Height (cm)	171.7±9.3	171.5±8.0	173.1±9.0
Body Mass (kg)	71.1±10.8	72.8±10.6	74.2±14.9
Abbreviations: yrs: Years; cm: Centimeters; kg: Kilograms; SD: Standard Deviation			

each repetition. An auditory metronome was set to 60 beats per minute to maintain a consistent pace throughout the assessment. Testing was terminated when participants either failed to attain full 170° knee extension or failed to keep up with the metronome's 60 beats per minute on two occasions. Maximum numbers of properly performed repetitions were collected and recorded. Prior to Session 3, participants were randomly-selected into the Experimental, Placebo, or Control group by allowing each participant to pull out a slip of paper from a sex-specific bag. Once the slip of paper was selected, it was discarded, thereby ensuring the researchers that there would be an equal distribution of 5 males and 5 females within the Experimental, Placebo, or Control group. Description of Session 3 for each group is described below.

Session Three: Experimental (EXP)

The purpose of Session 3: EXP was to determine if TENS enhanced baseline, muscular endurance knee extension. Participants warmed up for 5 minutes on a stationary cycle ergometer prior to the assessment. Researcher attached one lead with two electrodes to the participant's non-dominant quadriceps. In an effort to provide TENS for the major muscles that were specifically responsible for knee extension and to minimize inter-subject variability of electrode placement, one electrode was placed at the distal end of the Vastus Medialis, while the other electrode was placed at the proximal end of the Vastus Lateralis. Researcher then turned 'on' the BioMed Impulse 2000 TENS Unit (Vista, CA USA) and the unit began to deliver an impulse at a constant pulse rate of 2 Hz and constant pulse width at 160 µs. Participants sat for 10 minutes with the TENS unit activated before beginning the experimental muscular endurance test. Upon completion of the 10-minute rest period, participants performed the muscular endurance test identical to Session 2 while the TENS unit remain activated throughout the testing procedure. Maximum number of properly performed repetitions were collected and recorded.

Session Three: Placebo (PLA)

The purpose of Session 3: PLA was to deploy the conventional sham technique to determine if there is a placebo effect of placing a non-activated TENS unit on subjects while performing the knee extension muscular endurance test. Participants in the PLA group were under the assumption of being in the EXP group and would be receiving TENS during this particular session. Procedures for this session were identical to the aforesaid EXP session, except for the fact that the lead which connected the electrodes to the TENS unit was not activated. Maximum number of properly performed repetitions were collected and recorded. Upon completion

of Session 3, participants were read a debriefing script which informed participants of being randomly-selected into the PLA group and did not receive TENS.

Session Three: Control (CON)

The purpose of Session 3: CON was to obtain pre- and post-knee-extension muscular endurance values without the influence and knowledge of the TENS unit. The CON group mimicked Session 2. Maximum number of properly performed repetitions were collected and recorded.

RESULTS AND DISCUSSION

Analyses were performed using SPSS Version 19. Analysis of covariance (ANCOVA) was used to compare the change in repetitions from Session 2 and Session 3 between each treatment group, while controlling for baseline repetitions. Tukey post-hoc test was used to determine the location of significance between treatment groups.

Table 2 reveals the quantity of male and female study participants within each group, additionally, the maximum number of repetitions performed within Sessions 2 and 3. As displayed within Table 3, results from the one-way analysis of variance (ANOVA) test revealed no significant differences between groups in the number of repetitions achieved at baseline ($p=0.703$) within Session 2, thus, muscular endurance levels within subjects were evenly distributed amongst the 3 groups. Further analysis revealed that EXP group performed significantly more repetitions in Session 3 when compared to the CON group ($p=0.001$) and the PLA group ($p=0.011$) when controlling for baseline repetitions. Because the percent change between the number of repetitions performed between Sessions 2 and 3 for the EXP group was significantly greater compared to the CON and PLA group, the first hypothesis was accepted. Lastly, the second hypothesis was also accepted because the percent change between the numbers of repetitions performed between Sessions

2 and 3 for the CON group was not significantly greater compared to the PLA group.

