Five Weeks of Yuishinkai Karate Training Improves Balance and Neuromuscular Function in Older Adults

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Abstract

Background: To test the efficacy of a documented 5-week karate training intervention for rehabilitation and neuroprotection in older adults.

Methods: Sixteen older adults (8 male, 8 female, age 59-90y), with or without chronic conditions, participated a 5-week karate training intervention. Dynamic balance, hand grip, ankle plantarflexion force, Timed Up and Go (TUG), and spinal cord excitability (via the soleus H-reflex) were assessed pre- and post-intervention.

Results: Participants completed 2437 steps, 1762 turns, 3585 stance changes, 2047 punches, 2757 blocks, and 1253 strikes. Karate training improved dynamic postural performance. The group average time for dynamic postural reaction was reduced (time to target (-13.6%, $p = 0.020$) and time to center (-8.3%, $p = 0.010$)). TUG was unchanged when considering the entire group ($p=0.779$), but reductions were found in 5 neurologically intact older adults (-4.5 to -8.6%; $p<0.05$) and increased for 1 Parkinson's Disease participant (3.8%, $p<0.05$). Strength increased in left arm (7.9%, $p=0.037$), right leg (28.8%, $p=0.045$), and left leg (13.3%, $p=0.024$) for the group. Spinal cord excitability remained unchanged across the group but 3 neurologically intact older adults (215.4%, 47.9%, -35.9%; $p<0.05$) and 2 Parkinson's Disease participants (152.4%, 195.3%; $p<0.05$) had modulated H-reflex amplitudes.

Conclusion: 5-weeks of karate training delivered in a fashion to mimic community-level programs provided an effective therapeutic "dose" to improve balance and strength in older adults. Whole-body training embodied in martial arts enhanced neuromuscular function and postural integration. Further quantitative work should explore threshold dose and development of martial arts interventions as functional fitness for older adults.

Background

Falls are the second leading cause of accidental deaths worldwide and are the largest comorbidity in people ages 65 years or older [1]. Dynamic postural regulation is critical for quality of life yet aging is associated with alteration of neuromuscular function and reduced capacity [2, 3]. As a consequence, many rehabilitation programs focus on enhancing balance, functional movements, and strength training to improve postural control and reduce the risk of falls [4]. Community-based interventions to maintain or enhance integrated function across the lifespan and after impairment are needed [1]. Mind-body exercises that combine physical and cognitive components may have greater adherence and improve overall health beyond traditional exercise programs [5, 6].

Martial arts such as karate use whole-body movement patterns that challenge balance and postural regulation using integrated training sequences called kata. Karate typically has more ballistic, powerful movement patterns while Tai Chi Chuan has more "circular" movement and practiced at slower speeds. Exposure to Shotokan karate training over 8-weeks with older adults and individuals with Parkinson's

ellness, and static balance of older adults [5, 6]. These studies evaluated demographic data, cognitive, and emotional variables through assessments of psychological measures and balance motor function through a one-leg stand [6]. Following interventions, there were improvements in static balance for the PD participants and some small changes in emotional and cognitive aspects [5, 6]. A subjective one-leg stand test analyzed static balance performance, however, there were no measures of dynamic balance reactions [6]. Physiological changes mind-body interventions like Tai Chi have also been effective in older adults and individuals with chronic conditions, such as PD [7–11]. However, the combined effects of martial arts on neurophysiology, balance reactions, and clinical aspects of health are not well documented.

To be clinically useful, further information is also required on the generalizability of various martial arts training approaches that might be commonly found in the community. A limitation to therapeutic application of martial arts is lack of details about exercise “dose” and the applied intervention timelines. For example, detailed accounting of numbers of repetitions of martial arts techniques and the duration of training, are critical for replication and extension. In work where martial arts have been used as the training stimulus and showed positive impacts on participants’ balance and psychological measurements, details and dose from what the participants practiced are absent [5, 6]. Investigation of effective therapeutic dose of martial arts is needed with documentation of movement tracking to advance the knowledge for future applications and real-world implementation. Additionally, the duration of training interventions has varied considerably from 5 weeks to 3 years [4–7, 12–24]. For clinical application, better documentation of activities undertaken, assessment of minimum timing for efficacious outcome, and extension to more commonly found community martial arts (eg. Hard-style systems like karate) are needed.

The purpose of this study was to test the efficacy of a short term, documented karate training dose in affecting function and multiple dimensions of health in elderly individuals, with or without chronic conditions. We predicted that the requirements of postural control in karate training would strengthen neurophysiological integrity and have beneficial effects on dynamic balance reactions and physiological function in older adults.

Methods

Participants

Sixteen older adults (8 male, 8 female, age 59-90y; 171.2 ± 4.7cm; 68.1 ± 8.9kg), with or without chronic conditions, participated in the study with informed written consent under a protocol approved by the University of Victoria Human Research Ethics Board (Protocol #18–213). An additional intake was canceled due to the COVID 19 pandemic. All methods were carried out in accordance with relevant guidelines and regulations. There were five older adults with chronic conditions (4 male, 1 female; 3 Parkinson’s disease, 1 vascular dementia, 1 stroke). Participants were recruited via posters, email, in-person events, and word of mouth. Inclusion criteria were that participants did not use a pacemaker and [illegible]ce. Exclusion criteria were previous or ongoing mind-body (e.g. any form of martial arts, qigong, or yoga) exercise experience. Participants completed the following assessments pre and post intervention in the subsequent order: spinal cord excitability, grip strength, plantarflexion force, dynamic balance, and Timed Up and Go (TUG) for integrated function.

