Effects of Adding Neuromuscular Electrical Stimulation to Traditional Military Amputee Rehabilitation

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ABSTRACT Background: Traumatic transtibial amputations lead to an early decline in the use and weight bearing of the residual limb. These changes result in progressive quadriceps muscle atrophy with strength loss that affects standing and walking. Neuromuscular electrical stimulation (NMES) may be useful as an adjunct to amputee prosthetic rehabilitation to maintain quadriceps muscle strength and mass. The objective of this pilot study was to compare the effects of a home-based NMES rehabilitation program plus the traditional military amputee rehabilitation program (TMARP) to the effects of TMARP alone on quadriceps muscle strength, functional mobility, and pain in military service members after a combat-related lower extremity amputation. Methods: In total, 44 participants, aged 19 to 46 years, with a unilateral transtibial amputation were randomly assigned to the TMARP plus NMES (n = 23) or to TMARP alone (n = 21). Both groups received 12 weeks of the traditional amputee rehabilitation, including pre- and postprosthetic training. Those in the NMES group also received 12 weeks of NMES, 15 to 20 minutes/day, 5 days a week. Participants were tested at 3-week intervals during the study (baseline, 3, 6, 9, and 12 weeks) for muscle strength and pain. For functional measures, they were tested after receiving their prosthesis and at study completion (weeks 6 and 12). Results: In both groups, residual limb quadriceps muscle strength and pain severity improved from baseline to 12 weeks. The NMES plus TMARP group showed greater strength than the TMARP alone group at 3 weeks, before receiving the prosthesis. However, 6 weeks after receiving their prosthesis, there was no group difference in the residual limb strength. Functional mobility improved in both groups between weeks 6 and 12 with no difference between the two treatment groups. Discussion: A home-based NMES intervention with TMARP worked at improving residual limb strength, pain, and mobility. NMES seemed most effective in minimizing strength loss in the amputated leg before receiving the prosthesis. Further research on amputation rehabilitation is warranted as NMES may accelerate recovery post amputation.

INTRODUCTION

Traumatic amputation was a major injury seen during the Operation Enduring Freedom, Operation Iraqi Freedom, and New Dawn conflicts. Between January 2001 and July 2011, combat-related transtibial amputations (TTAs) accounted for 41.8% (n = 683) of U.S. service members' amputations.[1] Only 21.5% of combat amputees return to active duty status[2] and only 31.2% of transtibial amputees return to high-impact recreational activities.[3]

With TTA, early decline in the use of the residual extremity results in progressive quadriceps muscle atrophy with strength loss that affects standing and walking. This loss is implicated in the progression of disability and impaired mobility. One approach that may decrease disuse atrophy in TTA rehabilitation is neuromuscular electrical stimulation (NMES) strength training. NMES is a noninvasive approach that delivers intermittent electrical impulses to stimulate involuntary muscle contractions. NMES has been used to strengthen the quadriceps muscles in individuals with disuse atrophy and in athletes.[4] NMES is particularly useful when the ability to perform volitional exercise is limited as a result of injury or surgery.[4,5] The effectiveness of NMES therapy at increasing strength and function has been demonstrated in those with anterior cruciate ligament reconstruction,[6] total knee arthroplasty,[7] and knee osteoarthritis.[8]

This pilot study compared the effects of the traditional military amputee rehabilitation program (TMARP) plus home-based NMES therapy to the effects of TMARP alone on lower extremity muscle strength, pain, and mobility in unilateral transtibial military amputees.

METHODS

Participants

From a pool of 96 U.S. service members with a traumatic unilateral TTA, 48 participants met inclusion criteria. Recruitment

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Clinical Trial Registration: ClinicalTrials.gov; "Strength, Pain and Function in Operation Iraqi Freedom/Operation Enduring Freedom Amputees: A Nurse-Managed Program": NCT00942890; https://clinicaltrials.gov/ct2/show/NCT00942890.

