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ARTICLE

The effects of modified Taekwondo on measures of functional fitness in older adults: a pilot study

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Abstract – Functional fitness represents the physical capacity needed to perform activities of daily living, independently without undue fatigue, deteriorates with age. Taekwondo is a traditional form of martial arts training that has shown several positive effects on fitness in younger adults. However, a paucity of research has investigated the impact of modified Taekwondo training in older adults. Therefore, this study aimed to implement a modified Taekwondo program for older adults over the age of 60 and determine its impact on functional fitness. Fifteen participants from a Taekwondo exercise class (average age: 72.7 years) and 10 non-exercising controls (average age: 73.8 years) participated. Functional fitness for all participants was pre-tested and post-tested using the following measures: = finger to nose test (FTNT) = timed single-leg stance (TSLS), timed up and go (TUG) = 30-second sit to stand test (30S2ST), 30-second arm curl test (ACT), two-minute step in place (2SIPT), chair sit and reach test (CSRT), back scratch test (BST). No significant differences were found between pre-test and post-test measures for both groups. Effect sizes showed that the intervention had a small effect on hand-eye coordination, timed single-leg balance, upper limb strength, aerobic fitness, and lower limb flexibility. Despite no functional effect, six weeks of modified Taekwondo training still reached improvements in balance, aerobic fitness, and lower limb flexibility.

Key words: strength, martial arts, flexibility, coordination, balance

Résumé – Les effets du taekwondo modifié sur les mesures de la condition physique fonctionnelle chez les personnes âgées : une étude pilote. La condition physique fonctionnelle se détériore avec l'âge, ce qui a des effets néfastes sur la santé et l'autonomie. Le taekwondo est une forme traditionnelle d'entraînement aux arts martiaux qui a montré plusieurs effets positifs sur la condition physique chez les jeunes adultes. Cependant, peu de recherches ont étudié l'impact d'un entraînement modifié au taekwondo chez les personnes âgées. Par conséquent, cette étude visait à mettre en œuvre un programme de taekwondo modifié pour les personnes âgées de plus de 60 ans et à déterminer son impact sur la condition physique fonctionnelle. Quinze participants d'un cours de taekwondo (âge moyen : 72,7 ans) et dix témoins non pratiquants (âge moyen : 73,8 ans) ont participé. L'aptitude fonctionnelle de tous les participants a été pré-testée et post-testée à l'aide des mesures suivantes: = test doigt-nez (FTNT = position chronométrée sur une jambe (TSLS), chronométré et partez (TUG) = test assis-debout de 30 secondes), test de flexion des bras de 30 secondes (ACT), pas en place de deux minutes (2SIPT), test d'assise et d'atteinte de la chaise (CSRT), test de rayure du dos (BST). L'analyse de la variance pour un design mixte a été utilisée pour évaluer les différences au niveau de signification de 0,05. Aucune différence significative n'a été trouvée entre les mesures pré-test et post-test pour les deux groupes. La taille de l'effet a montré que l'intervention avait un faible effet sur la coordination œil-main, l'équilibre chronométré d'une jambe, la force des membres supérieurs. Malgré des améliorations encourageantes de l'équilibre, de la capacité aérobie et de la flexibilité des membres inférieurs, six semaines d'entraînement de taekwondo modifié n'ont pas amélioré de manière significative les mesures de condition physique fonctionnelle chez les personnes âgées vivant dans la communauté.

Mots clés : force, arts martiaux; souplesse, coordination, équilibre

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Introduction

Functional fitness is a general framework representing the physiologic parameters associated with functional, physical tasks. These physical tasks are supported by physical abilities (strength, endurance, agility and flexibility) required for basic and advanced activities (Rikli & Jones, 2002) of daily living independently, without undue fatigue (Kostić, Uzunović, Pantelić, & Đurašković, 2011; Milanović *et al.*, 2013). Moreover, low functional fitness is a strong predictor of adverse health outcomes and reduced quality of life (St John, Tyas, Menec, & Tate, 2014). To prevent or retard declines in functional fitness, older adults should maintain a physically active lifestyle throughout the lifespan that promotes functional fitness.

The benefits of cardiovascular and strengthening exercise on functional fitness in older adults are well known and documented (Hurst, Weston, McLaren, & Weston, 2019; Paterson & Warburton, 2010). However, conventional methods of exercise are often associated with poor adherence (Rivera-Torres, Fahey, & Rivera, 2019) and large dropout rates (Osho, Owoeye, & Armijo-Olivo, 2018). For example, Viken *et al.* (2018) investigated the dropout rates in a large cohort (1,514) of older adults (mean age: 72.4 ± 1.9 years) and reported a dropout rate of approximately 15%. Furthermore, Bårdstu *et al.* (2020) investigated 144 community-dwelling older adults (mean age: 86.0, range: 83–91 years) who participated in a resistance training program for eight months. The researchers reported a 44% dropout rate despite only exercising twice per week during the research trial. Therefore, alternative physical activity methods that promote functional fitness may be of interest to clinicians and exercise professionals. Martial arts training has been proposed as one such alternative method of physical activity that promotes functional fitness (Cromwell, Meyers, Meyers, & Newton, 2007). For instance, Tai Chi, a slower form of martial arts that is popular among older adults, has been shown to significantly improve components of functional fitness such as reaction time, balance, mobility, flexibility and strength in older adults (Manor *et al.*, 2014; Taylor-Piliae, Haskell, Stotts, & Froelicher, 2006; Yıldırım, Ofluoglu, Aydogan, & Akyuz, 2016).

