



Case Report

Changes in gait kinematics and lower back muscle activity post-radiofrequency denervation of the zygapophysial joint: a case study

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Abstract

BACKGROUND CONTEXT: Using diagnostic anesthetic blocks, the lumbar zygapophysial (facet) joint has been shown to be the primary cause of pain in approximately 15% of patients with chronic low back pain. Radiofrequency neurotomy (RFN) of the lumbar medial branch innervating the zygapophysial joint has been shown to provide a significant decrease in pain in patients selected by dual comparative anesthetic blocks, but quantitative improvements in mobility have not been fully elucidated. A theoretical concern with RFN is that the multifidus muscle, a stabilizing paraspinal muscle, is also denervated during this procedure, which may have adverse effects on mobility and spine stability.

PURPOSE: The purpose of this study was to examine gait kinematics and muscle activity of the low back during treadmill walking both before and after RFN.

STUDY DESIGN: Case study.

PATIENT SAMPLE: One 33-year-old female, with 15 years of chronic left low back pain and a diagnosis of L4/L5 lumbar zygapophysial joint pain by dual comparative anesthetic blocks was studied.

OUTCOME MEASURES: Self-reported measures of perceived pain and effort; in addition to physiologic measures of heart rate, gait kinematics and surface electromyography (EMG) activity of the multifidus and erector spinae muscles were collected before and after the procedure.

METHODS: The participant walked for 15 consecutive minutes on a treadmill. The first and last 5-minute intervals were at a self-selected pace, and the middle 5-minute interval was at a 50% increase of the self-selected pace. Gait kinematics and lumbar paraspinal surface EMG activity were recorded during the last minute of each walking interval. Heart rate, perceived effort, and perceived pain were also collected at the end of each walking interval. Data were collected both 7 and 1 days before RFN, and on the following days post-RFN: 0, 8, 14, 28, and 58.

RESULTS: Perceived effort did not change despite an increase in treadmill speed and heart rate. Pain decreased by 60% in the first two weeks and by 92% by 4 weeks post-RFN. There were also gradual positive changes in gait kinematics across all post-sessions and an immediate and sustained decrease in surface EMG activity over the left multifidus and erector spinae muscles following RFN.

CONCLUSIONS: The results of this pilot study are the first to show quantitative positive changes in gait and muscle activity post-RFN, suggesting that the relationship between this procedure and mobility warrant further investigation. © 2013 Elsevier Inc. All rights reserved.

Keywords:

Radiofrequency denervation; Lumber zygapophysial pain; Gait; EMG

FDA device/drug status: Not applicable.

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Introduction

A World Health Organization study in the primary care setting reported an overall prevalence of persistent pain in 20% of primary care patients, with approximately 48% of those patients reporting low back pain [1]. Using diagnostic

anesthetic blocks, the lumbar zygapophysial joint (aka facet or z-joint) has been shown to be the primary pain generator in 15% of patients with chronic low back pain [2]. Current treatment options for lumbar zygapophysial joint pain include medical management, physical therapy, interventional procedures, and surgery [2]. Conservative therapy with medical management has been shown to be effective at reducing pain [3–8], yet no studies to date have shown the ability of oral or topical medications to completely eliminate lumbar zygapophysial joint pain. There is also little evidence to support the use of one medication over another [9–11]. Procedural interventions for zygapophysial joint pain are the second most common type of procedure performed in pain management centers throughout the United States [2]. Yet, the effect of these procedures on mobility and pain has not been fully elicited.

Radiofrequency neurotomy (RFN) is a procedure where a controlled burn is generated via radiofrequency energy through a small diameter probe. This procedure can apply a thermal burn to the lumbar medial branch nerves, which innervate the lumbar zygapophysial joint, thus hopefully diminishing its afferent pain signals. When used with correct technique on patients selected via dual comparative medial branch blocks, this procedure has been shown to provide a significant decrease in lumbar zygapophysial joint pain [2]. The literature does however have mixed results because of differences in patient selection criteria and technique used [12–16], with reports of sustained relief of back pain in 50% to 80% of subjects without previous back surgery and 35% to 50% of patients with failed back surgery syndrome [17–20].

