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Effects of Tai Chi Training on Muscle Strength, Mobility, and Quality of Life in Patients with Peripheral Neuropathy

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ABSTRACT

An estimated 20 million people in the U.S. suffer from peripheral neuropathy (PN). Patients with PN develop gait abnormalities. Foot pain is one of the factors affecting walking ability. As a result, a large number of individuals with PN suffer from a reduction in daily physical activity, mobility and reduced quality of life (QOL). Tai Chi appears to be safe and effective in promoting strength and functional capacity in older patients with other chronic disabilities. This study aimed to assess the effects of Tai Chi on muscle strength, mobility, and QOL in patients with PN. Thirty seven participants (men=21, women=16) completed the study; Tai Chi exercise group (Ex, n=20, age: 71 ± 9.50 years) and control group (Con, n=17, age: 75 ± 9.02 years). Exercise training consisted of 12-week progressive Tai Chi (i.e., Yang Style), offered 3 times per week, 60 minutes per session. Before and after training, lower muscle strength [One repetition maximum (1RM) for leg extension and leg curl], functional mobility [timed up-and-go; TUG], and QOL were evaluated. Muscle strength increased significantly in the Ex group [leg extension: pre = 26.76 ±16.05; post = 46.12 ± 25.55 kg; leg curl: pre = 28.69 ± 13.51; post = 44.22 ± 13.97 kg; ($p < 0.05$)]. The TUG decreased significantly in the Ex group [pre = 12.34 ± 5.73; post = 7.43 ± 2.87 sec; ($p < 0.05$)]. No significant changes were observed in the Con group. Finally, post-test QOL subscales and total scores were significantly higher in the Ex group ($p < 0.05$). These findings demonstrated that Tai Chi was capable of increasing lower extremity muscle strength, functional mobility, and QOL in this limited sample of patients with PN. Interestingly, the exercise training program was able to reduce the risk for loss of functional mobility (i.e., decreased TUG) among the participants.

Keywords: *Strength; Functional Mobility; Quality of Life; Neuropathy; Tai Chi*

INTRODUCTION

An estimated 20 million people in the U.S. suffer from peripheral neuropathy (PN), a pathology associated with damage to peripheral nerves that results in the loss of physical function and decreased quality of life (QOL) [1]. The symptoms usually begin in the toes before presenting in the fingers and progressively spreading proximally [2]. PN has numerous causes, including hereditary, toxic, metabolic, infectious, inflammatory, ischemic, and paraneoplastic disorders. Importantly, two-thirds of PN cases remain undiagnosed, relegated to the nebulous designation of ‘‘idiopathic’’ or ‘‘cryptogenic’’ neuropathy [3, 4], with patients commonly developing gait abnormalities, balance and mobility problems. Foot pain is one of the factors affecting walking ability and as a result, a large number of individuals with PN suffer from a reduction in daily physical activity, functional independence, and reduced QOL [5]. For instance, patients with PN exhibited lower scores on the 6-minute walk and the Timed Up-and-Go tests [6] compared with age-matched controls.

People with PN usually do not perform a lot of physical activity due to their functional limitations and as a result the available research related to exercise and PN is inconclusive [7, 8]. A systematic review of exercise for people with PN, regardless of etiology, concluded there is inadequate evidence to evaluate the effects of exercise on functional ability in these patients [7]. Although there was some evidence that targeted exercise programs were moderately effective in increasing muscle strength, these studies were limited by poor methodological quality, and the authors concluded there was inadequate evidence to evaluate the effect of exercise on functional ability in persons with neuropathy. A review by Visovsky et al., [8] reached the same conclusions as previous authors; studies examining the effectiveness of exercise for treatment of PN are needed.

Considering the gait and balance challenges associated with PN [6], low velocity, low impact exercises might be the most effective for this clinical population. Tai Chi, is an ancient Chinese healing/martial art that consists of a series of graceful movements with deep and slow diaphragmatic breathing. Substantial evidence exists on the physical and psychosocial benefits of Tai Chi for various populations [9, 10]. Furthermore, Tai Chi training appears to be safe and effective in promoting balance, strength, and functional capacity in older patients with chronic disabilities [10, 11]. Tai Chi exercise is a relatively "low tech" approach to preventing disability and maintaining physical performance in older adults. Thus, the purpose of this study was to assess the effects of Tai Chi on muscle strength, functional mobility, and QOL in patients with PN.