Despite the benefits of Tai Chi, the slowness of this exercise may not appeal to some older adults. Harder forms of martial arts training such as Taekwondo and Karate contain many of the successful elements of Tai Chi; however, they are completed at a faster pace and with more physically challenging exercises and exertion (Brudnak, Dundero, & Van Hecke, 2002; Cromwell *et al.*, 2007; Marie-Ludivine, Papouin, Saint-Val, & Lopez, 2010). For instance, Marie-Ludivine *et al.* (2010) reported a significant improvement in reaction time (20%) and postural sway (18%), following 12-months adapted Karate training in a group of 50-year-old men. In addition, Cromwell *et al.* (2007) reported significant improvements in mobility (9%) and balance (16%) following 11 weeks of modified Taekwondo training in a group of older men and women aged 59–88 years. However, there is a paucity of research investigating the benefits of Taekwondo training on functional fitness in older adults.

Taekwondo is a Korean martial art that encompasses kicking, blocking, and striking techniques while simultaneously stabilizing the body for efficient movement of the extremities to maintain balance during the performance of these dynamic movements (Cromwell *et al.*, 2007). Thus, Taekwondo training may engage and challenge multiple physiological systems and thereby have the potential to overcome many of the impairments associated with advancing age. However, the effectiveness as an exercise intervention to improve physical function in healthy old adults living within the community is largely unknown. Therefore, this study aimed to evaluate the effects of six weeks of supervised Taekwondo training on physical function in adults over 65 who were free-living within the community. We hypothesised that six-weeks of modified Taekwondo training would lead to a significant improvement in functional fitness.

Methods

Participants

Community-dwelling older adults were recruited as a convenience sample from a modified Taekwondo class offered to the community through Southern Cross University. A total of 14 participants agreed to undergo a fitness assessment before and after completing a six-week modified Taekwondo class. These older adults included 10 women and five men aged 60 to 75 years. All exercise participants selected for this study had not previously undertaken Taekwondo training (or other martial arts training). Our study design (Fig. 1) was quasi-experimental where our participants in the treatment group and control group were not randomly assigned (Maciejewski, 2020). A control group of older adult volunteers who did not participate in the modified Taekwondo classes was assessed and the exercise participants. These no exercising control participants were recruited from community groups within the area. The control group consisted of three women and nine men aged 65–79 years. Informed consent was obtained from all participants prior to any testing.

All participants underwent a pre-exercise screening to ensure they had no established cardiovascular, metabolic, or respiratory disease nor signs or symptoms of these conditions (Norton, 2005). All participants were free from severe pathologies that would preclude exercise. Potential participants reporting uncontrolled hypertension, uncontrolled diabetes, congestive heart failure, disabling rheumatoid arthritis, debilitating osteoporosis, or a recent fracture were excluded from participation at the time of the study. Of those selected, two control group participants reported occasional use of an assistive device but did not require its use during the testing procedures. They were included in the study.