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occurred at three military medical centers with comprehensive amputee care programs. Inclusion criteria were unilateral TTA, military service member at the time of injury, and age ≥18 and ≤55 years. Exclusion criteria included comorbidities contraindicated for strength training, pregnancy, implanted pacemakers or defibrillators, and comorbid combat injuries severe enough to affect participation. All participants gave written consent and the study was approved by the Institutional Review Board. On the basis of pilot data, the sample size was estimated at 23 subjects per group with an α of 0.05 and power of 0.8 to detect a change of 2.6 kg/wk.

Study Design

We conducted a randomized controlled trial, where all participants received 12 weeks of in-clinic TMARP. Participants assigned to NMES group received 12 weeks of home-based NMES therapy applied bilaterally to the quadriceps femoris muscles.

Participants were randomized to groups after the initial study visit using a blocked randomization scheme from a random number generator. Assignment was concealed until completion of baseline testing. All study visits and testing were conducted during single patient sessions.

Quadriceps femoris muscle strength and subjective outcome measures were assessed at baseline and weeks 3, 6, 9, and 12. After participants received their prosthesis (usually around week 6), functional mobility measures were tested at weeks 6 and 12.

Intervention Programs

Traditional Military Amputee Rehabilitation Program

The TMARP protocol[9] was individualized for amputees on the basis of functional ability, skill level, and other injuries. Preprosthetic training usually began 1 week after final surgical closure of the residual limb, but no later than 6 weeks and generally lasted 6 weeks. The treatment goal was to prepare participants for prosthetic use.

After participants received their prostheses, training focused on prosthetic ambulation, balance drills, and postprosthetic gait analysis. Throughout rehabilitation, participants received cardiovascular training and muscle strengthening. The postprosthetic training lasted approximately 6 weeks.

Home-Based NMES Therapy

In addition to TMARP training, participants in the NMES program performed 12 weeks of bilateral quadriceps neuromuscular strength training at home using the EMPI 300 PV muscle stimulator (EMPI, St. Paul, MN). Subjects sat in a semi-reclined position with knees placed in 0 to 30° knee flexion, using a bed or chair with a footrest. Two reusable electrodes (3 × 5 inches, Axelgaard; EMHI, Miami, Florida) were placed on each leg: one directly over the distal bulk of the vastus medialis muscle about 2 cm above the patella and one over the proximal portion of the rectus femoris muscle. Muscle contractions were elicited by electrical impulses generated by the EMPI 300 PV with a pulsed current programmed for symmetrical biphasic rectangular waves, a rate of 50 pulses per second, duty cycle of 10 seconds on/50 seconds off, and phase width of 300 μs at 50% amplitude. Stimulation alternated between legs with 15 contractions per leg during each session completed 5 days a week. To ensure consistent interventions, participants trained at 30 to 40% of maximal voluntary contraction during weeks 1 to 6, and 40 to 50% of maximal voluntary contraction during weeks 6 to 12; incremental increases were made at each study visit.

At the initial training visit, participants were trained on the 300 PV unit and application of the electrodes. Participants received verbal instructions and printed handouts detailing the proper training procedures to promote self-management of home NMES training. The NMES program used self-management, reinforcement, reeducation, and logs to promote adherence to the regime. Participants completed training logs reporting date, duration, and maximum amplitude achieved at each NMES home session. Pain levels were also recorded before and after NMES.

The first 5 minutes of each study visit reviewed training logs and pain levels to determine whether NMES goals were being met and to troubleshoot any issues. Participants were taught during study visits to adjust the amplitude required to achieve the desired goal during their home training sessions.

Follow-up telephone calls and text messaging to the NMES group tracked compliance with the NMES therapy throughout the study. For all participants, phone calls and texts were made to remind all participants of their study visits, track pain levels, and to control for individual contact made through phone calls and texts to participants in the NMES group.