Rotational movements of the trunk that require stabilization of the spine occur normally during walking [21]. Muscular co-contraction of anterior and posterior trunk muscles, including the multifidus, is felt to be the major stabilizing mechanism of the spine [22–24]. However, during RFN, the multifidus is denervated. Previous research has shown that a loss of reflexive activity of the multifidus muscle may result in instability and injury of the spine [25]. Taken together, this would suggest that while RFN may reduce zygapophysial joint generated pain in those selected via dual comparative medical branch blocks, there may also be significant changes in mobility and stabilization of the spine. Yet, to date, no study has examined changes in mobility and associated muscle activity pre- and post-RFN in patients with block confirmed lumbar zygapophysial joint pain. The purpose of this case study was to examine the effects of RFN on gait and muscle activity in the low back. Self-reported measures and physiological measures including gait kinematics and surface electromyography (EMG) activity over the multifidus muscle were collected during treadmill walking pre- and post-RFN. We hypothesized that low back pain and surface EMG activity over the low back would decrease, but there would be no changes in gait kinematics from pre- to post-RFN.

Methods

This case study included one 33-year-old female ex-collegiate volleyball player with 15 years of chronic left low back pain without radiation, which was worse with extension. She reported difficulties with walking for more than 15 minutes without pain and limitations in her normal activities of daily living. She had a normal neurologic examination with a negative seated slump test. She had no pain with multiple sacroiliac joint provocative tests including hip flexion abduction and external rotation, thigh thrust, sacral distraction, sacral thrust, and gaenslen's tests. She also had no pain with hip internal or external rotation or flexion adduction and internal rotation (FAIR test). Her only positive physical examination findings were pain with lumbar spine extension and tenderness to palpation over the left lower paraspinals at the L4–L5 spinal level (which was confirmed by palpation under fluoroscopic guidance). Her magnetic resonance imaging showed lumbar spondylosis affecting left L4–L5 zygapophysial joint (Fig. 1), with no evidence of spondylolisthesis or spondylolysis. Her symptoms lead to the presumptive diagnosis of lumbar zygapophysial joint pain. She failed multiple conservative therapies including non-steroidal anti-inflammatory medications, extensive physical therapy, and even an intra-articular injection of corticosteroid in the left L4/L5 zygapophysial joint. She underwent dual, comparative, medial branch blocks targeted at the left L3 and L4 medial branches that innervate the left L4/L5 zygapophysial joint. The first block was done with 0.3 cc of 0.5% marcaine and the second block with 0.3 cc of 2% lidocaine. She had 100% short-term pain relief with each block that corresponded to the length of the respective anesthetic. She therefore underwent RFN of the left L4–L5

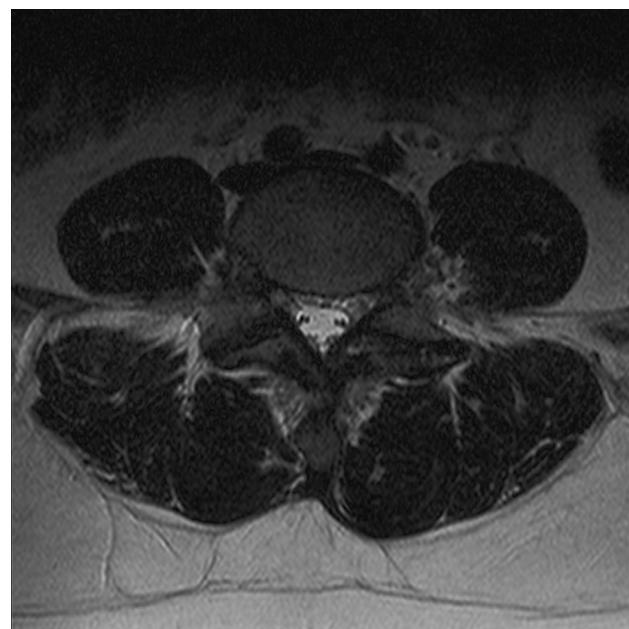


Fig. 1. Magnetic resonance imaging showing lumbar spondylosis affecting left L4–L5 zygapophysial joint.

zygapophysial joint using the guidelines published by the International Spine Intervention Society [26].