Study flowchart showing the experimental timeline

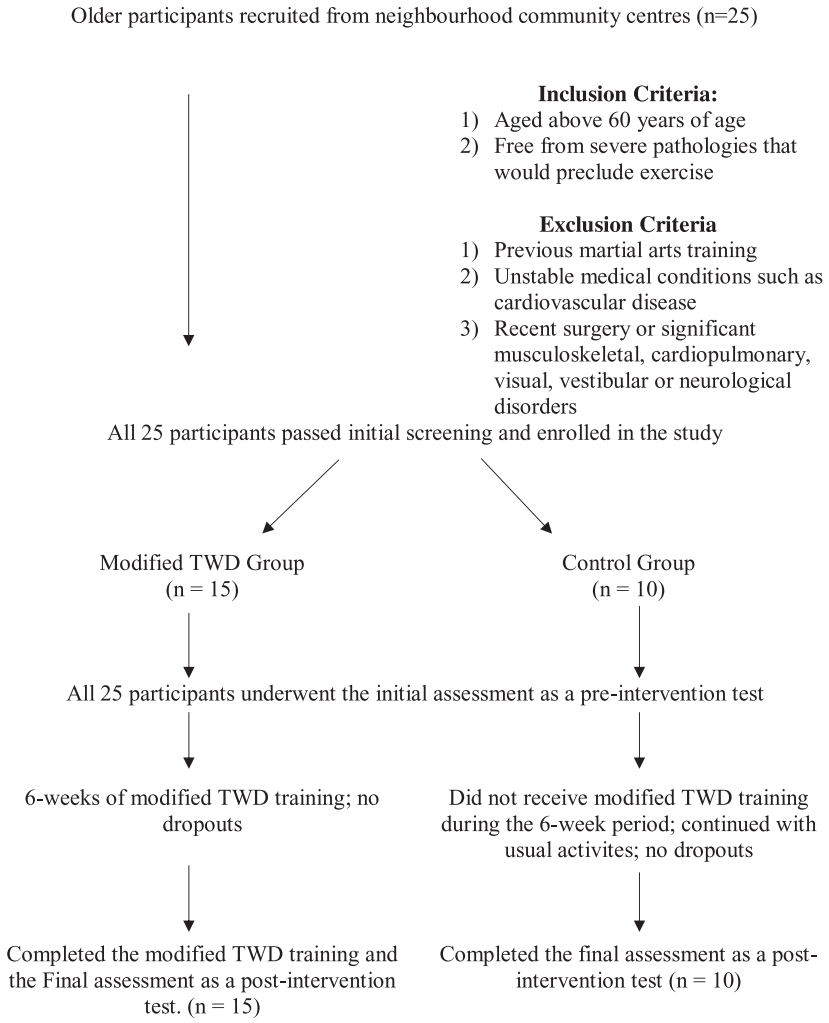

Figure 1. Study flowchart showing the experimental timeline

Procedures

Before the first modified Taekwondo class, all participants were pre-tested using the measures described below. These outcome measures were chosen as they have been previously deemed valid measures of functional fitness (Jones & Rikli, 2002; Rikli & Jones, 2013) and had demonstrated success in the older adult population (Langhammer & Stanghelle, 2011; Lanzino *et al.*, 2012; Rikli & Jones, 1999; Swaine, Lortie, & Gravel, 2005). These same measures were repeated following the six-week modified Taekwondo training intervention.

Functional fitness

The Senior Fitness Test is a valid method to assess functional performance in healthy, older adults (Rikli & Jones, 1999). The test battery consists of six functional strength measures in the arms and legs, endurance, mobility, and flexibility (Rikli & Jones, 2013). In addition to the Senior Fitness Test, hand-eye coordination was assessed using the timed finger-to-nose test, (Lanzino *et al.*, 2012). A single-leg stance time for balance (Vellas *et al.*, 1997) was added to the outcome measures of this study. All tests were modified and adapted to the metric and weight systems in this study. A 2-kg and 4-kg hand weights were used in the bicep curl test based upon gender; flexibility was measured in centimetres. These adaptations were made to make the testing repeatable and more precise. Following a standardized warm-up of 5-minutes of stationary cycling at 50-watts, the following tests were conducted in this order.

Finger to nose test

Following a demonstration of the required movement, subjects were asked, with their eyes open, to extend their arm out front at shoulder level fully and to flex the elbow to touch their nose and return the arm to the fully extended position, in rapid succession. Subjects practiced the movement without a time constraint to ensure their

comprehension of the task and then performed three trials. Subjects were then instructed to perform the tests as quickly and accurately as possible following the command: 1, 2, 3, go. Timing began on instruction to start. The time to complete five cycles of movement (*e.g.*, start with their finger on the nose, fully extend the arm and return the finger to the nose) was recorded with a conventional stopwatch precise to two decimal places. The best of three trials was recorded.

Timed single-leg stance

Subjects were timed as they stood on their dominant leg, flex the opposite knee, allowing the foot to clear the floor and balance on one leg for as long as possible. One trial was recorded.

Timed up and go

The timed up and go test (TUG) is the time taken to get up from a seated position, walk 2.4 meters, turn, and return to the seated position as quickly as possible. Test scores were recorded with a conventional stopwatch precise to two decimal places. The best of two trials were recorded.

30-second sit to stand

The sit-to-stand test is the number of stands from a seated position in 30 seconds, with the participants arms folded across the chest. One trial was recorded.

30-second arm curl test

The arm curl test was the number of bicep curls completed in 30 seconds with the participant's dominant hand. One trial was recorded. Weights of 2 kg were utilized for female participants and 4 kg for males. These weights were modified slightly from the original weights prescribed for women (2.27 kg) and men (3.63 kg) due to equipment availability.

2-minute step test

The 2-minute step test requires participants to march in place as fast as possible for two minutes while lifting their knees to a height midway between their patella and iliac crest when standing erect. The number of right-sided steps at the criterion height from one trial was recorded.

Chair sit and reach test

The number of centimetres measured from the extended fingers and the tip of the toe while keeping the dominant leg extended with ankle dorsiflexed. The best of two trails were recorded.

Back scratch test

The number of centimetres between the extended middle fingers, with the dominant hand reaching over the shoulder and the non-dominant hand, reaches the middle of the back. The best of two trials was recorded.

These measures of functional fitness are specific to the movement patterns carried out in the modified Taekwondo exercises. By way of example, kicking on one leg may cause an improvement in single-leg balance, which may be reflected in improved single-leg balance time. Striking the reaction ball may enhance hand-eye coordination, leading to improved finger-to-nose times. Long, wide stances may improve leg strength due to the sustained isometric contraction of the quadriceps, which may be reflected in improved sit-to-stand scores. Finally, kicking motions stretch the hamstrings, which may enhance sit and reach scores.