Outcome Measures

Lower Extremity Muscle Strength

Isometric knee extension and flexion measurements were performed using the Nicholas Manual Muscle Tester (NMMT) (kg) (Lafayette Instruments; Lafayette, Indiana).[10] To reduce the influence of tester strength, the adjustable strap attachment from Ergo-Kit Manual Muscle Tester system was used for stabilization of the NMMT during strength testing (Workability Systems, Cincinnati, Ohio). Participants were positioned in an isometric testing chair with adjustable seat height, so that the legs dangled vertically. They were secured with Velcro straps and the seat was adjusted to support the femur in 90° of hip flexion. The participant's knees were placed in 70° flexion. Using the NMMT, knee flexion and extension were tested at (1) 5 cm distal to the tibial tuberosity (both legs) and (2) 60% of the distance from the tibial tuberosity to the medial malleolus (intact leg only).

For each location, participants performed three maximal efforts holding each contraction for 4 seconds, separated by 30-second rest intervals. The highest value of the three trials was accepted.

Pain Intensity

Two subscales of the Brief Pain Inventory (BPI)[11] were used for pain intensity: pain severity and pain interference during daily activity. Pain severity, a 4-item subscale, assesses pain at its "worst,""least," "average," and "current" level, with scores ranging from 0, no pain, to 10, pain, as bad as one can imagine. A mean severity pain score was calculated from the four items. Pain interference was measured as how pain hindered daily activities including general activity, walking, work, mood, enjoyment of life, relations with others, and sleep. The interference score represented the mean of the seven items. Initially developed to assess pain in cancer patients, the BPI has been validated with other patient populations with nonmalignant pain.[12]

Compliance/Adherence to Treatments

Adherence with the NMES intervention was measured in two ways. Participants kept daily training logs reporting each NMES session. Second, a hidden compliance monitor in the 300 PV gave the total number of sessions performed, total session time in hours, and the average session time in minutes. For a session to be recorded, the participant had to complete the entire 15-minute treatment, and wait for the device to complete the full timed cycle before turning the power off. Overall adherence was defined as the percentage of prescribed sessions (5 per week) that were completed according to the daily training log.

Demographic Information

Participants provided self-report of date of birth, gender, rank and race, and mechanism of injury. A brief medical history questionnaire was completed to assure safe usage of the EMPI 300 PV stimulator.

Functional Mobility

We used four tests to quantify functional mobility postprosthesis, at weeks 6 and 12. These tests could only be performed by participants who were able to walk with a prosthetic.

Timed Up and Go Test

The timed up and go test (TUG)[13] assessed mobility through the assimilation of walking, turning, balance, and transfer. Using a standard height armchair, participants were seated with their back against the chair and arms resting on the chair's arms. On the command "go," the participant stood, walked 3 m at a normal pace, turned around, returned to the chair, and sat down. Before assessment, one practice test was performed. Participants were instructed to complete the test at a comfortable speed. Using a stopwatch, participants were timed to the nearest second.

30-Second Chair Stand Test

The 30-second chair stand tested lower-body strength and dynamic balance.[14] Participants were instructed to sit in the middle of the chair, feet flat on the floor with arms crossed against the chest. On the command "go," the participant rose to a full stand with hips and knees fully extended, and then returned to a fully seated position. In 30 seconds, participants completed as many full stands as possible, and the number of completed rises was recorded.

Timed Stair Climb Test

The timed stair climb test (SCT)[14] measured the time required for participants to ascend and descend 4 steps while wearing their prosthesis. Participants were instructed to go up 4 steps (6-inch rise, 11.5-inch run) to a 30-inch square platform, turn around, and then return to the bottom of the stairs at a self-selected pace. Handrails were used if needed. Two trials were averaged to produce a single score.

2-Minute Walk Test

The 2-minute walk test (2-MWT)[14–16] measured the distance an amputee walked at a usual pace and a fast pace over a 2-minute period. Participants were allowed to stop or use an assistive device if needed. This test assessed the participant's functional mobility or prosthetic walking speed.

