

Preserving Bone Health After Acute Spinal Cord Injury: Differential Responses to a Neuromuscular Electrical Stimulation Intervention

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Abstract

Objective: *Determine factors associated with improved response of bone to an intensive neuromuscular electrical stimulation intervention (NMES) after acute spinal cord injury (SCI).*

Design: *Randomized controlled trial.*

Participants/methods: *Individuals with C4 to T12 ASIA A or B SCI, less than 12 weeks post-injury. The control group received usual care and the exercise group received one hour electrical stimulation 5 days a week for six weeks. Dual-energy X-ray absorptiometry (DXA), measures were collected at baseline, post-intervention, and 6 months follow up. This study was based on between-subjects research design. Bone density between groups via DXA measure at baseline and 3 month follow up was analyzed using Two-Way ANOVA model.*

Results: *25 participants have completed the trial. Participants under age of 21 years who received NMES had a gain in bone density compared to those receiving NMES who were older than 21 ($p=.0001$). Participants with a body mass index (BMI) less than 18.5 had significantly less BMD at baseline compared to those with higher BMI ($p=.001$). After intervention, the low BMI group who received NMES demonstrated a gain in bone mass during the period of follow-up (Initial BMD 0.97 g/cm^2 vs Post-intervention BMD 1.1 g/cm^2). This is in contrast with the low BMI controls who had BMD decreased from 0.9 g/cm^2 to $.634 \text{ g/cm}^2$ ($p=.02$).*

Conclusion: *Interim DXA results demonstrate trends toward a larger effect of NMES in the population under the age of 21 and participants with a lower baseline BMI.*

1 Introduction

Osteoporosis is a well-known secondary condition that occurs rapidly after acute SCI and continues throughout the lifespan of the individual. Nearly one third of bone loss occurs within the first 3-4 months post-SCI [9], and continues to a lesser degree over the next couple of years [3], [5].

Previous studies have used electrical stimulation for lower extremity ergometry [1], [4], [7], standing [14] and strengthening [2] in chronic and acute SCI, ranging in frequency of training in number of days per week, and duration ranging from weeks to months. Results have been inconclusive [6], [7], [11], [12]. Belanger, et al. [2] found a positive increase in BMD was seen with an increase in frequency to 5 days a week in electrical stimulation with resistance training.

This study is currently being conducted at the National Rehabilitation Hospital, to determine if an intensive NMES intervention could prevent loss of BMD after an acute SCI. Interim DXA results from this study have been presented previously [11]. These interim results showed that at baseline there were no differences between the control and NMES group, and at 3 months post intervention there was a significant difference ($p=.05$) between the control and NMES at the distal femur and proximal tibia indicators, demonstrating retention of bone for the NMES group and a continued loss of BMD for the control group.

A new objective with this study, is to determine if there are individual factors associated with improved response of bone to intensive NMES after acute SCI.

2 Methods

All patients were recruited during acute rehabilitation at the National Rehabilitation Hospital (NRH) in Washington, D.C. Inclusion

criteria included: 18 years of age or older, traumatic SCI C4 to T12, ASIA A or B, less than 12 weeks post injury, and spinal cord lesion above T12. Patients with a history of cardiovascular disease, malignancy, menopause, abnormal thyroid function, recent corticosteroid use greater than 14 days, or taking bisphosphate or parathyroid hormone (PTH) were excluded.

The control group received usual standard care and the exercise group received one hour electrical stimulation 5 days a week for six weeks. Outcome measures were collected at baseline, post-intervention, and 3 months post-injury, and included: DXA, CT, serum osteocalcin, alkaline phosphatase, serum calcium, N-telopeptide, and urine calcium.

The intervention group received electrical stimulation their quadriceps bilaterally for 1 hour, or until fatigue, 5 days a week for 6 weeks. Electrical stimulation was administered using a Compex Motion Stimulator[®] (Compex SA, Zurich, Switzerland) and surface electrodes. Surface electrodes were placed 15cm laterally, and 5cm medially from the superior patellar margin. Stimulator settings were as follows pulse duration 300 μ sec, pulse frequency 25 Hz, amplitude 0-150mA, and On: Off time 5sec: 5sec. The lower extremities were positioned at a 70 degree knee flexion and stimulated to achieve full knee extension. PT monitored each exercise session for consistency and each patient in exercise group for any complication with the electrical stimulation.

Measurements:

BMD was determined by use of DXA. The DXA's were performed at the Washington Hospital Center, an NRH sister facility, using the Lunar Prodigy Bone Densitometry System (Lunar Corporation, Madison, WI).

Measurements were taken of the lumbar spine, femoral neck, distal femur and proximal tibia. The modified lumbar protocol was applied to the distal femur and proximal tibia [8], [13]. The same DXA radiologist was used for testing and participant setup. Measurements were taken of the legs bilaterally. The DXA was taken initially and repeated at post-intervention, and 3 months post-intervention.

Bone density of the distal femur and proximal tibia between groups was analyzed using a Two-Way ANOVA.

3 Results

27 participants have enrolled, and 25 participants have completed this trial (13 exercise, 12 control). A Two-Way ANOVA analysis of the distal femur and proximal tibia DXA results was performed between subgroups. Based on the population characteristics we analyzed age, gender, level of injury, and body mass index (BMI). We found no significant difference between gender and level of injuries. Significant differences were seen between age and BMI groups. Participants 21 and older showed a trend for less bone density loss with NMES, though not significant ($p=.74$) Participants under the age of 21 years who received NMES had significantly less bone loss than those receiving NMES who were older than 21(exercise group showed 16% increase in BMD, whereas the control group showed 59% loss in BMD ($p=.0001$). Participants with a BMI less than 18.5 had significantly less BMD at baseline compared to those with higher BMI ($p=.001$). After intervention, the low BMI group who received NMES demonstrated a gain in bone density during the period of follow-up (Initial BMD = 0.97 g/cm² at the distal femur and proximal tibia vs. Post-intervention BMD 1.1 g/cm² at the distal femur and proximal tibia; $p=0.02$). This is in contrast with low BMI controls who did not receive NMES training, the BMD decreased from 0.98 g/cm² to .63 g/cm² at the distal femur and .81 g/cm² to .49 g/cm² ($p=.001$) at the proximal tibia.

4 Discussion and Conclusions

Presented data supports our hypothesis that an intensive lower extremity NMES program appears to delay BMD loss after acute motor complete SCI. A larger effect of an acute NMES program in the population under the age of 21 and participants with lower BMI was demonstrated. These preliminary results indicate that a subpopulation in acute SCI with a low BMI at baseline and or under the age of 21 may preferentially benefit from and intensive e-stim intervention to preserve bone health.

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