Modified Taekwondo training

The modified Taekwondo classes met for 1 hour, twice per week for six weeks. The modified Taekwondo classes followed a standardized curriculum for older adults (Ageless Taekwondo, Australian Taekwondo), provided by a first-degree black belt Taekwondo instructor who had training to teach this modified form of Taekwondo. Classes started with a short warm-up of joint mobility exercises and gentle stretches for the torso, upper and lower limbs for 5 minutes. These exercises were followed by coordination and reaction time exercises for a further 5 minutes. Modified Taekwondo exercises began with a series of singular blocking, striking, and kicking movements performed while standing in place. These exercises were progressed to include direction changes and stepping movements in which the participants must turn before executing a block, strike or kick. Participants then practiced modified kicking and punching strikes on foam sticks and kick shields. Classes concluded with a further series of gentle stretches for 5 minutes (Tab. 1).

Non-exercising controls were asked to maintain their current lifestyle and were asked to report any lifestyle changes such as an extended illness, injury, or participation in a structured exercise program. No participants reported any of these lifestyle changes during the 6-week study period. After the study, they were encouraged to commence a structured exercise program by one of the research assistants

Statistical analyses

Descriptive statistics were presented as mean ± standard deviation (SD). Two-way repeated-measures ANOVA was used to determine group (TWD, CT) × time (pre, post) interactions or main effects where no interaction effect existed ($P < 0.05$). If an interaction effect was noted, dependent and independent *t*-tests were then used to examine between and within-group effects. Corrections were applied for multiple comparisons, with the corrected alpha accepted at $P < 0.025$. Effect sizes (Cohen's *d*) and *t*-tests were also used to compare the within-group and between-group changes. Threshold values for small, moderate, and large effects were 0.2, 0.5, and 0.8, respectively (Sullivan & Feinn, 2012). All data were analysed using S.P.S.S. (Version 25.0, S.P.S.S., Armonk, NY). Dependent measures were finger to nose test (FTNT timed single-leg stance (TSLS), timed up and go (TUG),

Table 1. Periodisation of modified Taekwondo training.

Component	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Warm-up	Static stretching of the major muscle groups5 minutes	Static stretching of the major muscle groups5 minutes	Static stretching of the major muscle groups5 minutes	Static stretching of the major muscle groups5 minutes	Static stretching of the major muscle groups5 minutes	Static stretching of the major muscle groups5 minutes
Coordination – reaction ball	2 × 1-minute rounds with 30-second restAim: as many strikes on the ball as possible, stationary5 minutes	2 × 1-minute rounds with 30-secons restAim: as many strikes on the ball as possible, stationary5 minutes	2 × 1-minute rounds with 30-second restAim: as many strikes on the ball as possible, stationary5 minutes	2 × 1-minute rounds with 30-second restAim: as many strikes on the ball as possible, stationary5 minutes	2 × 1-minute rounds with 30-second restAim: as many strikes on the ball as possible, stationary5 minutes	2 × 1-minute rounds with 30-second restAim: as many strikes on the ball as possible, stationary5 minutes
Taekwondo techniques – blocking, punching and kicking	Stationary techniques1 set × 10 repetitions ● Horse stance forward punching – K.I.A. last punch ● Rising block in L-stance (L/R side) ● Downward block L-stance (L/R side) ● Front kick (L/R side)20 minutes (allow rest time for drink breaks, demonstration technique correction)	Stationary + forward stepping techniques1 set × 12 repetitions: ● H/S forward 3-level punching – K.I.A. last punch ● Rising block in L-stance (L/R side) ● Downward block L-stance (L/R side) ● Front kick (L/R side)20 minutes (allow rest time for drink breaks, demonstration technique correction)	Stationary + forward stepping techniques2 sets × 10 repetitions: ● H/S forward 3-level punching – K.I.A. last punch ● Rising block in L-stance (L/R side) ● Downward block L-stance (L/R side) ● Front kick (L/R side)20 minutes (allow rest time for drink breaks, demonstration technique correction)	Stationary + forward stepping techniques2 sets × 12 repetitions: ● H/S forward punching 3 levels -jaw, chest, stomach × Kia Last punch*Combinations* ● L/S forward L/R punch to jaw + R/kick -to knee ● L/S forward L/R punch to jaw + L/kick to knee ● L/S forward L/R punch to chest + R/kick to groin ● L/S forward L/R punch to chest + L/kick to groin ● Front kick L-stance (L/R side) ● Sidekick 90°R/side ● Sidekick 90°L/side20 minutes (allow rest time for drink breaks, demonstration technique correction)	Stationary + forward stepping techniques3 sets × 10 repetitions: ● H/S forward punching 3 levels – jaw, chest, stomach × Kia Last punch*Combinations* ● L/S forward L/R punch to jaw + R/kick to knee ● L/S forward L/R punch to jaw + L/kick to knee ● L/S forward L/R punch to chest + R/kick to groin ● L/S forward L/R punch to chest + L/kick to groin ● Front kick L-stance (L/R side) ● Sidekick 90°R/side ● Sidekick 90°L/side20 minutes (allow rest time for drink breaks, demonstration technique correction)	Stationary + forward stepping techniques3 sets × 12 repetitions: ● H/S forward punching 3 levels – jaw, chest, stomach × Kia last punch*Combinations* ● L/S forward L/R punch to jaw + R/kick to knee ● L/S forward L/R punch to jaw + L/kick to knee ● L/S forward L/R punch to chest + R/kick to groin ● L/S forward L/R punch to chest + L/kick to groin ● Front kick L-stance (L/R side) ● Sidekick 90°R/side ● Sidekick 90°L/side20 minutes (allow rest time for drink breaks, demonstration technique correction)

Table 1. (suite).