MATERIALS AND METHODS

Study Participants

Forty participants with a physician's diagnosis of PN were recruited from the East Texas area via a local newspaper advertisement to participate in this study. The number of participants was limited to the number who could be safely accommodated in the space available at the university. The inclusion criteria for the study were (a) ability to maintain an upright posture for at least one minute voluntarily; (b) ability to walk at least 20 yards independently; (c) willingness to participate in the study; and (d) a diagnosis of bilateral PN. Individuals were excluded from participation if there was (a) a history or evidence of central nervous system dysfunction; (b) musculoskeletal deformity that could influence gait and balance; (c) a history or evidence of vestibular dysfunction; (d) a history of angina; (e) evidence of plantar ulcer; and (f) unstable disease (e.g., uncontrolled diabetes mellitus, arthritis, coronary artery disease, etc.). Following explanation of all the details of the study, each participant signed an informed consent approved by the Institutional Review Board. Following consent, physician's approval and a completed health history from the physician's office were required before the intervention began.

Experimental Design

Forty eligible participants were randomly assigned, by a lab technician blinded to the study, to either Tai Chi exercise (Ex, n = 20) or control group (Con, n= 20). The Health and Physical Activity Questionnaire [12] was used to determine the level of physical activity behavior, and the medical history of each participant before the study started. The Con group did not participate in any exercise activity during the study, instead maintaining their daily routines. Each participant in the Ex and Con groups was examined during two separate visits (i.e., before and after the 12-week exercise program) for the measurement of muscle strength, functional mobility, and QOL.

Exercise Program

Exercise consisted of 12-week progressive Tai Chi (i.e., Yang Style), offered 3 times per week, 60 minutes each time. The Yang style is the most popular form of Tai Chi [13]. A typical Tai Chi practice session lasted 60 minutes, included diaphragmatic breathing and gentle stretching exercises for warm-up (10 min), learning and practicing Tai Chi Yang Style 10 forms (45 min), and cool down (5 min). A Tai Chi Master who taught Tai Chi class at University level for 30 years administrated this Tai Chi intervention. In the first three weeks the participants learned the breathing technique, the coordination of breathing and Tai Chi movements, concentration technique of Tai Chi and Tai Chi 10 forms. After the first three weeks of learning and practicing the Tai Chi 10 forms, the participants were led by the Tai Chi Master and were able to follow and imitate the flow of the Tai Chi movements and postures of the Tai Chi Master in the rest of the training sessions. In addition, other well-trained individuals were present to observe and to ensure safety among the participants.

Study Procedures and Assessments

Muscle Strength

One Repetition Maximum (1RM) was conducted on weight machines (i.e., Life Fitness) designed for lower body (i.e., leg extension and leg curl) muscle groups. The 1RM test is a reliable test of muscular strength [14]. Participants were asked to lift the heaviest weight they were able to lift within their comfort level one time. In order to eliminate inter-observer variability, the same investigator performed these procedures before and after training. Prior to the measurements participants were familiarized with the procedures and instructed on the correct techniques.

Functional Mobility

A timed up-and-go (TUG) test was used to assess functional mobility using a previously

established protocol [15]. The TUG test is a useful and highly reliable test in detecting mobility impairment [16, 17]. The TUG test requires standing up from a chair, walking 3 meters (m), and turning and walking back to the chair as quickly as possible. A firm chair with arm rests was placed in the middle of a well-lit, indoor hallway. In front of the chair, a distance of 3 m was marked on the floor and a large cone was placed on the opposite end from the chair. The test began with the participant seated with their back against the chair, arms in lap, and feet just behind the distance-marker on the floor. Instructions were to stand up using the arm rests if needed, walk safely to and around the cone, walk back to the chair, and sit all the way back in the chair as fast as possible. The timer was started on the word "go", and stopped when the participant's back touched the back of the chair. The average time to complete each of 2 separate trials was recorded and used for analysis.

QOL

The Functional Assessment of Cancer Therapy-General (FACT-G) instrument was used to assess QOL. Reliability and validity of this instrument have been established in numerous studies [18, 19]. Briefly, the FACT-G is a 27-item instrument with four primary QOL domains: Physical Well-Being (7 items), Social/Family Well-Being (7 items), Emotional Well-Being (6 items), and Functional Well-Being (7 items) (18). Each item is rated on a scale ranging from "0" ("not at all") to "4" ("very much"). Items are reverse scored as indicated, summed, multiplied by number of items in the subscale and then divided by the number of items answered. Subscale scores range from 0-24 (Emotional Well-Being) and 0-28 (Physical Well- Being, Social/Family Well-Being, and Functional Well-Being). Subscale scores are summed to provide a total FACT-G score. Higher scores are indicative of better QOL.