Study design and control procedures

The study took place over six months total, which included the recruitment, data collection, and training of two cohorts. Each intervention intake spanned over nine weeks total (Fig. 1). Baseline control tests were performed in the first three weeks (one test per week), followed by five weeks of karate training (one-hour sessions on Monday, Wednesday, and Friday yielding 15 sessions total). The post-intervention tests took place on week 9. The karate sessions were delivered by black-belt instructors experienced in teaching martial arts in community-based settings. This “dosing” schedule was used to replicate both the approach taken in previous strength and locomotor interventions conducted in our laboratory [25–30] as well as to mimic the timing and delivery taken in other community-based martial arts programs [5, 13, 22, 24]. Since rehabilitative applications often necessitate time efficiency, preference for a short duration for compliance and demonstration of efficacy was chosen. This general design (5 weeks of training, 15 sessions total) has also been proven effective with prior modalities and interventions [5, 22, 24–27, 30, 31]. A successful feasibility assessment of the study protocol was conducted in two healthy, university-aged individuals (please refer to supplementary materials).

A multiple baseline approach, as well as a within-participant control design was performed as in our recent intervention studies [25–27, 32, 33]. The three pre-intervention assessments allow participants to create a baseline of their variability that enables them to act as their control. This reduces the impact of between-subject variability and allows for single participant statistical analysis using 95% confidence intervals from the pre-intervention data. The triple baseline procedure provides higher internal consistency of measures and decreased variability compared to using a control group [25, 26, 30, 34]. The order of test administration, time of the day, and other environmental conditions were consistent for each participant and testing sessions. In addition, participants were asked not to start any new forms of exercise throughout the training intervention, but they were also asked to maintain their pre-existing exercise routines.

Karate training intervention contents

Each karate training session consisted of a warmup involving general arm and leg movement followed by practicing individual techniques of punches, step punching, open hand striking and blocking. Instruction and explanation of the fighting applications of all techniques were also provided to create additional context for the movements practiced. The bulk of the practice was repetition (~ 45–60 s per cycle) of the training pattern kata “Pinan Nidan”. This kata consists of 13 stepping, 11 turning, 7 punching, 2 striking and 13 blocking movements in 9 directions and with 21 stance changes. The version used is from the traditional Yushinkai system, but many karate styles include this kata and related patterns in their training curriculum. Pinan Nidan was selected because it emphasizes whole body integration, bodyweight shifting and balance changes, but does not include any static single leg standing or kicking. At each session, an average of 10 repetitions of Pinan Nidan was completed with a minimum of 150 kata cycles across the 5-week training period. Movements were done at slow speed and modified according to the range of motion, functional ability, and neurological status of each participant. Volunteer “spotters” were distributed amongst the participants to provide support when needed. The repetitions of each technique (e.g. step, block, punch, etc.) practiced by the participants were documented by two researchers.

Balance Assessment

A commercially available balance board (Wii Balance Board, Nintendo, Kyoto, Japan) was used with customized software (LabVIEW 2011 National Instruments, Austin, TX, USA), and data were sampled at 100 Hz. The validity ($r = 0.99$) and reliability ($ICC = 0.88$) of balance board has been confirmed [35] and used in several previous studies to assess postural control [33, 36, 37].

During the dynamic balance assessment, each participant stood barefoot on the balance board, feet at shoulder width, eyes open, hands on the hips, and in front of a laptop screen that displayed the center of pressure as a white dot as described previously [36–38]. The trial began with a target (red) dot on the screen and moved in a random sequence amongst eight cardinal and ordinal directions. Participants were instructed to shift their weight distribution so that their center of pressure met the target as quickly and accurately as possible. Following the initial practice trial, participants completed five trials with one to five minutes of rest between the intervals. The time to reach target (tTarget), time to return to center from target (tCenter), and the sum of tTarget and tCenter (tTotal) were obtained and used for analysis [38].

Clinical Assessment

The TUG test was used as a clinical measure of functional capacity. TUG is a simple test that investigates the mobility of an individual through the evaluation of both static and dynamic balance [39, 40]. The test is known to assess the fall risk and measure the progress of balance, sit to stand, and walking in elderly individuals, primarily those with neurological or chronic conditions [40].

Strength Measures

Grip strength was assessed using commercial handgrip dynamometers (Right: Takei Scientific Instruments Company Ltd., Niigata, Japan; Left: Lafayette Instrument Co.). Participants were in a seated posture with one arm relaxed on the lap and the test arm extended and palm facing downward with shoulder abduction at a 45° angle. Measurements were alternated between the right then left hand to avoid fatigue with three trials completed on each side. During each trial, the participant performed maximal isometric contraction for 5s. Strain gauge load cells (Omegadyne Ltd., Model 101–500) were used to measure ankle plantarflexion force on each leg. Muscle activation from the soleus, tibialis anterior, and vastus lateralis muscles were recorded with a customized Matlab program (Nantick, MA, USA).

Muscle Activity and Spinal Cord Reflex Excitability

Hoffmann (H-) reflexes were evoked as proxy measures of spinal cord excitability while participants stood with both feet flat on the floor. An overhead harness system was utilized to ensure that there was no risk of falling [38]. Electromyography was collected using bipolar surface electrodes placed bilaterally on the tibialis anterior, vastus lateralis, and soleus muscles while a grounding electrode was placed over the right or left patella. Recordings were amplified (500 or 1000 times for soleus and 5000 times for other muscles) and filtered (10-1000 Hz for soleus and 100–300 Hz for others) (P511 Grass Instruments, AstroMedInc, West Warwick, RI, USA) and sampled at 2.5 kHz on a computer running customized software (LabVIEW, National Instruments, Austin, TX, USA).