Component	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Fitness – punching and kicking techniques on the foam paddles and kick shield	Stationary techniques on foam paddles/ kick shield1 set × 10 repetitions to instructors count ● Left/right reverse punching on paddles ● L/R groin kick on paddles2 × 1-minute rounds, 2-minute rest between rounds ● Left/right reverse punching on foam paddles ● L/R front kick on a shield15 minutes (allow rest time for drink breaks, technique correction)	Stationary techniques on foam paddles/kick shield1 set × 12 repetitions to instructors count ● Left/right reverse punching on foam paddles ● L/R groin kick on paddles2 × 1-minute rounds, 2-minute rest between rounds ● Left/right reverse punching on foam paddles ● L/R front kick on a shield15 minutes (allow rest time for drink breaks, technique correction)	Stationary techniques on foam paddles/kick shield2 sets × 12 repetitions to instructors count ● Left/right reverse punching on paddles ● L/R groin kick on paddles2 × 1-minute rounds, 1-minute rest between rounds ● Left/right reverse punching on foam paddles ● L/R cross punch + R/front kick on a shield ● L/R cross punch + L front kick on a shield15 (allow rest time for drink breaks, technique correction)	Stationary techniques on foam paddles/kick shield2 set × 12 repetitions to instructors count ● Left/right reverse punching on paddles ● L/R groin kick on paddles2 × 1-minute rounds, 1-minute rest between rounds ● Left/right reverse punching on foam paddles ● L/R cross punch + R/front kick on a shield ● L/R cross punch + L front kick on a shield20 minutes (allow rest time for drink breaks, technique correction)	Stationary techniques on foam paddles/kick shield3 set × 10 repetitions to instructors count ● Left/right reverse punching on paddles ● L/R groin kicks on paddles ● Squat + L/R groin kicks on paddles2 × 1-minute rounds, 1-minute rest between rounds ● Left/right reverse punching on foam paddles ● L/R cross punch + R/front kick on a shield ● L/R cross punch + L front kick on a shield ● L/R sidekicks on a shield20 minutes (allow rest time for drink breaks, technique correction)	Stationary techniques on foam paddles/kick shield3 set × 12 repetitions to instructors count ● Left/right reverse punching on paddles ● L/R groin kicks on paddles ● Squat + L/R groin kicks on paddles2 × 1-minute rounds, 1-minute rest between rounds ● Left/right reverse punching on foam paddles ● L/R cross punch + R/front kick on a shield ● L/R cross punch + L front kick on a shieldL/R sidekicks on a shield20 minutes (allow rest time for drink breaks, technique correction)
Cooldown – static stretching and deep breathing exercises	Static stretching and deep breathing exercises10 minutes	Static stretching and deep breathing exercises10 minutes	Static stretching and deep breathing exercises10 minutes	Static stretching and deep breathing exercises10 minutes	Static stretching and deep breathing exercises10 minutes	Static stretching and deep breathing exercises10 minutes
Rating of perceived exertion	Low intensity – Borg Scale9/6–20	Low intensity – Borg Scale 10/6–20	Moderate intensity – Borg Scale 11/6–20	Moderate intensity – Borg Scale 12/6–20	Moderate intensity – Borg Scale 13/6–20	Moderate intensity – Borg Scale 14/20
Total time	55 minutes	55 minutes	55 minutes	60 minutes	60 minutes	60 minutes

Table 2. Participant demographics.

	TWD group	Control group
Number	15	10
Age (years)	74.4 ± 5.0	72.5 ± 3.0
Mass (kg)	76.0 ± 12.8	84.9 ± 14.5
Height (cm)	167.3 ± 7.8	175 ± 0.0
Body mass index (kg/cm$^{2)}$	26.3 ± 4.3	27.8 ± 4.3

Notes: mean ± standard deviation.

Table 3. Mean ± standard deviations for functional fitness measures.

	Modified TWD group				Control group			
Test	Pre	Post	Absoluter	%r	Pre	Post	Absoluter	%r
FTNT (number)	3.9 ± 1.0	3.7 ± 0.7	−0.2 ± 1.0	−5.6	4.5 ± 1.6	3.5 ± 0.9	−0.9 ± 1.7	−21.5
TSLS (second)	21.0 ± 31.1	30.5 ± 50.3	9.4 ± 44.0	45.0	69.7 ± 100.9	40.7 ± 35.0	−28.9 ± 74.0	−41.6
TUG (number)	6.3 ± 1.3	5.7 ± 1.0	−0.6 ± 0.9	−9.8	5.8 ± 1.7	5.9 ± 2.4	0.1 ± 1.4	1.7
30S2ST (number)	11.5 ± 2.6	11.6 ± 1.8	0.1 ± 2.2	1.2	12.6 ± 3.4	13.2 ± 4.3	0.6 ± 3.4	4.8
30ACT (number)	16.0 ± 3.1	16.8 ± 3.4	0.8 ± 3.3	5.0	20.3 ± 5.1	19.5 ± 5.3	−0.8 ± 3.0	−3.9
2SIPT (number)	73.8 ± 24.4	85.2 ± 22.0	6.9 ± 24.2	15.4	106 ± 21.8	105.2 ± 29	−0.8 ± 39.1	−0.8
CSRT (cm)	−7.0 ± 12.2	−3.7 ± 9.5	3.6 ± 4.3	52.0	−7.5 ± 12.2	−13.4 ± 13.6	−2.7 ± 6.4	−40.3
BST (cm)	−7.0 ± 6.7	−7.3 ± 9.3	−0.3 ± 8.4	3.8	−13.2 ± 8.1	−10.2 ± 9.4	1.8 ± 8.7	23.4