During this procedure, the left L3 and L4 medial branches were targeted with an 18 gauge curved sharp tip introducer needle, with a 10 mm active curved tip. The probe was placed parallel to the medial branches at the junction of the transverse process and superior articular pillar on both the L4 and L5 vertebral bodies. Motor and sensory stimulation was conducted. Sensory stimulation with 0.2 volts of 1.0 ms duration at 50 Hz stimulation produced her typical pain. Motor stimulation with 0.3 volts of 1.0 ms duration at 2 Hz resulted in multifidus twitching with no leg twitching noted. After instillation of 1 mL of 0.5% marcaine and a 35-second warm up period, a single continuous lesion was applied for 90 seconds at 80°C at each level. A second parallel lesion was also applied to increase the total burn area. She received no additional therapy, intervention, or medication throughout the time course of the study.

A total of seven sessions of data were collected before and after this procedure; 7 days prior, 1 day prior, as well as Days 0, 8, 14, 28, and 58 post-RFN. During each session, gait kinematics and surface EMG were collected while the participant walked on a treadmill for 15 consecutive minutes. To facilitate accurate comparison between sessions, data were collected at the same time of day and the participant was asked to maintain her normal routine in regard to liquid consumption and activity level before each collection. In addition, surface EMG electrode placement was measured [27] by the same researcher and maintained in the same location as accurately as possible for each collection. For each 15-minute session, the participant walked for 5 minutes at a comfortable self-selected speed, followed by an increase of 50% of this speed for 5 minutes, and then followed by 5 minutes at the original self-selected speed. This protocol was used to examine changes in gait and muscle activity during normal walking, a more strenuous activity, and recovery from a strenuous activity. Gait kinematics and surface EMG over the right and left multifidus (between L4 and L5) and erector spinae muscles (between L3 and L4) [27] were collected during the last minute of each 5-minute walking interval to allow for stabilization of the walking pattern. Heart rate, rate of perceived effort using the Borg Scale [28], and perceived pain using the visual analog pain scale were recorded at the end of each 5-minute walking interval (Fig. 2).

Thirty-nine retroflective markers were placed over bony landmarks according to the Plug-in-Gait marker system,

and gait kinematics were captured using an 8-camera Vicon motion capture system [29]. Motion capture data were sampled at 120 Hz and subjected to a Woltring Filter. Multiple toe-off and heel-strike events were identified on both feet to allow calculation of velocity, stride length, stride time, and double support time [30]. Before testing, surface EMG of the lumbar paraspinal muscles was collected at rest in the supine position. Surface EMG data were filtered and full-wave rectified. The rectified signal was integrated with respect to time over a 1-second interval, averaged, and normalized to the mean area at rest [30].

Data from both collections before RFN were averaged and are shown as PRE. Data from the session collected on the Day 0, at 2 hours post-RFN, are designated as ACUTE POST. Data collected on Days 8 and 14 post-RFN were averaged and are shown as POST1. Data collected on Days 28 and 58 post-RFN were averaged and are shown as POST2. Given that it can take up to 4 weeks for the procedural pain to diminish post-RFN [31], the division of the data into ACUTE POST (immediate recovery), POST1 (within 1–2 weeks post), and POST2 (within 4–6 weeks post) captures the participant's mobility at different stages of functional recovery following an RFN. Percent change from PRE across all walking conditions was calculated for each outcome time frame including ACUTE POST, POST1, and POST2.