The tibial nerve on the dominant leg was stimulated at the popliteal fossae using 1 ms square wave pulses to evoke H-reflexes in the soleus. Bipolar surface electrodes were used for stimulation delivered pseudo randomly 3-5s apart for all trials using a Digitimer (Mendtel, NSW, Australia) constant current stimulator (model DS7A). A non-contact milliammeter (mA-2000, Bell Technologies, Orlando, FL, USA) was used to measure the current delivered for each stimulus. A recruitment curve was collected by continuously increasing stimulation intensity until at least three maximal M-waves were recorded. Participants monitored the electromyography level on a computer at 10% of the Maximal Voluntary Contraction for plantarflexion which was determined before the experiment. M-wave and H-Reflex (M-H) recruitment curves of 40 stimulations were collected for each trial. These curves were used to determine the maximum action potential of the soleus muscle (M_{max}) amplitudes to normalize data [27].

Data Analysis & statistical methods

All statistical analyses were performed using SPSS (v.24, Armonk, NY: IBM Corp.). All the participants were analysed as one group, then single subject analyses were done for all participants and categorized based on if they were neurologically intact or if they had a chronic condition (3 Parkinson’s disease, 1 vascular dementia, 1 stroke). For group comparisons, the three pre-intervention sessions were first compared via Repeated Measures Analysis of Variance (rmANOVA). Sphericity was assumed via Mauchly’s Test ($p > 0.05$) and if not, degrees of freedom and p-value were corrected using the Greenhouse-Geisser method. When there were no differences between the pre-intervention results, an averaged pre-intervention value was compared to the post-intervention results using a paired t-test, as done in previous training studies [25–27]. The difference between post and baseline values were expressed as percent change from the pre-intervention results (%Δ). For individual and group comparisons, a 95% confidence interval (CI) was established from the triple baseline. Post-intervention values were then compared to the respective 95% CI and considered statistically significant if they fell outside this range. Effect size (Cohen’s *d*) was calculated to provide a standardized magnitude of changes [39]. Small (0.2–0.5), medium (> 0.5–0.8), and large (> 0.8) effect sizes descriptors were used as in a similar study [13]. The level of significance was set at $p < 0.05$, with group data reported to 3 decimal places and $p < 0.05$ for the single subject and the group 95% CI analyses.

Results

Training Repetitions Completed

The participants were guided through a set of warm-ups, kihon (basic techniques), Pinan Nidan kata cycles, and kumite (applied self-defense) applications in each intervention session. The participants had a total average of 2437 steps, 1762 turns, 3585 stance changes, 2047 punches, 2757 blocks, 884 open-hand strikes and 369 closed-hand strikes, with a total of 13,841 movements throughout the intervention. The training contents varied daily so it was our goal to record all motions for all the participants and quantify what was done over the 5 weeks (Fig. 2).

Dynamic Balance Assessment

Training generally improved reactive balance performance. The group average time for dynamic balance reaction reduced by -13.6% for tTarget ($t(14) = 1.742$; $p = 0.020$; $d = 0.450$), -8.3% for tCenter ($t(14) = 2.959$; $p = 0.010$; $d = 0.763$), and − 11.8% for tTotal ($t(14) = 2.071$; NS $p = 0.057$; $d = 0.535$), respectively (Fig. 3). The 95% CI analysis of the group data showed that there were significant changes for tTarget, tCenter, and tTotal. Pre-intervention ANOVA showed a difference between the baseline tests for tTarget ($F_{2,28}$=4.518, $p = 0.020$), tCenter ($F_{2,28}$=6.8, $p = 0.004$) and tTotal ($F_{2,28}$=5.601, $p = 0.009$).

One neurologically intact older adult participant had significant dynamic balance reaction reduction for tTarget (-44.4%, $p < 0.05$), three for tCenter (-15.9%, -20.6%, -14.4%; $p < 0.05$) and two for tTotal (-34.9%, -35.9%; $p < 0.05$). For the older adults with chronic conditions, two participants with PD showed significant reductions for tCenter (-11.5% and − 26.4%; $p < 0.05$) and one for tTarget (-33.7%; $p < 0.05$). Neither showed individual changes in tTotal. The participant with vascular dementia had − 5.3% ($p > 0.05$) reduction for tCenter and increased in time for tTarget by 11% ($p > 0.05$) and tTotal 4.9% ($p > 0.05$). The chronic stroke participant showed significant increase for tCenter (12%; $p < 0.05$) and no individual changes in tTarget or tTotal.

Clinical Assessment

Group data for the TUG were unchanged following the intervention ($t(15)$=-0.369; $p = 0.717$; $d = 0.092$) and the 95% CI did not show changes either (0.6%, $p > 0.05$). Four of the neurologically intact older adults showed significant reduction in time for TUG (-6.3%, -7.8%, -4.5%, -8.6%; $p < 0.05$), while seven had no change (7.2%, 1%, 5.4%, -2.2%, 0.8%, 4.0%; $p > 0.05$). One of the PD participants showed significant increased time in the TUG test (3.8%, $p < 0.05$). The individual with vascular dementia had no change and the chronic stroke participant had a significant increase in TUG (14%, $p < 0.05$). Pre training control was achieved since ANOVA showed no differences between the triple baseline for the TUG ($F_{2,30}$=0.252, p = 0.779)

Strength measures

In the group, strength significantly increased in the right leg (28.8%; $t(10)$=-2.286; $p = 0.045$; $d = 0.689$) and for the left leg (13.3%; ($t(11)$=-2.616; $p = 0.024$; $d = 0.755$), respectively (Fig. 4). Evaluation of the group data from the 95% CI showed that there were significant differences for the right and left legs ($p < 0.05$)

Across the group, smaller changes were found for the left arm (7.9%; $t(15)=-2.260$; $p = 0.039$; $d = 0.563$) and in the right arm (6.3%; $t(15)=-1.765$; $p = 0.098$; $d = 0.440$), with the 95% CI analyses showing changes for the left and right arms. Baseline control was achieved since ANOVA showed no differences between the triple baseline for the right arm ($F_{2,30}=0.479$, $p = 0.624$), left arm ($F_{2,30}=0.067$, $p = 0.935$), right leg ($F_{2,20}=0.210$, $p = 0.812$), and left leg ($F_{2,22}=0.183$, $p = 0.834$).