r: change; FTNT: finger to nose test; TSLS: timed single-leg stance; TUG: timed up and go; S2S: 30-second sit to stand test; AC: 30-second arm curl test; 2SIPT: 2-minute step in place; CSRT: chair sit and reach test; BST: back scratch test.

30-second sit to stand test (30S2ST), 30-second arm curl test (30ACT), 2-minute step in place test (2SIPT), chair sit and reach test (CHSRT), back scratch test (BST). Statistical analyses were assessed at the 0.05 level of significance.

Results

A total of 25 participants volunteered for this study; 15 in the Taekwondo intervention group (10 women, 5 males; mean age: 73.6 [±5.1 years]) and 10 age matched-sedentary controls (3 women, 5 men; mean age: 72.3 [±5.1 years]). There was no significant difference in mass between groups, however the control group was heavier (10.5%). There was also no difference in the mean body mass index between groups (Tab. 2).

Results of pre-test to post-test for the modified Taekwondo training group outcome variable are shown in Table 3. There were no significant improvements for any of the dependant variables in the TKD group. However, time to complete five finger-to-nose touches (coordination) improved by 5.6%; single-leg balance improved by 45.0%; TUG performance improved by 9.8%; 30-second sit to stand performance improved by 1.2%; 30-second arm curl performance improved by 5.0%; 2-minute step in place test performance improved by 15.4%; chair sit and reach performance improved by 52.0% and back scratch performance improved by 3.8%. The effect size analysis in the TWD group indicated that the intervention had a small effect on FTNT, TSLS, 30ACT, 2SIPT, and CSRT (Fig. 1). Comparison of pre-test to post-test scores for non-exercising control resulted in no significant differences in any outcome variables (Tab. 3). Of the total 12 classes, participants attended an average of 10.5 ± 1.0 classes with an average attendance rate of 88% (71–100%).

Discussion

This pilot study aimed to investigate the effects of a six-week modified Taekwondo training program on physical function in adults over 65 years. To the best of the author's knowledge, no studies to date have investigated the effects of modified Taekwondo training on measures of functional fitness in older adults. We identified that six weeks of modified Taekwondo training did not significantly improve functional fitness however, there were improvements across all outcome measures that represent improved physical functioning across a number of physiological domains.

Hand-eye coordination

Hand-eye coordination is necessary for many activities of daily living and self-care, particularly in older adults (Pei *et al.*, 2008). It was hypothesized that hand-eye coordination would improve following modified Taekwondo training as the eyes must follow hand movements during punching and blocking techniques. However, in the present study, six weeks of modified Taekwondo training

program did not significantly improve hand-eye coordination. Previous research (Lee, Hui-Chan, & Tsang, 2015) has demonstrated significant improvements in hand-eye coordination following 12 weeks of sitting Tai Chi training, performed three times a week in a group of frail older adults (84 ± 8.1 years). In addition, Pei *et al.* (2008) have reported that older adults (67.8 ± 5.1) who have been practicing Tai Chi for one to two hours, five to seven times a week for three years, demonstrated better hand-eye coordination than active, older adults (68.2 ± 5.2) who do not. In the present study, the modified Taekwondo training was only performed twice per week for one hour, over six weeks. Thus, it may be concluded that six weeks were not adequate training to realise the benefits of the modified Taekwondo training on hand-eye coordination.

Balance

It was hypothesized that movements performed on one-leg, such as kicking techniques would improve single-leg balance. Nonetheless, in the present study, timed single-leg balance did not reach significance, despite showing a 45% improvement accompanied by a small effect. Variability of post-test scores in the modified Taekwondo training group was more significant than the variability of pre-test scores (Tab. 2). This change in variability suggests that some participants improved more than others. It is not unusual to have participants respond to any training stimulus to different degrees, with some improving, some with no change and some participants actually decreasing. The latter two may be attribute to an insufficient training stimulus (Mujika & Padilla, 2000). Increased variability and small sample size may explain the lack of significance observed for this measure. In a similar study, Cromwell *et al.* (2007) reported a non-significant improvement for single-leg balance despite showing a 60% increase in the single-leg balance following 11 weeks of Taekwondo training, performed twice per week for one hour, in a group of healthy, older adults (72.7 ± 7.0 years). However, the researchers observed a significant improvement in multiple direction reach test performance, suggesting Taekwondo training may be more sensitive to dynamic rather than static balance. In contrast, Pons Van Dijk, Lenssen, Leffers, Kingma, & Lodder (2013) reported a 47% in timed single leg balance following one year of Taekwondo training, performed for one hour a week, in a group of healthy, middle-aged to older adults (40–75 years). Taken together, the results of the present study suggest that six weeks of modified Taekwondo training does not improve static balance in older adults however, there is an apparent improvement in balance.