Statistical Analyses

The primary goal of the analyses was to test for differences between the groups (TMARP plus NMES vs. TMARP alone) over time (baseline, 3, 6, 9, and 12 weeks) on lower extremity strength and pain. We also examined group differences postprosthesis for functional mobility at 6 and 12 weeks. Statistical analyses were completed using R, version 3.1.2 (www.r-project.org). Baseline characteristics were compared between groups using an independent sample t test for continuous variables and Fisher's exact test for categorical data. Using intent-to-treat analyses, all participants were included in their assigned treatment group. Multiple imputation was used to address missing data. Twenty datasets were prepared using the program Amelia II.[17]

Robust regression models were constructed to (1) examine the relationships of the outcome measures with time, group, and a time-by-group interaction over the trial's 12 weeks using linear mixed effects, (2) compare outcomes for groups at each observation time using linear regression, and (3) compare outcomes at time points from 3 to 12 weeks by groups, adjusting for prior visit measurements using linear regression to show change over time in each group. Robust linear regression was performed using the function rlm from the MASS library[18] or zelig (http://zeligproject.org) and robust linear mixed models used the package robustlmm in R. Robust regression minimizes the outlier effects of outliers by using M-estimators rather than ordinary least squares estimation. The models were calculated for each of the 20 imputed datasets, and the mean and standard errors for the coefficients were estimated using standard approaches for multiple imputation.[17] p values were estimated with degrees of freedom estimated using the method described by Rubin.[19] Two-sided p values of ≤ 0.05 were used to define statistical significance.

RESULTS

Study Attrition

The study assessed 110 participants for eligibility and 48 participants enrolled in the study (Fig. 1). Four participants withdrew before collection of baseline data. The randomized sample included 23 participants in the NMES and 21 in the TMARP groups. Ten participants withdrew before completing the study (see Fig. 1). Of the total 14 who withdrew, 8 were in the NMES group and 6 in the TMARP group ($p = 0.54$).

Characterization of Completers

Completers did not differ from noncompleters on age ($p = 0.67$), race ($p = 0.44$), mechanism of injury ($p = 0.T$), or rank ($p = 0.8$), lower extremity muscle strength for the residual limb (knee extension: $p = 0.61$; knee flexion: $p = 0.43$) or the intact limb (knee extension: $p = 0.63$; knee flexion: $p = 0.54$). There were also no differences on BPI pain severity scores ($p = 0.81$) and BPI interference scores ($p = 0.87$).

Adherence

Adherence on the basis of participant's self-reported daily logs showed use of the unit for approximately 50% of the recommended sessions whereas the 300 PV compliance monitor showed a 27% adherence rate. A limitation of the 300 PV compliance monitor is if the device is turned off before completing its timed cycle, the device will not record the session time.

Participant Characteristics

There were no pretreatment demographic differences between the two study groups or in baseline levels of lower