Statistical Analysis

All values are means ± standard deviation (SD) or ± standard error (SE) when appropriate. Baseline characteristics between groups were compared by means of an independent samples *t* test. Training-induced changes were analyzed using repeated measures ANOVA within and between group differences. All statistical analyses were performed using SPSS version 20.0 (SPSS, Chicago, IL, USA). The level of significance for all analyses was set at $p < 0.05$.

RESULTS

From the 40 participants, three in the Con group dropped the study before the post-assessments were taken, due to minor health issues not related to the program. Thus, a total of 37 individuals with bilateral PN participated in all aspects of this study; Ex group (n = 20; age: 71 ± 9.50 years), and Con group (n = 17; age: 75 ± 9.02 years). The participant characteristics are presented in Table 1. Forty-three percent of the participants were women, and 57% men. The oldest participant tested was 90 years old, and the youngest was 50 years old. Eighty-four percent of the participants were over the age of 65. The physical activity behavior indicated that these participants were low-to-moderately active. The length of time that subjects held the diagnosis of PN ranged from 12 months to 20 years, with 60% of the participants experiencing PN for over 10 years. The etiology of PN was Diabetes Type 2 in approximately 30% of the subjects. In 8% of patients the etiology was chronic low back pain, and 3% of patients were cancer survivors. In the remaining subjects (59%) the etiology was unknown. Forty-three percent of the patients had stage I hypertension (i.e., physician diagnosed) on the basis of resting systolic blood pressure (SBP ≥ 140 mmHg). There was no significant difference between the Con and Ex in age, body mass index, systolic and diastolic blood pressures, or heart rate.

Table 1. *Participant Characteristics*

Variable	Con (n = 17)	Ex (n = 20)
Age, (y)	75 ± 9.02	71 ± 9.50
Height (cm)	170 ± 12.04	173 ± 8.63
Body weight (kg)	83 ± 20.15	87 ± 12.92
BMI ($kg \cdot m^{-2}$)	28 ± 5.69	29 ± 3.82
Resting SBP (mmHg)	142 ± 18	137 ± 14
Resting DBP (mmHg)	75 ± 11	76 ± 7
Resting HR (bpm)	66 ± 10	67 ± 10

Values are means ± SD. y, years; cm, centimeters; kg, kilograms; BMI, body mass index; SBP, systolic blood pressure; mmHg, DBP, diastolic blood pressure; HR, heart rate; bpm, beats per minute.

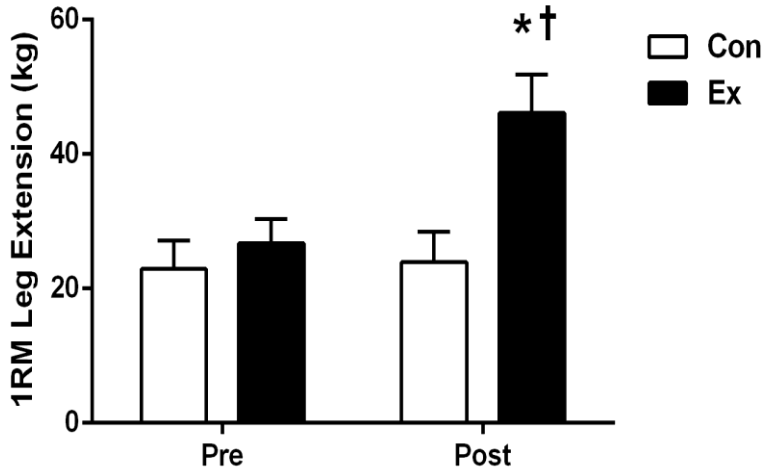

Figure1. *One repetition maximum (1RM) leg extension. Values are means ± S.E. * p < 0.05 for Con-pre and Con-post vs. Ex-post; † p < 0.05 for Ex-pre vs. Ex-post*

The average values for lower muscle strength assessments between the Con and Ex groups are presented in Table 2 and Figs. 1 and 2. Following the 12-week Tai Chi exercise program, lower muscle strength increased significantly in the Ex group. The Ex group experienced a 72% increase for leg extension (pre = 26.76 ±16.05; post = 46.12 ± 25.55 kg, $p < 0.05$), and a 54% increase for leg curl (pre = 28.69 ± 13.51; post = 44.22 ± 13.97 kg, $p < 0.05$). Finally, the post-intervention lower muscle strength for the Con group remained almost the same as baseline.