Five neurologically intact participants had significant increases in the right leg (88.7%, 70.7%, 114.2%, 101.6%, 28.8%; $p < 0.05$) and five had significant increases in the left leg strength (45.8%, 54.1%, 21.3%, 104.8%, 32.9%; $p < 0.05$). The neurologically intact older adults had five individuals with significant increases in the right arm strength (10.0%, 52.8%, 10.1%, 5.1%, 4.8%; $p < 0.05$). Three participants had significant increases for the left arm (20.5%, 17.3%, 4.1%; $p < 0.05$).

Two participants with PD showed significant increases in right leg force (36.3%, 26.1%; $p < 0.05$) and all three had significant increases in left leg force (115.8%, 12.2%, 45.9%; $p < 0.05$). Two participants with PD showed significant increases (42.6% ,19.0%; $p < 0.05$) and one with a significant decrease (-17.9%, $p < 0.05$) in right arm strength. One PD participant had significant increased strength for the left arm (18.9%, $p < 0.05$).

The individual with vascular dementia showed significant ($p < 0.05$) increases for right leg (20.8%), right arm (20.8%), and left arm (57.4%), respectively. The chronic stroke participant had a significant increase for left arm strength (15.1%; $p < 0.05$).

Spinal Cord Excitability

Gross assessment of spinal cord reflex excitability, as observed by the H_{max}/M_{max} ratios, were unchanged across the group. The pre-intervention averages for H_{max}/M_{max} ratios were 15% while the post-intervention was 18.6% (Δ23.7%; ($t(12)=-1$; $p = 0.335$; $d = 0.279$), and the group post data was outside of the 95% CI established at baseline. Pre training control was achieved since the ANOVA test showed no differences between the triple baseline ($F_{2,26}=0.665$, $p = 0.523$).

Two of the neurologically intact older adults showed significant increases in spinal cord excitability (215.4%, 47.9%; $p < 0.05$), while one showed a significant decrease (-35.9%; $p < 0.05$). Two PD participants had significant increases in spinal cord excitability (152.4%, 195.3%; $p < 0.05$). No individual changes were observed in the vascular dementia and chronic stroke participants (Fig. 5).

Discussion

A realistic community-level dose of martial arts training appears efficacious as a therapeutic intervention for improving balance and posture in older adults with and without chronic conditions. Our observations suggest an approach worthy of further refinement and assessment.

Dynamic balance and postural corrections improved by karate training

Following the training intervention, all participants showed improved performance in postural control through a decrease in time taken for dynamic postural reaction during the balance test. This enhanced dynamic balance performance leads to better postural control in older adults with or without chronic conditions, which is congruent with similar studies that observed the stabilizing effects of 'hard' martial arts [3, 13, 16, 17, 40]. Balance requires complex neuromechanical integration of muscular, somatosensory, visual, and vestibular coordination [2, 17, 41–43]. Our data suggest that this multisensory integration was improved by karate training.

The Pinan Nidan kata focuses on shifting of body weight distribution and does not have any kicking motions, so the maintenance and strengthening of balance control were anticipated. Studies of martial arts such as Tae Kwon Do and Ving Tsun (Wing Chun) improved hand grip strength, balance and gait in older adults of similar ages to those in our study [16, 17, 44]. The results of the Ving Tsun intervention highlighted that the complex functionality through balance measures could be regained after a year of training, for 2–8 hours per week [16].

Postural regulation is key for the prevention of falls in elderly populations; therefore, the changes are correlated with improved skeletal and proprioceptive muscle strength that minimizes the risk of injuries [2, 42–45]. Coordination of different limbs is needed for the enhancement of gait control, which can be accelerated through exercises involving whole-body movements [2, 7, 16, 43, 46, 47]. As the data suggest, quicker time for dynamic postural reaction infers that participants may have gained more stability in their legs which could minimize the risk of falls [17, 21]. Additionally, the improvements in balance correlate to the musculoskeletal control in various muscles in the body [17], suggesting that overall strength was gained.

Karate is a type of martial arts training using coordinated movement patterns that can induce physiological changes to corticospinal excitability, which might relate to an increase in integrity of coordination of neuronal locomotor activity [17, 44]. Such exposure could access the interlimb coordination that exists due to the coupling of neural oscillators (2 that control arm & 2 that control leg movements), subserving rhythmic movements that are seen during daily activities (Quinzi et al. 2014; Zehr et al. 2016). Since mobility is compromised with aging, the enhancement of these integral patterns is critical for maintaining function in the body. We speculate that interlimb circuits may be amplified due to the increases in coordinated use that produces both upper and lower limb strength enhancement, such as previous work with arm and leg interventions in chronic stroke participants [25, 26, 29].

Effects on muscle strength

Strength was improved in both the arms and the legs, which aligns with previous research that showed rehabilitation with arm and leg cycling improved walking function after training [12, 25, 26]. Strength in

veek training protocol, suggesting that influences from descending and interlimb pathways may have been amplified due to exercise. Previous studies in our lab with chronic stroke participants evaluated how the linkages between central pattern generator networks required for arm and leg movement during locomotion improved with arm and leg cycling training [25, 26]. It is conceivable that such central pattern generator networks and related interlimb connections might be enhanced by the karate training [25, 26].