Timed up and go

Timed up and go performance is a measure of functional mobility, which is essential for older adults who need to ambulate in the community, such as crossing the street more quickly and efficiently. In the present study, timed up and go performance, despite improving by 9%, did not reach significance following six weeks of modified Taekwondo training. In contrast, Cromwell *et al.* (2007) demonstrated significant improvements (9%) in timed up and go performance following 11 weeks of Taekwondo training in older adults. In addition, Schachner (2018) reported significant improvements (35%) in timed up and go performance following 12 weeks of modified martial arts training, performed two times per week, for 12 weeks in a group of healthy, older adults (70.5 ± 8.6 years). In older populations, lower limb extensor force and balance are closely related to timed up and go performance (Benavent-Caballer *et al.*, 2016). The lack of improvement in timed up and go performance observed in the current may be explained by an insufficient strengthening stimulus from the stances and semi-squatting postures during striking and block techniques, nor the improvement in balance from the kicking techniques. Thus, the present study results suggest that six weeks of modified Taekwondo training may not be long enough to elicit improvements in functional mobility among older adults.

30-second sit to stand test

Lower limb strength is an independent predictor of mobility decline and disability in older adults (Buchman *et al.*, 2007; Visser *et al.*, 2005) and therefore an essential component of functional fitness. It was theorized that the semi-squat postures held during punching and blocking techniques and forceful kicking techniques during the modified Taekwondo training would increase lower limb strength. However, in the present study, 30-second sit to stand performance did not significantly improve (1%). These results contrast to Schachner (2018), who observed significant improvement (36%) in 30-second sit to stand performance. Similarly, Fong *et al.* (2014) observed that the lower limb strength of healthy, older adults (62.7 ± 3.7 years) who undertake regular Ving Tsun Kung Fu training (two hours per week, three months) as measured by the five-time sit to stand test, was significantly greater than healthy, age-matched controls. The lack of improvement in the present study could be attributed to an insufficient number of leg muscle contractions needed to elicit improvements in strength. It has been suggested that improvements in lower limb strength that result from martial arts training maybe attributed to the number of contractions, amplitude, and timing of leg muscle activation (Fong *et al.*, 2014; Voigt & Klausen, 1990).

30-second bicep curl test

Upper limb strength is also highly predictive of functional limitations and disability in older age (McGrath *et al.*, 2021; Rantanen *et al.*, 1999); therefore, increasing upper limb strength may prevent functional limitations from developing into older age. We hypothesized that arm muscle contractions resulting from the punching exercises might approach an equivalent intensity of 40–50% of 1-repetition maximum, the minimum threshold needed to elicit improvements in muscular

strength (Liguori & Medicine, 2020) which have previously been reported in martial arts training studies, where the participants have undergone punch-bag training (Voigt & Klausen, 1990). However, six weeks of modified Taekwondo training did not significantly increase upper limb strength, despite an encouraging 5% improvement, with a small effect. These results contrast to Schachner (2018), who demonstrated a significant 25% improvement in upper limb strength as measured by the 30-second arm curl test, following 12 weeks of modified martial arts training in a group of healthy, older adults. Moreover, Brudnak *et al.* (2002) reported a non-significant improvement in upper limb strength, as measured by 30-second push-up performance in a group of healthy, older adults (63–81 years), following 17 weeks of Taekwondo training. The lack of improvement in upper limb strength in the present study may be attributed to an insufficient volume of punches. For example, Voigt and Klausen (1990) reported that the participants in their study completed on average 650–900 contractions across 16 weeks of karate training. Taken as a whole, the results of the present study suggest that six weeks of modified Taekwondo training does not improve upper or lower limb strength in older adults.

Chair sit and reach test

A lack of hamstring flexibility is associated with gait limitation and risk of falling (Jones, Rikli, Max, & Noffal, 1998) and problems with dynamic balance (Brown, 1993), making hamstring flexibility an essential component of functional fitness in older adults. It was theorized that the kicking motions would create a dynamic stretch of the hamstrings, leading to improvements in hamstring flexibility (Opplert & Babault, 2018). In the present study, improvements in hamstring flexibility did not reach significance, despite improving by 52% with a small effect. These results are in contrast to similar martial arts training studies in older adults. For instance, Cromwell *et al.* (2007) reported significant improvement (11%) in hamstring flexibility measured by the sit and reach test. In addition, Brudnak *et al.* (2002) also observed a 3.5-cm improvement in hamstring flexibility. The lack of significant improvements in the present study could be attributed to the frequency and duration of training utilized in the present study. By way of example, the participants in the present study undertook static stretching in the warm-up and cool-down components of the training sessions; however, the total duration, nor the frequency (twice per week) may not have met the the American College of Sports Medicine (ACSM) guidelines (Liguori & Medicine, 2020), which states stretching exercises need to be performed for a minimum frequency of three days per week, at an intensity where the stretch is held to a point of tightness or slight discomfort and repeated for a total of 60 seconds per stretching exercise to see improvements in flexibility. Moreover, De Baranda and Ayala (2010) reported significant improvements in hamstring flexibility after 12 weeks of stretching following the ACSM flexibility guidelines.