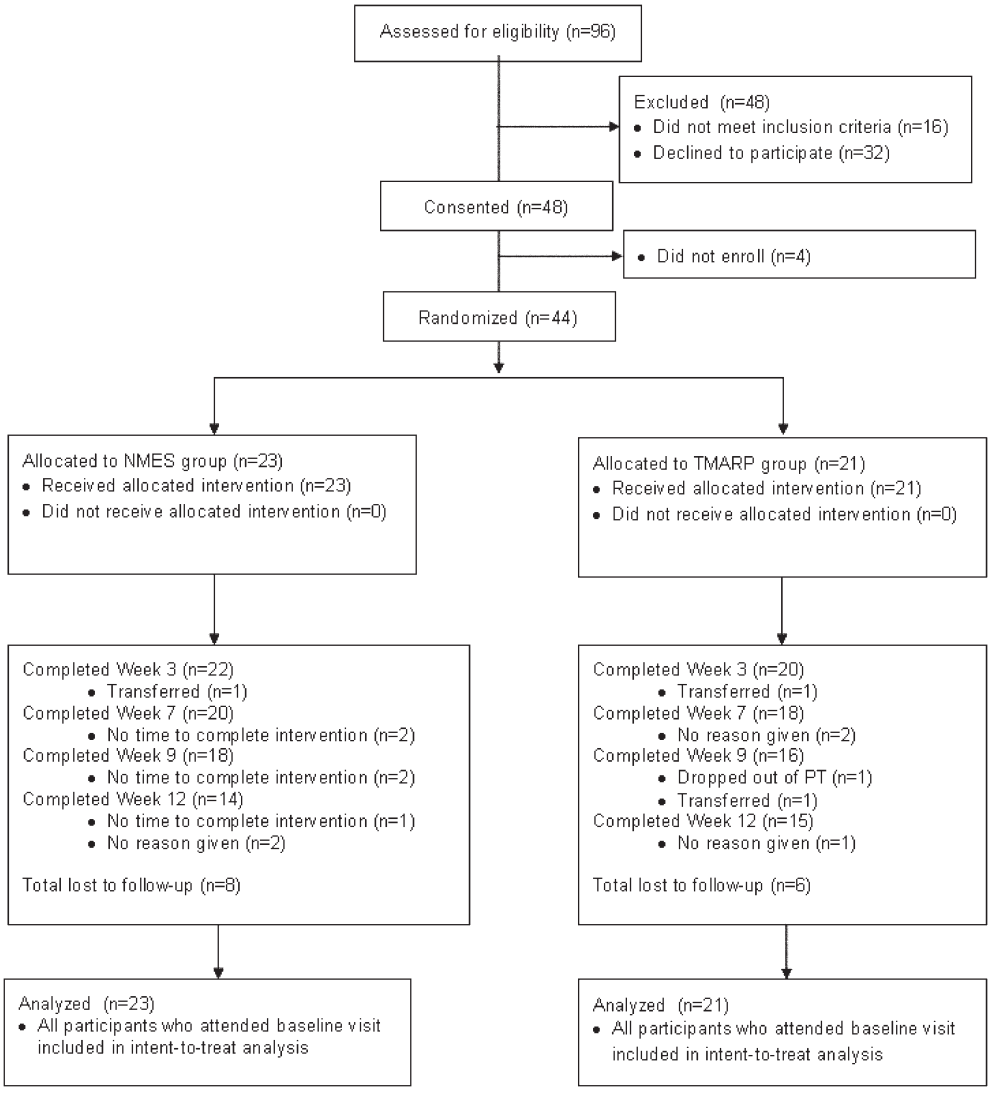

FIGURE 1. Participant flow diagram.

extremity strength, functional mobility, or pain (Table I). At entry into the study, the two treatment groups showed similar strength in the intact and amputated legs, though the amputated leg was 40 to 50% weaker than the intact leg (Table I). Pain was reported by most subjects with similar levels in both groups.

Lower Extremity Muscle Strength

Lower extremity muscle strength improved during the study for both treatment groups (see Table II). The most marked increases in strength (measured 5 cm below the tibial tuberosity) were found in the residual limb (TMARP plus NMES: 62.1% knee extension, 53.5% knee flexion; TMARP only: 47.3% knee extension, 31.8% knee flexion) as compared to the intact limb (NMES: 14.1% knee extension, 5.8% knee flexion; TMARP: 7.2% knee extension, 13.4% knee flexion). Although the increases were greater in the TMARP plus NMES group than in the TMARP only group, no significant differences were observed for either the group effect or interaction between group and time (Table II). There

TABLE I. Baseline Participant Characteristics by Study Group ($N = 44$)