Table 2. *Muscle Strength and Mobility Assessments.*

Variable	Con-pre (n = 17)	Ex-pre (n = 20)	Con-post (n = 17)	Ex-post (n = 20)
Leg Extension (kg)	22.94 ± 17.46	26.76 ± 16.05	23.91 ± 18.65	46.12 ± 25.55*†
Leg Curl (kg)	31.55 ± 15.72	28.69 ± 13.51	32.15 ± 15.68	44.22 ± 13.97*†
TUG (sec)	11.10 ± 4.61	12.34 ± 5.73	10.87 ± 4.51	7.43 ± 2.87*†

*Values are means ± SD. kg, kilograms; TUG, timed up-and-go; sec, seconds. * p < 0.05 for Con-pre and Con-post vs. Ex-post; † p < 0.05 for Ex-pre vs. Ex-post comparison at the measured characteristic.*

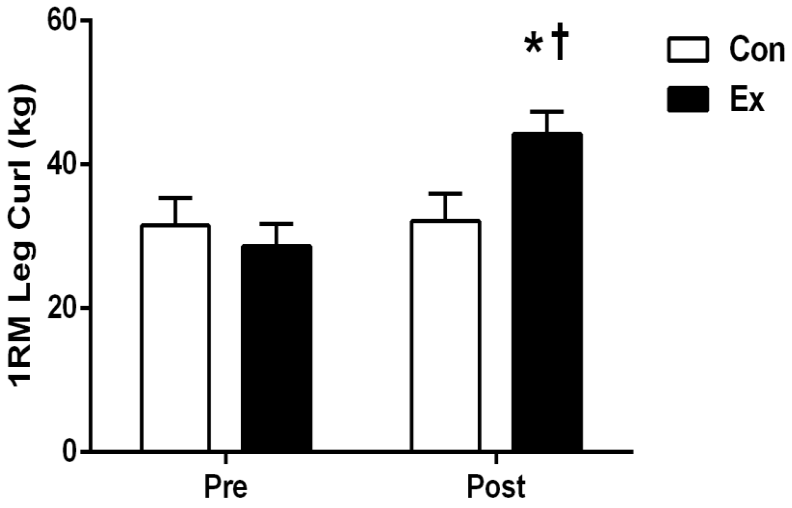

Figure2. *One repetition maximum (1RM) leg curl. Values are means ± S.E. * p < 0.05 for Con-pre and Con-post vs. Ex-post; † p < 0.05 for Ex-pre vs. Ex-post.*

The average values for functional mobility between the Con and Ex groups are presented in Table 2 and Fig 3. The average baseline TUG was 11.10 ± 4.61 and 12.34 ± 5.73 sec for the Con and Ex groups, respectively. Following the 12-week Tai Chi exercise program, the TUG decreased significantly in the Ex group. Indeed, the Ex group experienced a 66% decrease from baseline (12.34 ± 5.73 to 7.43 ± 2.87 sec, $p < 0.05$). Finally, the post-intervention TUG for the Con group remained almost the same as baseline (11.10 ± 4.61 to 10.87 ± 4.51 sec).

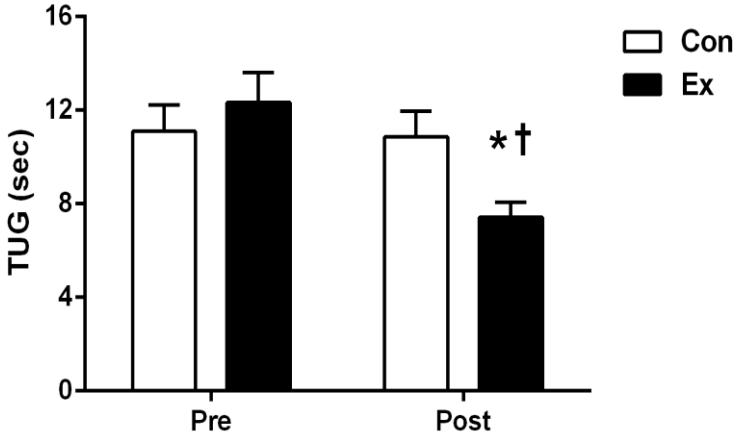

Figure 3. *Timed Up-and-Go (TUG). Values are means ± S.E. * $p < 0.05$ for Con-pre and Con-post vs. Ex-post; † $p < 0.05$ for Ex-pre vs. Ex-post.*

Differences in QOL subscale and total scores were non-significant at baseline. Within-subjects analysis demonstrated significant improvement ($F = 7.262$; $p = 0.019$) in total QOL scores over time for the Ex group. Post-test total QOL scores for the Con group declined, but did not significantly change over time. Following the 12-week Tai Chi exercise program, the repeated measures mixed model (Pillai's Trace) comparing group by time indicated significantly higher total QOL scores in the Ex group when compared to the Con group (Table 3). Between subjects QOL subscales scores were also significantly higher in the Ex group (Table 3).