Back scratch test

Shoulder flexibility is a determinant of independent living and essential for activities of daily living such as getting dressed and reaching for objects above shoulder height (Cunningham, Paterson, Himann, & Rechnitzer, 1993; Stathokostas, McDonald, Little, & Paterson, 2013). It was theorized that the large ranges of motion that occur during punching and blocking techniques would lead to an improvement in shoulder flexibility. However, in the present study, six weeks of modified Taekwondo training did not significantly improve shoulder flexibility. These results are in disagreement with de Queiroz *et al.* (2016), who observed a 46% improvement in shoulder flexibility as measured by the back scratch test, in a group of older adults (69.5 ± 6.1 years) following 12 weeks of Brazilian Jiu-jitsu training. To date, no other martial arts training studies have investigated the effects of hard martial arts training on shoulder flexibility in older adults. Taken together, the results of the current study suggest that six weeks of modified Taekwondo training may not be a sufficient enough period to see improvements in lower limb and upper limb flexibility.

Limitations

We acknowledge several limitations to the current pilot study. Firstly, as we did not collect training logs throughout the duration of this study, we are unable to rule out the possibility that participants may have performed additional training modalities that may have influenced the final results. Secondly, we acknowledge that the participants were not randomly allocated into groups, the small sample size and difference in participant numbers in the TWD ($n = 15$) and controls ($n = 10$) groups. The limitations of a small sample size are well documented in the literature (Faber & Fonseca, 2014) and how a small number of participants increases the liklihood of assuming a false premise (type II error) (Deziel, 2018), such as the effectiveness of a modified Taekwondo training program on parameters of functional fitness such as in this study. In our sudy, we required participants to attend all sessions, testing and training, which were conducted on fixed days of the week as opposed to seeking input of best day and time to conduct sessions from potential participants. Small sample size research is often attributed to ethicsal, financial or general feasibility reasons (Konietschke, Schwab, & Pauly, 2020). In this study, we believe our small sample size is primarily attributed to the latter, feasibility. This is due to the limited availability of the training room utilized, session instructor and researchers. Therefore, prior to the study with no potential participant input, we were limited to specified days and times. Despite the majority of participants (potential and actual) being retired, the day/time we were restricted to may have been perceived as not convenient to suit individuals schedules due to various commitments. Thirdly, it appears that six weeks of training were not adequate stimulus to achieve statistically significant improvements in functional fitness, given similar hard

martial studies, have utilized training durations ranging between 12 weeks and one year. With regard to the actual modified Taekwondo exercises completed, there may have also been inherent weakness in the actual graduated program of exercises. For example, initial training sessions, although they involved punching, kicking blocking, the primary focus was on technique to ensure participants' safety. Additionally, as the participants were primarily sedentary completing only incidental physical activity (walking, housework, gardening, activities of daily living) a conservative training stimulus program was utilized. Therefore, in actuality, participants may have only been exposed to rigorous modified Taekwondo training for a maximum of four weeks, and possibly less. Additionally, the actual effort of participants was not monitored. Rating of perceived exertion (RPE) was assessed by the instructor during each class to ensure participants were not over exerting themselves; however, this was only for monitoring exertion and was not recorded as an outcome variable. Heart rate was only recorded (and blood pressure and arterial oxygenation) pre- and post-exercise, there was no assessment of exercise intensity *via* heart rate during sessions. Also, no sensors or any devices were utilized to assess the impact power of punches and kicks, which would be indicative of physical exertion. Therefore, aside from the six-week duration of the study, collectively there were additional factors that may have also contributed to the lack of significance identified.

Notwithstanding these limitations, the importance of the current the study includes being one of the first studies to investigate the effects of the modified Taekwondo training on functional fitness in older adults and the use of field-based measures that can be replicated by group fitness instructors and Taekwondo coaches who commonly work in community settings. While this study was exploratory in nature due to the small sample size, the improvements in functional fitness do suggest the benefits that this type of training may have on the larger population of community-dwelling older adults.

Summary

In conclusion, our data suggest that six weeks of modified Taekwondo training does not result in significant improvements in functional fitness measures. However, encouraging improvements were observed for single-leg balance, aerobic fitness, and lower limb flexibility suggesting a more extended training period (>12 weeks) and more frequent weekly training sessions (three days per week) may be necessary to realize the functional benefits of modified Taekwondo training in older adults. Future studies should employ training programs that utilize three training sessions per week for a minimum of 12 weeks.

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Author contribution statement

Luke Dev Vecchio and Ben Exton conceived the study. All authors designed the study methodologies. Luke Del Vecchio and Mike Climstein conducted the data analyses. All authors contributed to developing the final manuscript.
L/R: left side and right side; H/S: horse stance; L/S: L-stance.

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