The improvement of strength in both the arms and legs of the participants highlights that whole-body movements without the use of machinery can allow for changes in neuromuscular performance. The locomotor circuits that exist evoke the supraspinal and spinal regulatory mechanisms that are needed for neurological interaction during activities such as walking (Kaupp et al. 2018; Dragert and Zehr 2013; Zehr 2002). The primary goal of rehabilitation following neurotrauma is to regain function in movements such as walking and it is also important to strengthen these connections with aging to avoid the risk of falls [1]. We predict that training through holistic approaches involving whole body movement could maintain or enhance the intrinsic systems that exist through coordinated movement in all limbs.

Spinal cord excitability after 5-weeks of training

Spinal cord excitability as assessed by H-reflex amplitude, was measured from an upright position to be as task-specific to the training stimulus [26]. We found no strong group effect, but 5 of 16 participants did show significant changes following the completion of the intervention. While the upright position is ideal for matching training conditions, group Ia presynaptic inhibition is modulated in this posture [49–51]. Since changes in reflex amplitude due to training in other work [27] shows Ia PSI as a mechanism of neuroplasticity, our choice of standing may have weakened our ability to detect change. Future work should include reflex measurement across a variety of tasks from sitting, standing, and walking [49] to better assess any changes in reflex excitability.

Amongst this population, the largest magnitudes of change were observed in individuals with PD. Following neurotrauma, there is a greater capacity for restructuring of circuitries that can be attributed to the neural plasticity in the participants [9]. The single subject analysis revealed that five (31%) of the participants showed significant changes in this study and two of the greatest changes came from the PD participants. Other research with PD presents that neurological integrity of movement is lost, therefore regaining strength and function is of utmost importance. It was anticipated that those with neurological impairments would demonstrate noteworthy transformations due to the nature of the condition and the motor systems involved with complex movements such as martial arts [5, 9, 11, 46].

Therapeutic efficacy of a typical community martial arts training “dose”

While important and useful, past martial arts training interventions provide few details about the actual content of physical performance and lacks a record of techniques used and the number of movements. Here we aimed to provide insight into the quantity required. Other martial arts interventions mention the style of exercises used, such as Shotokan karate with a mixture of kihon, kumite, and kata [5, 6]. A recent publication included a detailed overview of planned movements for a 10-week training intervention, with a weekly syllabus showing the intended progression of the techniques [13] but there was no quantification of the movements done during the session or how many were done by each participant. Here we add to the literature and assist future investigations by documenting specific movement volume throughout the training period.

Although the results were efficacious, we still do not know the “threshold” for the dosages of movements to produce significant benefits across all measures and this should be further explored. Studies on strength training with chronic stroke participants show training-induced neural plasticity following a 5-week intervention with similar timelines to our karate study [29, 30]. Strength training as well as locomotor training studies in chronic stroke participants exemplify how dose can be evaluated in a controlled setting [25, 26, 29, 30]. For example, previous work on arm cycling produced a final dosage of almost 26,000 revolutions after 5 weeks of training [26] and another study of arm and leg cycling was similar, also after 5 weeks [31]. Strength training with chronic stroke participants showed desired results could occur in the intervention period, with dosages of approximately 375 repetitions of maximal wrist extensions [28] for improved wrist extension, 470 repetitions of maximal hand grip contractions [52] for changes in the handgrip strength, and 720 repetitions of ankle contractions [30] for changes in the legs. The calculation of dose is simpler in controlled environment and our understanding is that this is the first time a martial arts “dosage” has been quantified. Additionally, balance assessments in older adults typically focus on gait stability through training with specific motor tasks [2, 46] but evaluation of specific martial arts techniques such as stance changes have not been done in the literature. Regardless, we hope that this preliminary report will create a foundation for doses of movement techniques required to produce changes in older adults with or without chronic conditions.

The martial arts training duration, frequencies, and requisite participant commitments vary within the literature, ranging from 5 weeks to 3 years (Jansen et al. 2017; Dahmen-Zimmer and Jansen 2017; Fong et al. 2013; Fleisher et al. 2020; Chateau-Degat et al. 2010; Cho and Roh 2019; Chung et al. 2020; Cromwell et al. 2007; Domingos et al., 2019; Hackney and Earhart 2008; Hadad et al. 2020; Hong 2000; Jackson et al. 2012; Li et al. 2012; 2002; Ouergui et al. 2014; Pliske et al. 2016). An evaluation of over 15 martial arts training studies notably showed the differences that exist. Most of the studies had training sessions of 1 hour per visit, and these occurred between 1–3 times a week [4–7, 13–16, 19, 22, 24]). Additionally, the studies usually had around 15 participants, ranging from 11 to 23 individuals [5, 22]. For the studies that had participants training once a week, they were usually longer in duration (30 weeks-3 years) (Dahmen-Zimmer and Jansen 2017; Fong et al. 2013; Domingos et al., 2019.; Hadad et al. 2020). The number of total training sessions varied from 15 to 48 sessions total [5, 7], leading to inconsistencies in the literature and preventing the understanding of necessary training dose. The studies observed a broad range of measures such as balance, physical function, strength, and quality of life, which is congruent with our training intervention. What remains unknown is the minimum timing needed for efficacious community martial arts intervention.