	Neuromuscular Electrical Stimulation Group ($n = 23$)	Traditional Military Amputee Rehabilitation Program Group ($n = 21$)	p Value
Demographics			
Age, Years[a]	26.5 (5.9)	27.1 (6.3)	0.74[b]
Male, *n* (%)	22 (96)	21 (100)	1.00
Race, *n* (%)			0.70[c]
White	18 (78)	17 (81)	
African American	2 (9)	0 (0)	
Asian/Pacific Islander	0 (0)	1 (5)	
Other	1 (4)	2 (10)	
Mechanism of Injury, *n* (%)			0.61[c]
Land Mine	3 (13)	1 (5)	
Improvised Explosive Device	16 (70)	15 (71)	
Projectile (Gunshot/Grenade)	3 (13)	1 (5)	
Motor Vehicle Accident	0 (0)	1 (5)	
Other	1 (4)	3 (14)	
Time From Injury to Amputation, *n* (%)			
≤30 Days	17 (74)	17 (81)	
30–365 Days	2 (9)	1 (5)	
>365 Days	4 (17)	3 (14)	
Rank, *n* (%)			0.78[c]
Enlisted	20 (87)	18 (86)	
Officer	3 (13)	1 (5)	
Completed Program, *n* (%)	15 (65)	15 (71)	0.75[c]
Physical Performance			
Residual Leg Strength (kg-force)			
Upper			
Extension[d]	26.4 (13.4)	24.5 (10.7)	0.60[b]
Flexion[d]	14.4 (6.3)	14.8 (8.6)	0.84[b]
Intact Leg Strength (kg-force)			
Upper			
Extension[d]	45.3 (17.9)	46.0 (24.4)	0.91[b]
Flexion[d]	27.6 (10.8)	26.2 (6.8)	0.60[b]
Lower			
Extension[e]	39.1 (16.5)	39.0 (11.9)	0.99[b]
Flexion[e]	21.0 (8.3)	23.4 (8.4)	0.45[b]
Functional Tests			
Timed Stair Climb (Seconds)	7.8 (4.4)	7.4 (2.9)	0.73[b]
30-Second Chair Stand (No. Rises)	15.7 (8.0)	16.9 (7.4)	0.66[b]
Timed Up and Go (Seconds)	7.7 (5.1)	7.3 (2.7)	0.78[b]
2-Minute Walk (Inches) Fast	6678 (1745)	6871 (1601)	0.77[b]
2-Minute Walk (Inches) Usual	4504 (1823)	5143 (1600)	0.30[b]
BPI			
Severity	3.3 (1.5)	2.9 (1.5)	0.41[b]
Interference	3.1 (2.4)	2.9 (2.4)	0.79[b]

Statistics based on raw data. No baseline differences between groups were statistically significant. [a]Values are *M* (SD). [b]Independent samples *t* test. [c]Fisher's exact test. [d]Measured at 5 cm distal to tibial tuberosity. [e]Measured at 60% of distance from tibial tuberosity to medial malleolus. No baseline differences between groups were statistically significant.

TABLE II. Lower Extremity Muscle Strength, Pain, and Functional Mobility by Study Group ($N = 44$)

	Neuromuscular Electrical Stimulation Group ($n = 23$)					Traditional Military Amputee Rehabilitation Program Group ($n = 21$)					Robust Linear Regression Model (t)		
	Week 0	Week 3	Week 6	Week 9	Week 12	Week 0	Week 3	Week 6	Week 9	Week 12			
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	Time	Group	Group × Time
Strength													
Residual Limb													
Extension (kg-force)	26.4 (13.4)	34.1[a] (12.7)	36.9[a] (12.6)	39.1[a] (16.5)	42.8[a] (14.8)	24.5 (10.7)	27.6 (12.5)	33.8[a] (17.3)	35.7[a] (14.0)	36.1[a] (15.4)	3.73[b]	0.66	0.89
Flexion (kg-force)	14.2 (6.2)	16.7 (7.0)	18.7[a] (6.9)	19.9[a] (7.6)	21.8[a] (6.6)	14.8 (8.5)	14.8 (7.4)	16.8 (7.3)	18.4 (7.5)	19.5[a] (8.4)	3.15[b]	0.30	0.71
Intact Limb													
Extension (kg-force)	45.4 (17.6)	41.4 (16.1)	45.2 (13.7)	45.7 (16.1)	51.8 (16.6)	45.7 (23.8)	45.2 (24.3)	45.0 (19.5)	46.0 (16.7)	49.0 (20.7)	1.30	0.20	0.57
Flexion (kg-force)	27.8 (10.7)	28.7 (9.4)	32.2 (10.3)	30.9 (9.7)	29.4 (9.9)	25.4 (7.1)	27.1 (10.2)	26.9 (10.9)	28.8 (9.9)	28.8 (10.1)	1.26	0.93	−0.20
Pain													
BPI Score													
Severity	3.3 (1.6)	2.4[a] (1.6)	2.2[a] (1.4)	2.6 (1.7)	2.4[a] (1.9)	2.9 (1.5)	2.6 (1.4)	2.2 (1.7)	2.2 (1.6)	1.8[a] (1.6)	−2.32[c]	−0.09	0.59
Interference	3.1 (2.4)	2.2 (2.0)	2.4 (2.3)	2.8 (2.7)	2.7 (2.8)	2.9 (2.4)	2.5 (2.2)	2.3 (2.6)	2.0 (2.5)	2.1 (2.5)	−1.2	−0.15	0.90
Functional Mobility													
Timed SCT[d] (Seconds)			7.5 (4.4)		5.6[e] (4.0)			7.8 (3.8)		4.7 (3.3)	3.07[a]	−0.83	
30-Second Chair Stand Test[d] (No. Rises)			15.7 (8.4)		19.4[e] (9.2)			18.1 (11.4)		21.7[e] (9.9)	3.21[b]	0.06	
TUG[d] (Seconds)			7.7 (4.8)		7.1[e] (4.4)			7.3 (3.9)		6.3[e] (3.5)	3.53[b]	0.69	
2-MWT[d] (Inches)			4,452 (1,949)		5,657 (1,919)			5,081 (2,324)		5,853 (2,420)	3.17[b]	0.01	
Usual Pace													
2-MWT (Inches)			6,369 (2,316)		7,692 (2,072)			7,308 (2,557)		8116 (2,763)	5.65[b]	0.11	
Fast Pace													