Findings from the current study are congruent with the study conducted by Hererro et al. [4]. Within the aforementioned 4-week training study, subjects displayed an increase in muscular strength by 40.2% when combined with electromyostimulation. In the current study, EXP subjects displayed an increase of 11.2% in the quantity of muscular endurance between Session 2 and Session 3. Furthermore, results within Hererro and colleagues [4] study also revealed that the subjects receiving electromyostimulation plus weight training elicited greater increases in muscular strength when compared to the subjects that performed the weight training program without electromyostimulation. Said findings are similar to the current study whereby EXP group elicited greater changes in the quantity of repetitions compared the PLA group between Sessions 2 and 3 (Table 3). Moreover, results from the current study concur with the meta-analyses conducted by Harkey and associates [5]. Using a web search spanning from 1965 through 2012, Harkey and colleagues [5] concluded that TENS was the most effective means to enhance disinhibitory voluntary muscular activation of the quadriceps. Given that the EXP subjects within the current study were exposed to TENS prior to and during the trial, these previously-mentioned findings may explain why the EXP group were able to significantly increase the quantity of knee extension repetitions from Session 2 to Session 3.

The current study also revealed no significant differences between the CON and PLA group with respect to the quantity of knee extension repetitions. This finding conflicts with the work conducted by Rakel and associates [4]. More specifically, Rakel and colleagues [4] revealed that there were no significant differences between TENS and PLA-TENS, which suggests that individuals who were expecting to receive TENS, but in actuality, did not, performed equally as well as if they were receiving pain management from TENS treatment. This incongruence may be

Table 2: Maximum Knee Repetitions of Study Participants within each Group for Sessions 2 and 3.

	Control Mean±SD		Placebo Mean ± SD		Experimental Mean ± SD	
	Male (n = 5)	Female (n = 5)	Male (n = 5)	Female (n = 5)	Male (n = 5)	Female (n = 5)
Session 2	20.6 ± 6.7	22.0±6.2	18.8±1.3	21.0±4.2	20.6±3.6	22.2±3.6
Session 3	18.6 ± 4.0	21.4±5.5	19.0±10.8	20.4±4.5	23.6±5.5	24.0±4.5

Abbreviations: SD: Standard Deviation

Table 3: Mean repetitions and percent change between Sessions 2 and 3.

Groups	Session 2 Mean±SD	Session 3 Mean±SD	Change (%)
CON	21.3±6.1 ^a	20.0±4.8 ^b	- 6.1%
PLA	19.9±3.1 ^a	19.7±3.3 ^b	- 1.0%
EXP	21.4±3.5 ^a	23.8±4.7 ^c	+ 11.2%

Significant at $p \leq 0.05$.

^aNo significant difference in baseline repetitions between CON, PLA, and EXP groups.

^bNo significant difference in mean repetitions between Session 2 and Session 3 amongst CON, and PLA groups.

^cSignificant difference in mean repetitions between Session 2 and Session 3 amongst EXP group.

Abbreviations: CON: Control Group; PLA: Placebo Group; EXP: Experimental Group; SD: Standard Deviation

attributed to the difference in which the PLA-TENS was provided between the current study and the study conducted by Rakelet al. [4]. Rakeland colleagues [4] provided a transient sham technique whereby the TENS unit was programmed to deliver current for 30 seconds and then ramp off over the next 15 seconds so that it was active for a total of 45 seconds. This technique allowed the participant to feel the TENS sensation for only 45 seconds, then afterwards, the unit is turned off. The current study, however, mimicked the conventional sham technique similar to the study conducted by Rakel and Frantz [3] whereby the TENS unit displayed an active light indicator, but yet was not emitting any type of current. This difference between transient versus conventional sham techniques may explain the differences in findings between the current study and Rakel and associates [4].

CONCLUSION

In the current study, use of TENS during weight bearing quadriceps muscular endurance activity significantly improves the number of repetitions performed by apparently-healthy individuals. From an applied perspective, findings from this study suggests that TENS may be used by practitioner and clinicians, such as athletic trainers, physical therapists, and exercise physiologists, not only as a therapeutic device, but also as an ancillary tool to potentially augment quadriceps muscular endurance training regimes. Future research investigating the efficacy of TENS and its ergogenic potential is needed, specifically, examining the influence of TENS upon other muscle groups. Additionally, within the current study, TENS stimulation was used prior to and during the muscular endurance trial. It

would be of interest to determine the ergogenicity of TENS and its potential lingering effect if used only prior to exercise and not during the exercise.

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