Limitations And Recommendations

This project suggests that 5-weeks of martial arts training leads to better overall movement in neurologically intact older adults and those with chronic conditions. While useful data were obtained that support the use of community based martial arts training as therapeutic adjuncts in older adults, there are some important recommendations for the future:

1) Enhanced documentation and assessment of physical performance. For example, incorporating detailed enumeration of techniques as here combined with movement tracking using activity monitors during training. This would be especially useful in studies assessing threshold dose;

2) Expanding the reach of this approach into the community to assess uptake, and implementation compared to traditional exercise alone;

3) Combining the measures here with enhanced assessment of other outcomes around mental health, such as emotional well-being and mood [5, 6];

4) The study was underpowered for some outcome measures. We suggest that future research needs to be conducted with a greater sample size with multiple intakes (something that was rendered impossible here due to the COVID 19 pandemic);

5) The TUG is typically used to assess individuals with chronic conditions [17] but since most participants (n = 11) were neurologically intact, there were subtle differences in the pre- and post-values. Clinical tests more specifically related to posture and balance (e.g. BERG balance test) would be better used in place of the insensitive TUG [53];

6) Assessment of dynamic balance is an important factor when the intervention trains this parameter. Future work should consider our and related approaches to capture this effectively;

7) Simple measures of spinal cord reflex excitability as assessed by the H-reflex were insensitive here. Suggestions are to assess multiple sizes of H-reflexes with recruitment curves, H-reflexes conditioned by somatosensory stimulation, and interlimb reflexes in future work;

Holistic, whole body integrated exercise programs are being implemented worldwide due to the benefits that are gained both mentally and physically. Future work should build on this and prior foundational work [5, 6] to explore the promise of mindful, enjoyable and engaging activities that contain content widely available in the community. More attempts to emphasize the psychological impacts that occur from the physiological training are necessary. We suggest participants are more likely to continue with the practices beyond the intervention timeline. Indeed, anecdotally, over two thirds of the participants wanted to, and presently continue training in this “prehabilitation” after the intervention was completed.

Conclusions

Significant changes in balance and strength suggest that neuromechanical integrity can improve in aging populations after five weeks of karate training. More investigations of spinal cord excitability are needed. Our observations lay the groundwork for future explorations of dose, applications to neuropathology, and accessible development of martial arts interventions as “pre-habilitation” for older adults leveraging programs found widely in most communities.

Abbreviations

CI = Confidence Interval

H-reflex = Hoffmann reflexes

PD = Parkinson’s Disease

rmANOVA = Repeated Measures Analysis of Variance

TUG = Timed Up and Go

tTarget = time to Target

tCenter = time to Center

tTotal = sum of tTarget and tCenter

Declarations

Ethics approval and consent to participate

Informed written consent under the ethics protocol approved by the University of Victoria Human Research Ethics Board (Protocol #18-213).

Consent for publication

Not applicable

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Authors’ contributions

E. P. Z., H. M., A. H., and Y. S. conceived the experiment and contributed to the experimental design. Data collection, analysis, and creation of figures were completed by H. M., A. H., B. N., Y. S., G. P., B.F., and E.P.Z. The article was prepared by H. M. and E. P. Z., and the final draft of the article was edited by G. P., E. P. Z., B. F., Y. S., R. R., and H. M.

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Validity/ Reliability of Sports-Related Concussion Balance

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Supplementary File

Supplementary file is not available with this version.

Figures

Figure 1

Illustration of the testing and karate training protocol. A multiple baseline within-subject control design was used for this study.