Results

Following RFN, the participant reported a resolution of her pain and an increased ability to complete activities of daily living. She also reported an increase in overall physical activity such as walking and bicycling. The participant completed all seven testing sessions with no complications. Treadmill speeds and gait kinematics were considered

Table

Percent change from PRE session for all outcome measures

Measured variables during gait	ACUTE POST (%)	POST1 (%)	POST2 (%)
Treadmill speed	0	12	22
Heart rate	0.9	6	12
Perceived effort	7	0.6	1.5
Perceived pain	20	60	92
Velocity	7	14	32
Stride length	7	8	20
Stride time	0.5	6	9
Double support time	4	3	10
Left multifidus	37	41	36
Right multifidus	9	9	6
Left erector spinae	40	39	35
Right erector spinae	35	49	46

RFN, radiofrequency neurotomy.

Note: PRE session is the average of data collected before RFN; ACUTE POST refers to the data collected on Day 0, 2 hours post-RFN; POST1 refers to the average of data collected on Days 8 and 14 post-RFN; POST2 refers to the average of data collected on Days 28 and 58 post-RFN.

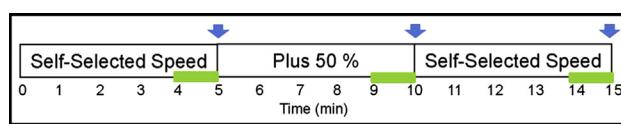


Fig. 2. Example of treadmill walking protocol. Green bars represent the time in which gait kinematics and surface electromyography were collected. Blue arrows indicate time that rate of perceived effort, perceived pain, and heart rate were collected.

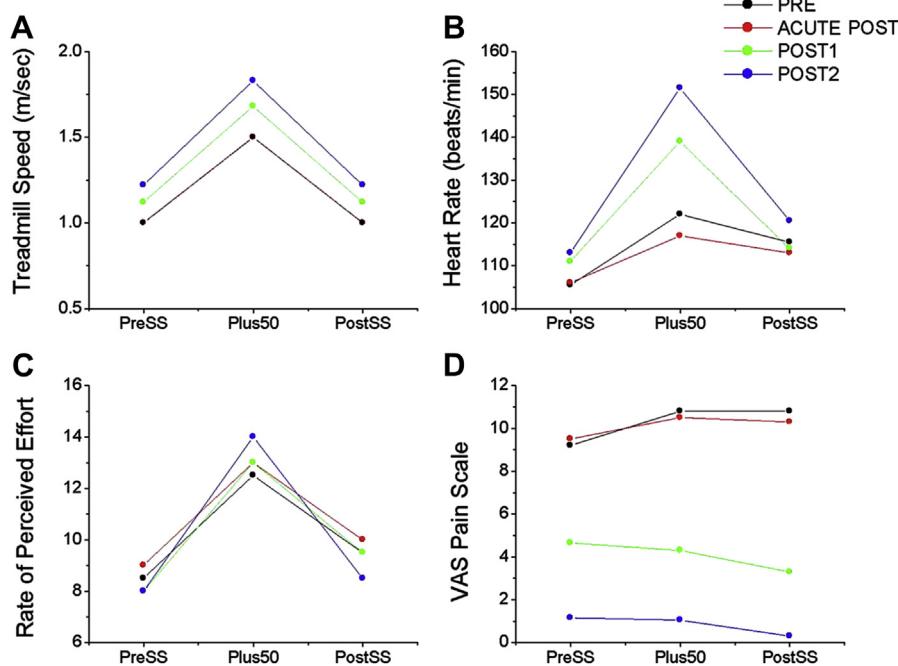


Fig. 3. Results for (A) treadmill speed, (B) heart rate, (C) rate of perceived effort, and (D) perceived pain across all three walking condition for each session. SS1, first time walking at participant's self-selected pace; Plus50, plus 50% of the self-selected pace; SS2, second time walking at participant's self-selected pace; VAS, visual analog scale.

within the normal range for a female of this age. Percent change scores from PRE are shown in Table for all outcome measures for ACUTE POST, POST1, and POST2.