Table 3. *Quality of Life Assessment*

FACT-G Scale	Con-pre (n = 17)	Ex-pre(n = 20)	F	Con-post(n = 17)	Ex-post(n = 20)	F
Physical Well-Being	21.84 ± 4.43	22.07 ± 3.20	0.01	19.64 ± 5.94	24.44 ± 3.31	7.713**
Social Well-Being	20.53 ± 5.95	24.33 ± 3.44	2.70	20.64 ± 6.30	26.13 ± 3.10	9.535***
Emotional Well-Being	16.47 ± 5.19	19.40 ± 3.07	3.22	17.00 ± 3.76	19.94 ± 3.51	4.890*
Functional Well-Being	19.63 ± 5.18	21.80 ± 4.33	1.90	18.29 ± 6.31	23.00 ± 3.56	6.573*
QOL Total	77.57 ± 17.49	88.57 ± 10.49	2.28	75.57 ± 19.39	94.64 ± 8.76	8.476**

*Values are means ± SD. FACT-G, Functional Assessment of Cancer Therapy-General Scale; QOL, quality of life. Data were analyzed using repeated measures ANOVA. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$*

DISCUSSION

This study aimed to assess the effects of Tai Chi on muscle strength, functional mobility, and QOL in patients with PN. The present data, indeed, supported the beneficial effects of Tai Chi on muscle strength, mobility and QOL among individuals with PN. Aging and disability are associated with a progressive decline in muscle strength, muscle mass and impaired physical function. The decline in muscle mass, strength and physical function can contribute to mobility impairments, falls, fractures, and physical disability. It has been well documented that elderly people can reverse the age-related decline in muscle strength through exercise [20]. In addition, leg strength is a good predictor of functional gait quality in older adults and consequently, strength training is commonly emphasized for this population [21]. Compared with high intensity exercise, Tai Chi is a wellness exercise with low-to-moderate intensity that involves neuromuscular coordination, low velocity of muscle contraction, no jumping, and is regularly practiced by older people [9, 22]. Importantly, cross-sectional studies have shown that Tai Chi practitioners

have better balance and proprioceptive function, muscle strength and endurance, and muscular reaction of lower extremities than their sedentary counterparts or regular jogging and walking enthusiasts [23, 24].

Previous studies have reported that Tai Chi is effective in promoting strength and functional capacity in older patients with chronic disabilities [10, 11]. Importantly, the present study reported that a 12-week Tai Chi exercise program was able to improve lower muscle strength in patients with PN. Indeed, lower muscle strength increased significantly in the Ex group (Table 2 and Figs. 1 and 2). Actually, the Ex group experienced a 72% increase for leg extension (pre = 26.76 ±16.05; post = 46.12 ± 25.55 kg, $p < 0.05$), and a 54% increase for leg curl (pre = 28.69 ± 13.51; post = 44.22 ± 13.97 kg, $p < 0.05$).

Tai Chi consists of performing a series of slow movements demanding guided motions of the hip, knee, and ankle joints in various directions, requiring concentric and eccentric contractions of the hip, knee, and ankle muscles [25]. In terms of hip degree and knee flexion as well as required extension, these movements are similar to resistance exercises, such as lunges, knee bends, and squats. This stimulation can not only increase muscle strength but also the range of motion of knee and ankle joints. The weakness of the lower limb muscle, especially of the hip flexors and knee extensors, was associated with the requirement of multiple steps to recover from forward loss of balance [26]. These results suggested Tai Chi may be a good form to slow down the decline in muscle strength in patients with PN.

Functional mobility entails motor skills essential for independent living. The TUG test provides a measure of functional mobility in older adults [15, 27]. Data regarding norms and threshold scores for the TUG test are available but are somewhat conflicting. For example, Steffen et al., [28] reported average TUG test times on a group of 60 to 69 years old men and women around 8 sec. Bischoff et al., [16] recommended the need for early evaluation and intervention for community-dwelling elderly women between 65 - 85 years of age, who scored above 12 sec on the TUG test. Others have identified a cutoff point of 16 sec as a parameter that significantly predicted falls in community dwelling older adults [29].