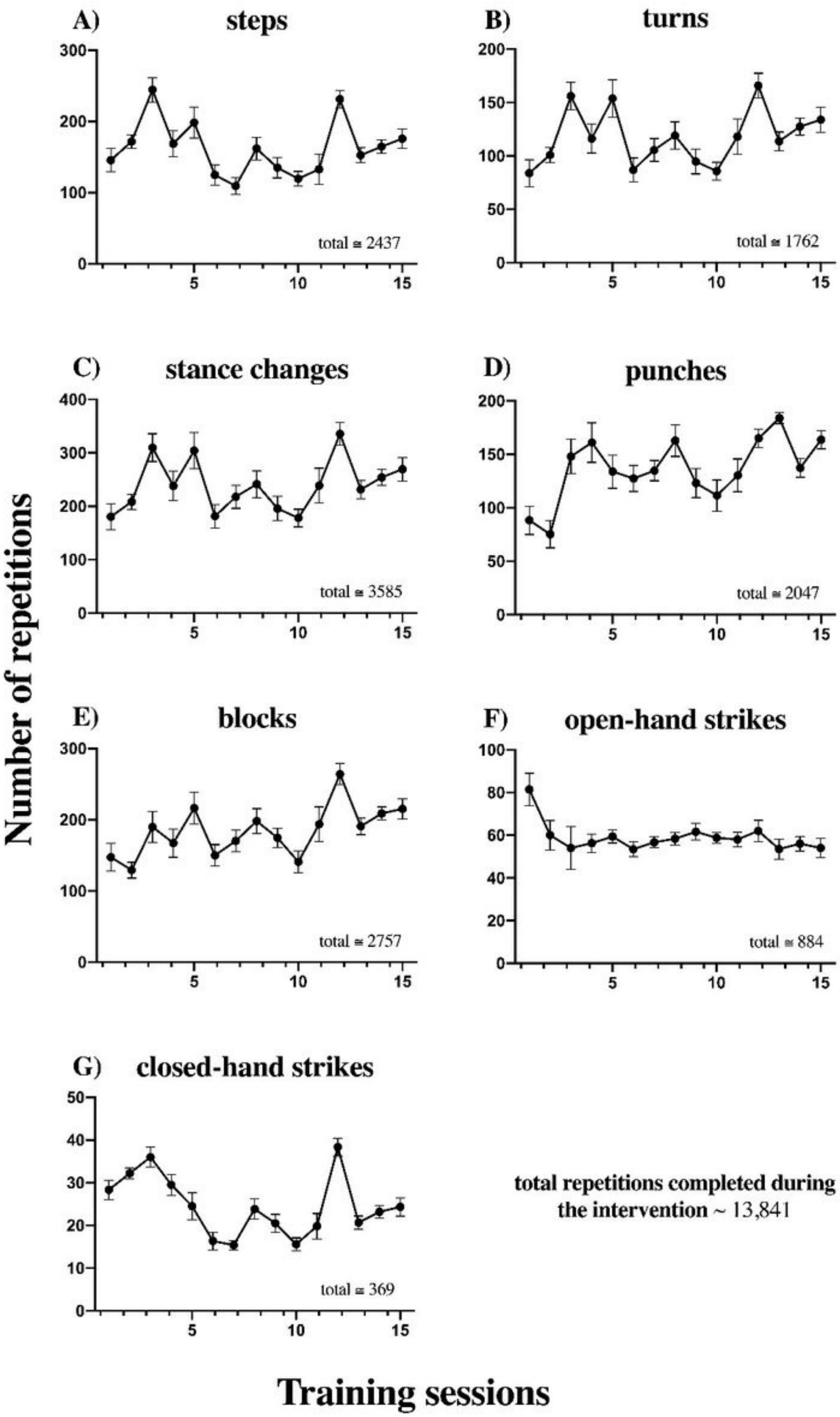

Figure 2

Daily movement repetitions during the karate training intervention categorized into different movement techniques. The data show the movements that were done during the warmup as well as during the pinan nidan kata repetitions. The group averages are displayed in the figures and the sum of each technique is summarized in the bottom right panel.

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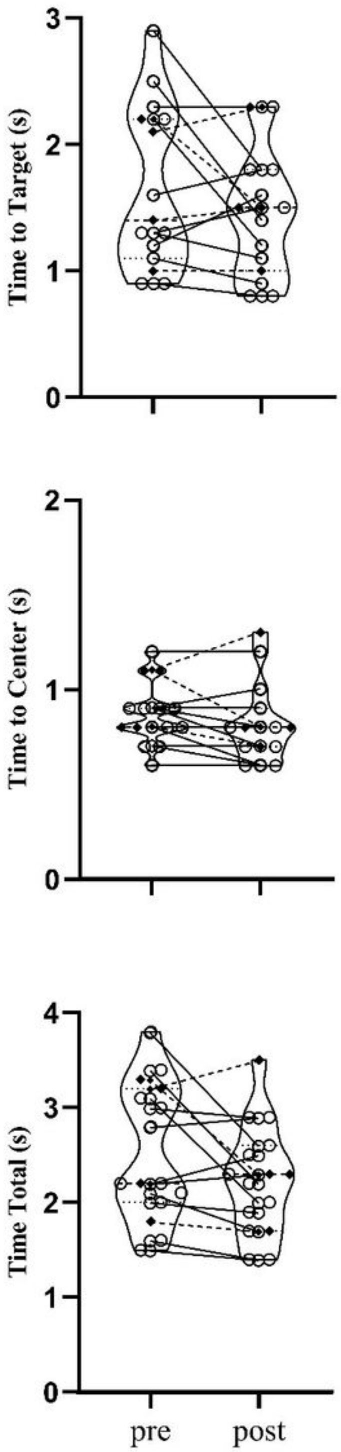

Figure 3

Time to reach the target (tTarget), to get back to center (tCenter) and the sum of them (tTotal) in the dynamic postural test. The open circles represent the neurologically intact older adults, while the filled diamonds and dotted lines represent the older adults with chronic conditions.