Fig. 3 shows treadmill speed, heart rate, perceived pain, and perceived effort over each walking condition (self-selected pace, plus 50%, and self-selected pace post 50% increase) for PRE, ACUTE POST, POST1, and POST2. For PRE and ACUTE POST, treadmill speed did not change. For POST1, treadmill speed increased by an average of 12%, and for POST2, treadmill speed increased by average of 22% (Fig. 3A). With this increase in treadmill speed, heart rate did increase by an average of 6% (POST1) and 12% (POST2) as would be expected (Fig. 3B). Perceived effort increased by an average of 7% for ACUTE POST, but there were minimal changes for POST1 (0.6%) and POST2 (1.5%) (Fig. 3C). Finally, there was a decrease in perceived pain during all walking sessions, with an average of a 20% decrease in ACUTE POST, 60% decrease in POST1, and 92% decrease in POST2. Note that in PRE and ACUTE POST, perceived pain increased with the increase in walking speed and was maintained when the speed returned to the self-selected speed. In contrast, for POST1 and POST2, perceived pain decreased with increased speed and duration (Fig. 3D).

Fig. 3 shows velocity, stride length, stride time, and double support time over each walking condition for PRE, ACUTE POST, POST1, and POST2. Across all testing sessions, velocity increased gradually from an average of 7% (ACUTE POST) to 14% (POST1) to 32% (POST2) (Fig. 4A). Likewise, stride length increased an average of

7% to 8% to 20%, respectively, from ACUTE POST to POST2 (Fig. 4B). There were no initial changes in stride time (0.5% ACUTE POST), but there were minimal decreases in stride time by an average of 6% for POST1 and 9% for POST2 (Fig. 4C). There were also decreases in double support time with an average of a 4% decrease for ACUTE POST, a 3% decrease for POST1, and a 10% decrease for POST2 (Fig. 4D). Note that although the treadmill speed was the same for PRE and ACUTE POST (Fig. 3A), velocity and stride length increased while double support time decreased for ACUTE POST.

Fig. 5 shows mean surface EMG area for the left and right multifidus and erector spinae muscles over each walking condition for PRE, ACUTE POST, POST1, and POST2. Activity over the left multifidus (RFN treatment side) decreased by an average of 37% initially (ACUTE POST) and was maintained for POST1 (41%) and POST2 (35%) (Fig. 5A). Likewise, activity over the erector spinae muscles decreased initially (ACUTE POST) by an average of 35% to 40% on the left side. This was maintained for POST1 (39–49%) and POST 2 (35–46%) (Fig. 5C and D). In contrast, the change in activity over the right multifidus muscle was less than 9% across all measurement times.

Discussion

Radiofrequency neurotomy of the lumbar medial branches to the lumbar zygapophysial joint has been shown to provide a significant decrease in pain in those with dual comparative