Statistics based on imputed data; strength measured at 5 cm distal to tibial tuberosity. [a]Significant within-group change from baseline ($p < 0.05$). [b]$p < 0.01$. [c]$p \leq 0.05$. [d]Adjusted for baseline. [e]Significant within-group differences from week 6 to week 12 ($p < 0.05$).

was a significant main effect of time for residual limb strength knee flexion and knee extension (p = <0.01); however, for the intact limb, the change was not significant.

Focusing on knee extension, Figure 2 presents post hoc comparisons between the two treatment groups at each testing session. In Figure 2A, residual limb strength at week 3, before subjects receiving their prosthesis, was significantly greater in the TMARP plus NMES group than in the TMARP group, adjusted for baseline strength (p = 0.04). By week 6, strength in the amputated leg was comparable in the two groups. The intact leg was stronger than the residual leg (Fig. 2B) at all time points.

Pain Levels

No group differences were observed in pain reported by the two groups during the study (Table II) for either the BPI severity or interference scores.

Functional Mobility

Functional mobility was assessed at week 6 (when the prosthesis had been received) and at week 12 (Table II). At week 6, no difference was observed between the two treatment groups on any functional mobility measurement. Between weeks 6 and 12, both groups showed improvement in mobility, but no differences were observed between the groups (Table II).

DISCUSSION

This study examined a novel approach to prosthetic rehabilitation for wounded warriors with unilateral TTA, combining NMES home-based therapy with in-clinic amputee rehabilitation. Both groups improved strength in the residual limb. It appeared that in the TMARP plus NMES group, the amputated extremity showed better strength recovery before receiving the prosthesis. This finding may suggest that home-based NMES program with in-clinic rehabilitation may assist in maintaining muscle mass and strength following amputation before receiving a prosthesis, but further studies in transtibial amputees are needed to affirm this conclusion.

Our observation that the addition of NMES to in-clinic prosthetic training may be valuable in the early phase of rehabilitation preprosthesis is consistent with other recent reports. A recent review[5] examining the evidence for adding NMES to volitional exercise during immobilization, found that NMES appeared to give greater strength improvement than volitional exercise alone. Similar findings were seen in a randomized controlled trial combining NMES with standard knee rehabilitation in postsurgery anterior cruciate ligament reconstruction.[20] The researchers found less strength deficit at 6-weeks postsurgery in the combined NMES/rehabilitation group, than controls; furthermore, the NMES subjects were stronger at study completion. Also, Paillard's[21] review examined the combined therapies of NMES and volitional exercise in postoperative knee-injured patients concluded that NMES complements voluntary exercise in the early phase of rehabilitation reducing postoperative muscle weakness by promoting strength increases. These studies of combined NMES therapy in immobilized postoperative subjects suggest that among transtibial amputees, combined NMES with in-clinic rehabilitation during the period before receiving their lower limb prosthesis may be helpful in improving quadriceps strength and reducing muscle atrophy, but further research is required to assess this potential benefits.