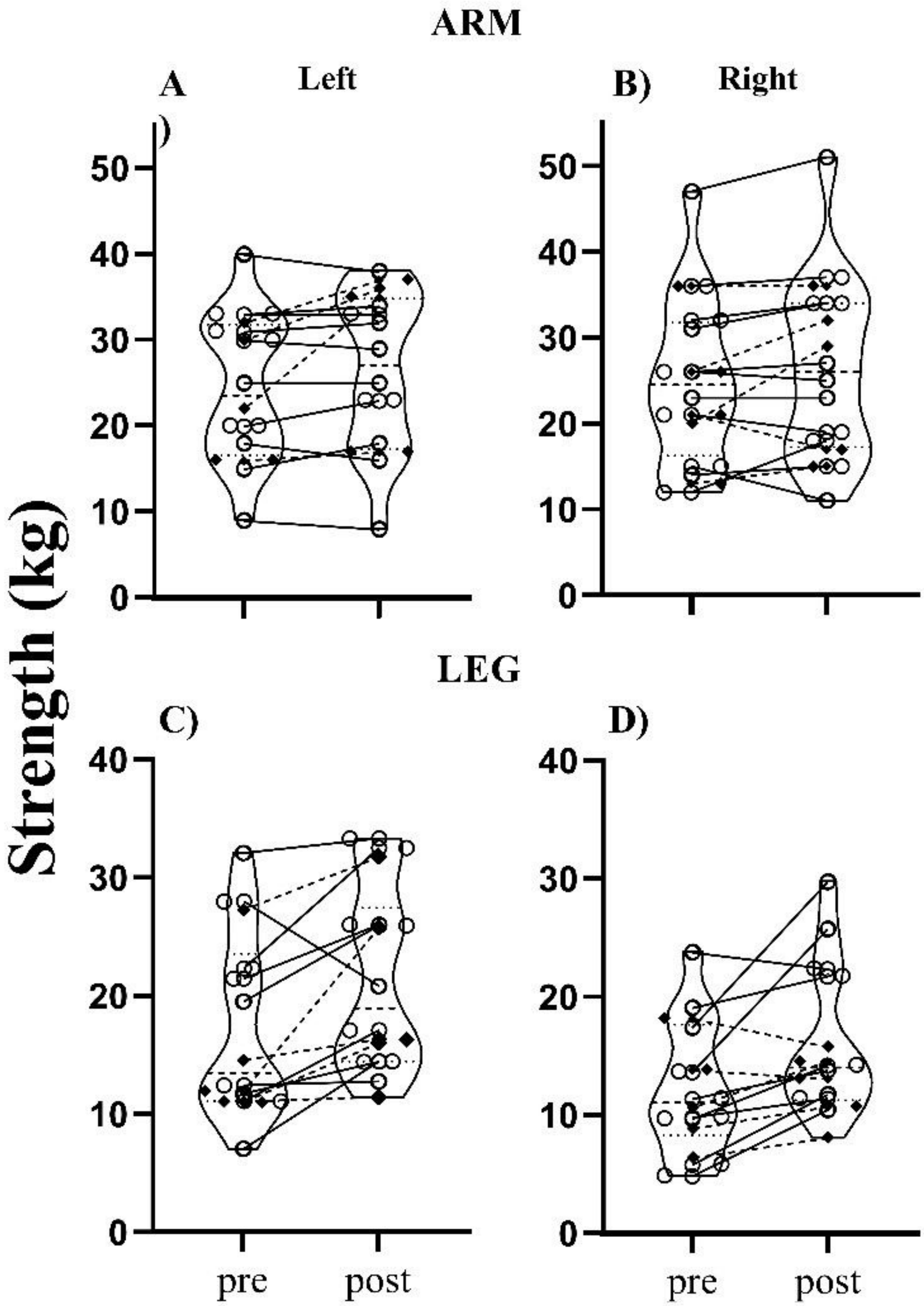

Figure 4

Pre-post comparison of strength, measures force in kilogram (kg), in the arms and legs. Open circles= Neurologically Intact Older Adults; Filled Diamonds= Older Adults with Chronic Conditions.

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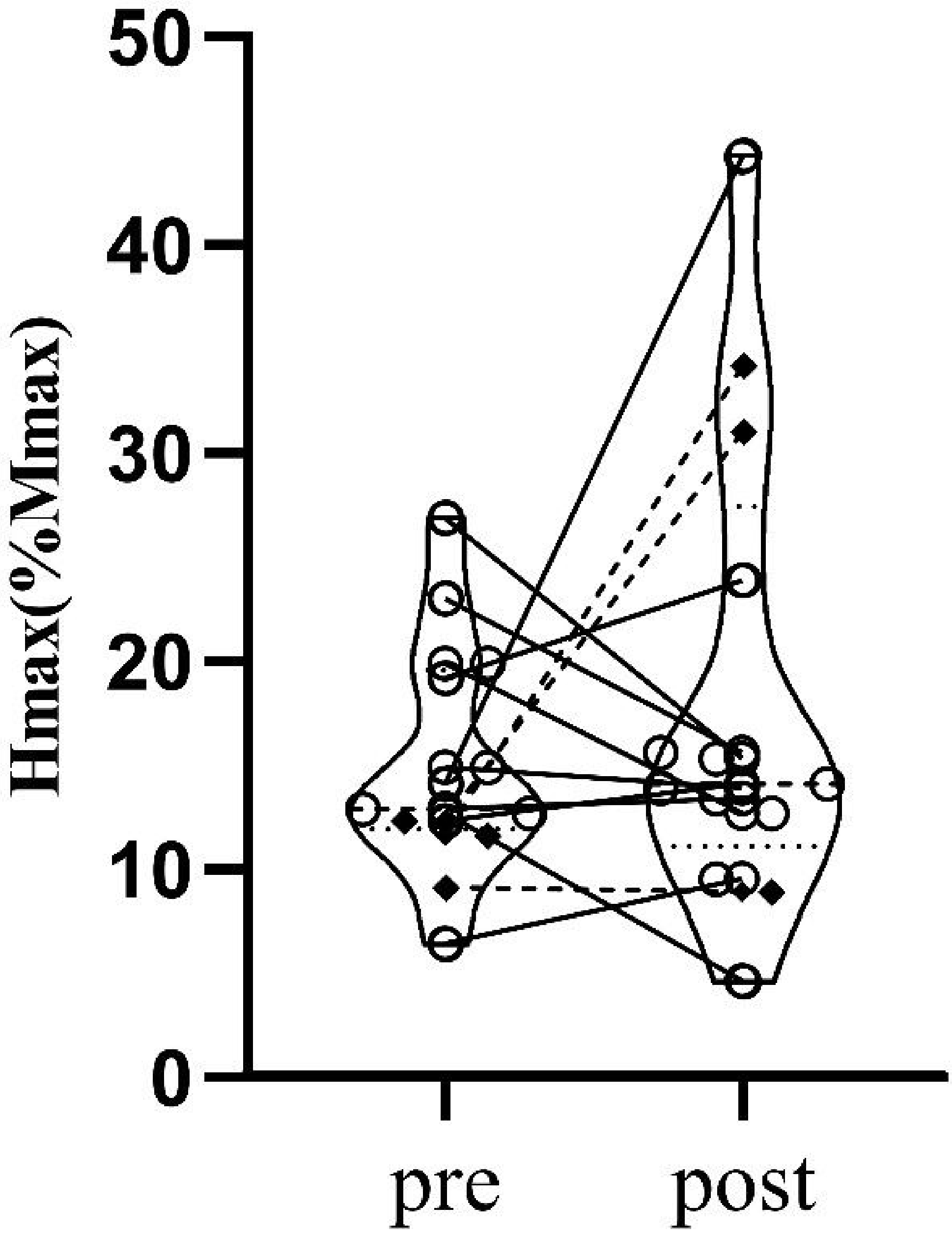

Figure 5

Pre-post comparison of spinal cord excitability ratios. Open circles= Neurologically Intact Older Adults; Filled Diamonds= Older Adults with Chronic Conditions.