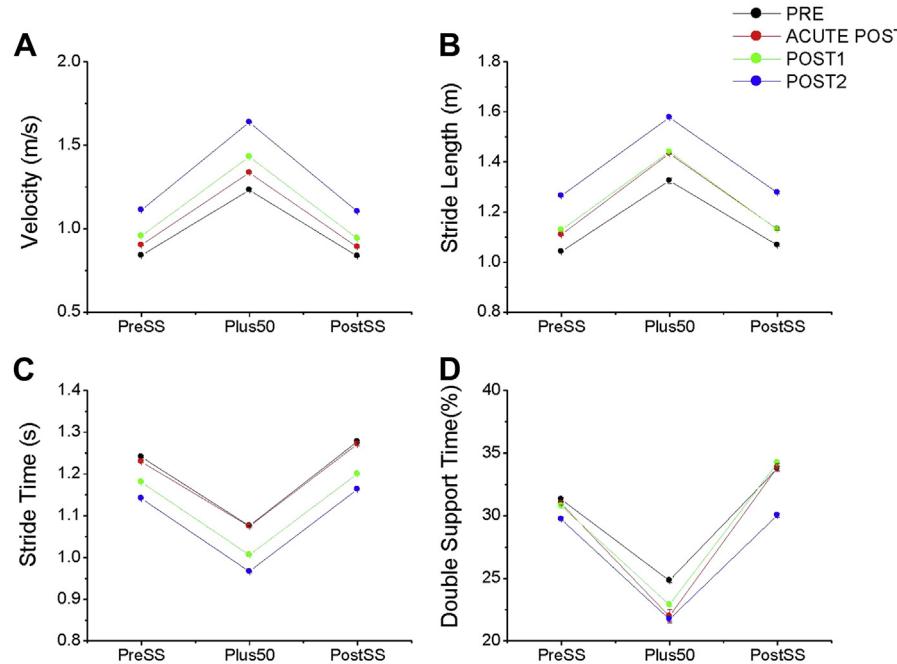


Fig. 4. Results for (A) velocity, (B) stride length, (C) stride time, and (D) double support time across all three walking condition for each session. SS1, first time walking at participant's self-selected pace; Plus50, plus 50% of the self-selected pace; SS2, second time walking at participant's self-selected pace.

anesthetic medial branch block confirmed pain, but improvements in functional mobility are lacking [2]. In keeping with previous research [17–20], RFN did dramatically decrease pain associated with lumbar zygapophysial joint for this participant. Moreover, this case study is the first to show that although the multifidus, a stabilizing paraspinal muscle, is denervated during RFN, mobility improved as evidenced by improvements in self-rated reports, heart rate, and gait kinematics. Moreover, this study is the first to show altered surface EMG activity over the multifidus.

There is a general assumption that the rate of perceived effort is influenced by perceived pain [32,33], yet this assumption has not been confirmed in individuals with chronic low back pain [34–36]. Previous research has suggested that monitoring heart rate in addition to rate of perceived effort is a more accurate method for monitoring activity in individuals with low back pain [36]. Interestingly, rate of perceived effort did not change in this study, whereas pain decreased dramatically and treadmill speed and heart rate increased. These results suggest that all three measures should be considered when monitoring physical activity in individuals with low back pain. Moreover, the participant in this study was able to work harder with less pain and at the same rate of perceived effort. This may suggest that individuals receiving RFN may have capacity for improvement in mobility post-RFN. Given that the long-term success varies following RFN [37], capitalizing on this acute capacity for improvement may prove beneficial for deterring future painful spine conditions. As this is a case study, additional research examining the association between rate of perceived effort, perceived pain, and heart

rate during physical activity in individual's pre- and post-RFN is needed to further justify the recommendation for therapy post-RFN.

Previous research has also shown that individuals with chronic low back pain show changes in the control of the low back muscles and that these changes may contribute the recurrence of low back pain [38–40]. Activity of the superficial muscles of the lower back is increased when measured by surface EMG in individuals with chronic low back pain [38]. This increased activity has been thought to reflect an adaptive motor control process to limit tensile forces and motion of painful structures of the back [39]. These changes in activity have been shown to persist despite the resolution of symptoms and pain [40]. Individuals with low back pain may also limit motion of the lower limbs. Previous research has shown that walking faster and taking larger step results in an increased rotation of the spine [41,42]. Thus, individuals with chronic low back pain may choose a walking pattern that involves decreased walking speed and step length to avoid large rotations of the spine [36,37]. The results of this study demonstrate a reduction of increased superficial muscle activity over the multifidus and erector spinae muscles with an increase in gait velocity and stride length during treadmill walking post-RFN. Taken together with previous research, these results may suggest that by eliminating pain and most importantly denervating the multifidus muscle (effectively reducing muscle activity), individuals with chronic low back pain may be forced to adapt to a different motor control strategy that results in abnormal spinal control. The results of this study are specific to one participant, and further research