The baseline group averages for the TUG test in this study (Con: 11.10 ± 4.61 sec; Ex: 12.34 ± 5.73 sec) (shown in Table 2 and Fig. 3) appears to be quite typical to those reported in patients with PN [30], indicating significant functional limitations. Undoubtedly, performance of the TUG test is a more complex interplay between physiological systems than the walk test. It is generally accepted that the TUG test does not focus on independent effects of organ impairments, such as low muscle strength, decreased balance and other impairments, but measures the interaction of these factors on the performance of activities of daily living (ADL). The initiation and subsequent continuation of a movement pattern is very much dependent on the ability to immediately increase blood flow to the working muscle. Thus, if the factors involved in the initial rise in blood flow with the onset of activity are impaired, this could result in the increase time needed to perform the TUG test. Indeed, it has been reported that diminished vascular function contributes to a decrease in physical function in individuals with PN [30]. The time taken to complete the task is strongly correlated to level of functional mobility (i.e., the more time taken, the more dependent in ADL and higher risk for falling). Interestingly, we reported here that following the 12-week Tai Chi exercise program, the TUG decreased significantly (i.e., “faster time”); the Ex group experienced a 66% decrease from baseline (12.34 ± 5.73 to 7.43 ± 2.87 sec, $p < 0.05$) (Table 2, Fig. 3).

Patients with PN, typically, do not perform a lot of physical activity due to their limitations, which in turn may have a negative effect on their QOL [5]. Tai Chi appears to be an effective intervention to improve QOL in patients with PN. The Ex group experienced significant improvements in all aspects of QOL, after the 12-week intervention. It is unknown if further improvements would result as of continued participation in the Tai Chi exercise program. Interestingly, those participants who did not participate in Tai Chi (i.e., Con group) reported declining QOL (though non-significant) scores over time. Therefore, the improvement may be greater than indicated in this study; not only did Tai Chi participant scores increase, one could theorize that QOL scores may have actually decreased had they had not participated in the Tai Chi exercise program, as seen in the control group. While one may anticipate improved physical and

functional status as a result of exercise, it is interesting to note that the Ex group also appears to have enhanced emotional and social well-being, suggesting that this mind-body exercise has impact beyond physical objective measures.

Regular exercise is an important therapeutic intervention for successful aging for persons to maintain strength, range of motion, and endurance. However, Healthy People 2000 (Department of Health and Human Services [DHHS], 1990) [31], and Healthy People 2010 (DHHS, 2000) [32], stated that most people, including older people, do not engage in regular exercise despite its known benefits. Furthermore, Healthy People 2020 established goals and objectives for older people to improve their health, function, and QOL, and addressed falls and fall-related injuries for the first time (DHHS, 2010) [33]. The "International Classification of Impairments, Disabilities, and Handicaps" (ICF) by the World Health Organization (www.who.int/classification/icf) emphasizes the influence of human body function and structure on the level of functioning, activity, and participation. Thus, the findings reported in the present study are quite relevant. Tai Chi exercise program can influence positively PN patients' functioning and well-being. Finally, efforts to improve health, strength, and function combine to increase the patient's QOL, enhance confidence in their abilities, reduce fall risks, and promote independence.

Conclusions

Though the small sample is a limitation of the study, the present findings demonstrated that in patients with PN, a 12-week progressive Tai Chi exercise program is capable of increasing lower extremity muscle strength and QOL. Furthermore, Tai Chi training was able to reduce the risk for loss of functional mobility (i.e., decreased timed up-and-go) among the participants. Considering the gait and balance challenges associated with PN, low velocity, low impact exercises, like Tai Chi, might be the most effective form of exercise for this clinical population. The present study underlies the importance of Tai Chi as an effective and safe exercise intervention suitable for patients with PN because of its slow and structured movements and should be replicated with a larger sample.

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Authors' Contributions

AAAE contributed to the conception, protocol development, and design of the study. Collection, analysis and interpretation of the data and drafting of the manuscript. BKH, MLH, and JEB participated in the protocol development, collection, analysis and interpretation of the data. CAR and GTK participated in the protocol development. YTW participated in the protocol development and lead the Tai Chi exercise program. All authors were involved in revising the manuscript, providing intellectual content, and approving the final version. All authors agree with the order of presentation of the authors.

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