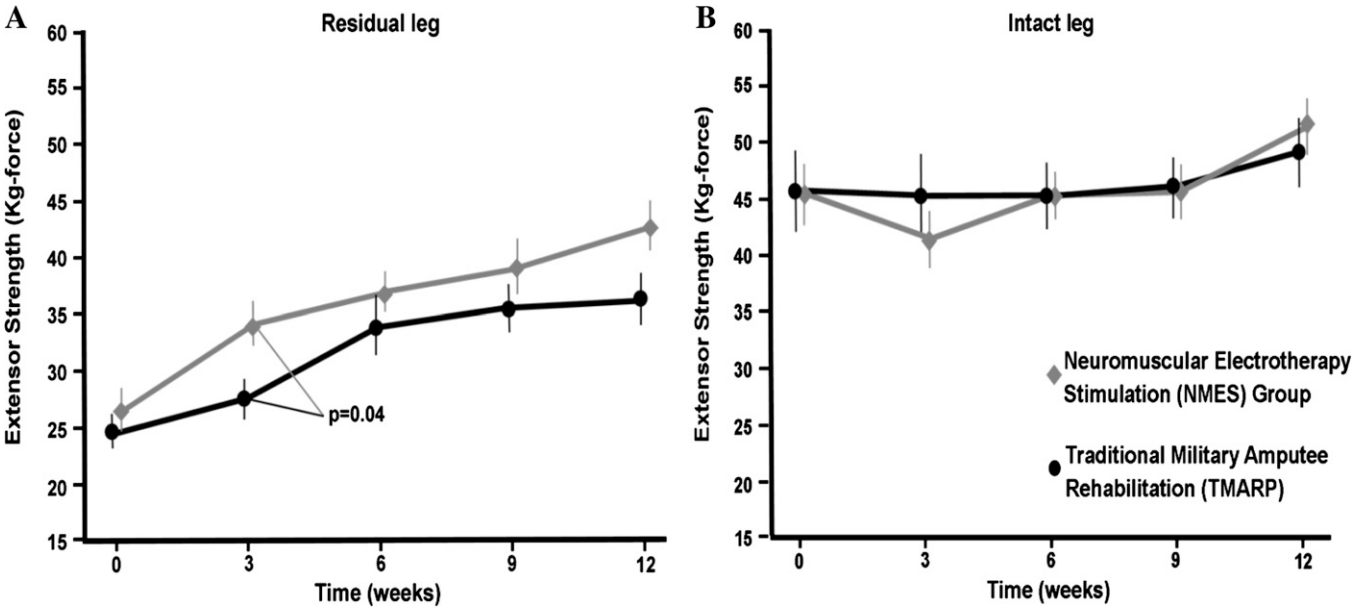

FIGURE 2. (A) Knee extensor strength for the residual leg and (B) intact leg at baseline, 3, 6, 9, and 12 weeks for the two treatment groups.

Limitations

A number of the study limitations need to be acknowledged. The sample was small and limited to active duty military amputees. We saw strength increases in both groups; however, we did not have the power to show group differences. The Nicholas Manual Muscle Test used to evaluate quadriceps muscle strength may not have detected small changes in strength that occurred. Compliance monitoring also had limitations. For those in the NMES group, compliance data were difficult to authenticate for the 300 PV in part because if the participant turned off the 300 PV before completing the training cycle, none of the time usage was recorded.

Conclusions

Despite limitations, this pilot study has implications for postamputation recovery. Using a NMES home-based therapy with traditional in-clinic physical therapy has potential to reduce muscle atrophy and minimize strength loss in the amputated leg during the preprosthetic period. In this study participants were generally young and healthy before amputation, and received extensive rehabilitation. In contrast, many community amputees receive less rehabilitation,[22] and are often in poorer physical condition. The addition of home-based NMES in this population may show greater improvements, and would benefit from further research.

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