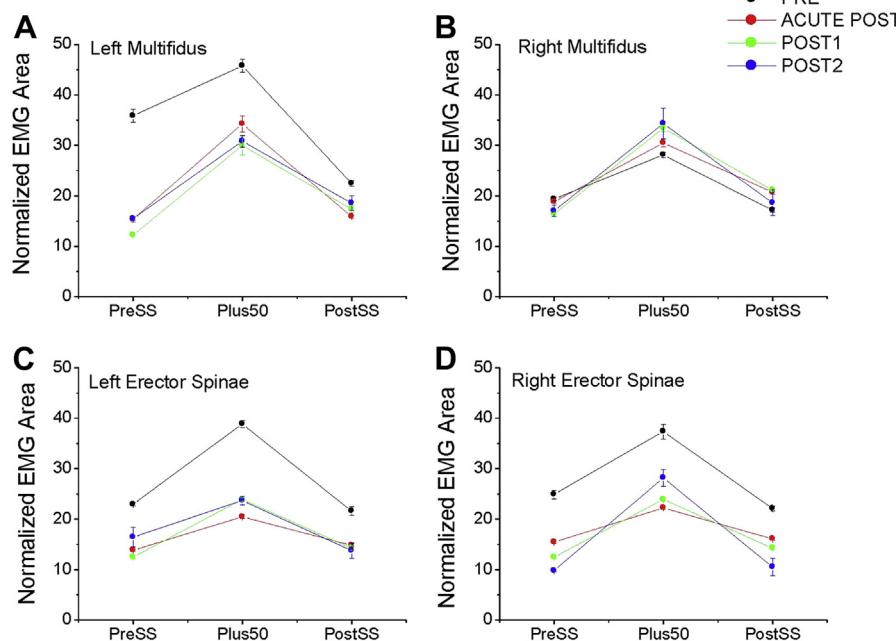


Fig. 5. Results from surface EMG over (A) left and (B) right multifidus muscles and (C) left and (D) right erector spinae muscles across all three walking condition for each session. SS1, first time walking at participant's self-selected pace; Plus50, plus 50% of the self-selected pace; SS2, second time walking at participant's self-selected pace; EMG, electromyography.

is needed. However, the participant in this study showed increases in velocity and stride length accompanied by decreases in activity over low back muscles post-RFN, which may be considered indicative of improvements in mobility.

Potential limitations

The participant in this study was younger (33 years) than most individuals receiving RFN. The potential for improvement post-RFN may be greater. However, the participant had been suffering from chronic back pain for approximately 15 years, and any improvement in mobility may be considered relevant. Also the follow-up was only 58 days. This time frame was meant to capture the changes following a clinically successful RFN. Further research is needed to determine if the changes are durable.

Although treadmill studies do help facilitate gait analysis, they can add confounding variables. For instance, increases in treadmill speed could account for changes in gait kinematics post-RFN [43]. However, the reverse is also true [44]. The participant may have had the ability to increase gait velocity and stride length post-RFN, which in turn required a faster treadmill speed. Moreover, the participant in this study chose her self-selected speeds without any feedback from previous sessions. Improvements in gait kinematics over time may represent a learning effect. While no studies have directly measured improvements in gait kinematics after repeated bouts of treadmill walking, studies have shown that low back pain alters walking performance [45]. Thus, it is possible that both a decrease in low back pain and a learning effect may have contributed to the

improvement in gait kinematics. Improvements in treadmill walking may also not carry over to improvements in other functional mobility tasks. At the 6-week follow-up appointment, the participant reported increased ability to ride a bicycle without pain and beginning to run for 5–10 minutes three times a week (before RFN she was unable to do either activity). For this participant, improvements in treadmill walking may be representative of improvements in functional mobility. Finally, this is a case study. The findings observed in this study may be due to natural history or a strong placebo effect.

Conclusion

The results of this pilot study are the first to show quantitative positive changes in gait and muscle activity post-RFN, suggesting that the relationship between this procedure and mobility warrants further investigation.

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