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Does Taekwondo improve physical fitness in adults older than 50?: A systematic review and meta-analysis

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Abstract

Purpose This systematic review and meta-analysis study aimed to assess the effect of Taekwondo training on improving physical fitness in adults older than 50.

Methods We used the electronic databases including PubMed, CINAHL, SPORTDiscus, Web of Science, RISS, NDSL, and KISS, between January 1967 and March 2020 using the keywords "Taekwondo" AND "physical fitness" in Korean or English. The effect size using standardized mean differences (SMD) and 95% confidence intervals was calculated for these variables to make comparisons between studies.

Results Thirty-one studies were included in the final meta-analysis. Significant positive effects of Taekwondo training were found on body fat (SMD=0.43), body mass index (SMD=0.21), body weight (SMD=0.30), static balance (SMD=-0.79), flexibility of lower body (SMD=-0.40), aerobic capacity (SMD=-0.47), agility (SMD=0.60), gait ability (SMD=-0.93), muscle endurance of lower body (SMD=-0.79), muscle endurance of upper body (SMD=-0.79), strength of lower body (SMD=-1.02), and strength of upper body (SMD=-0.39). No statistical differences were observed in fat-free mass, waist-hip ratio, dynamic balance, flexibility of the upper body, and power.

Conclusion Overall, the findings of this meta-analysis support that Taekwondo can have a positive impact on the physical fitness in adults older than 50. In order to validate the current findings, future research should focus on well-designed randomized controlled trials (RCTs) and implement Taekwondo intervention studies at multiple levels taking into account the limitations discussed.

Keywords Elderly, Exercise, Health, Martial arts, Senior

Ⅰ. Introduction

The average life expectancy of Koreans increased from 60.81 years in 1970 to 83.06 years in 2020, and the average life expectancy in 2070 is expected to be 89.33 years (Macrotrends, 2020). Unlike the steady increase in life expectancy over the past 50 years, the birth rate decreased from 4.53 per woman in 1970 to 1.05 per woman in 2017 (The World Bank Group, 2020). As a result, it appears that we have entered an aging society. As the age of population members increases, efforts to slow the changes in the human body caused by aging or induce healthy changes are required.

The development of medical technology and changes in food, clothing and shelter have increased life expectancy, but changes in the human body due to aging can-

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not be prevented. The biggest change in the human body due to aging is a decrease in stamina due to a decrease in skeletal muscle mass, which limits mobility, causes difficulties in daily life, and ultimately reduces the independent quality of life of the elderly and causes health problems. do. Physical activity includes daily life, regular exercise, and sports activities, and smooth physical activity is a big variable that can improve the quality of life. In particular, aerobic training has a positive effect on the maintenance of cognitive function in the elderly, and aerobic exercise combined with muscle strengthening or flexibility training may be much more effective in delaying cognitive decline (Kramer & Colcombe, 2018). A form of exercise such as martial arts has been reported to improve cognitive function than simple physical activity (Wayne et al., 2014). Taekwondo, a traditional martial art in Korea, is a sport that can be practiced by people of all ages, and its effects have been reported to change body composition and improve physical fitness (Kim, Choi, & Oh, 2018).

Elderly people are showed by being increased age a gradual decline in the physical fitness level is at high risk of falling (Jeoung & Pyun, 2022; Toraman & Yildirim, 2010). Several studies supported that for older people, improving and maintaining physical fitness level not only preventing falls but also contributes to improving quality of life and managing cardiovascular disease (Sampaio et al., 2020; Toraman & Yildirim, 2010; Williams, 2001). There is a need for research to verify the effectiveness of Taekwondo to improve age-related decline in physical fitness. Therefore, this systematic review and meta-analysis aimed to evaluate the effects of Taekwondo training on improving physical fitness in adults aged 50 years and older. We hypothesized that Taekwondo training will make positive effects on physical fitness in adults aged 50 years and older.

Ⅱ. Methods

A systematic search was conducted to investigate the effect of Taekwondo training on physical fitness in adults older than 50 followed by Preferred Reporting Items for Systemic Review and Meta-Analysis (PRISMA) guidelines (Liberati et al., 2009).

1. Search strategy

The initial search was conducted using electronic databases including PubMed, CINAHL, SPORTDiscus, and Web of Science for international journal articles as well as RISS, KISS, DBpia, and Korea National Assembly Library for Korean journal articles from inception to February 2020. We used the following searching terms for the initial search: Taekwondo OR sparring OR poomsae OR Kyorugi; VO_2max OR strength OR flexibility OR power OR agility OR speed OR endurance OR body composition OR mobility OR balance OR coordination OR cardiorespiratory OR physical OR aerobic. The search was limited to studies involving human participants, written in Korean or English, and reported peer-reviewed journals. The reference list of each article that was screened during the systematic search was hand searched to identify additional articles. An initial review for screening studies was conducted independently by 4 investigators (H.G.J., M.J.K., J.P., & I.L.).

2. Selection criteria

Potentially relevant studies found in the initial search were screened for eligibility. The inclusion criteria were as follows: 1) Inclusion criteria. The following inclusion criteria were used to select and screen studies; 2) The primary aim was to investigate the effect of Taekwondo on physical fitness; 3) Participants were adults older than 50; and 4) The primary outcomes consist of variables concerning physical fitness such as body composition; strength; muscular endurance; aerobic endurance; flexibility; agility; power; gait ability. The exclusion criteria were as follows: 1) Participants were younger than 50; and 2) Authors did not report point measure or values of outcomes (means, standard deviation, and sample size) to calculate standardized mean differences (SMD). The screening process consisted of checking titles, abstracts, and outcome variables.

3. Data extraction

All data were extracted by four independent researchers: two (H.G.J. & I.L.) for international journal articles and two (M.J.K. & J.P.) for Korean journal articles based on the aims of study. Researchers discussed disagreement on outcome variables and if consensus could not be reached, the other researcher (S.H.) consulted the issues until agreements. The outcome variables for this study were relative to the primary outcomes. All researchers extracted the data on the first author's name, publication year, sample size, characteristics of participants, information of intervention, results, and mean and standard deviation of outcome variables. The SMD with 95% confidence intervals were calculated for all outcome variables by subtracting the values of post-intervention from those of pre-intervention in the intervention group. The pooled SMD value was interpreted based on Cohen's criteria (Cohen 1992): (1) ≥ 0.8=large effect; (2) 0.5-0.8=moderate effect; (3) 0.2-0.5 =small effect; and (4)〈0.2=very small effect.

4. Risk of bias assessment

The Asymmetry of the SMD through funnel plots and Egger's regression was used to examine risk of bias. If an outcome variable with risk of bias was considered, the average SMD was calculated using the trim-and fill method (Duval & Tweedie, 2000).

5. Methodologic quality assessment

The quality of the included studies and the body of evidence were assessed using checklist proposed by Down & Black (D&B; Down & Black, 1998), which could evaluate both in RCT or non-RCT study. The checklist includes a total of 27 questions through 5 sections such as report, external validity, internal validity of bias, internal validity of selection bias, and power. The quality index percentage (QI%) was calculated through the following formula: [QI%=(D&B score of the study/32) x 100]. For quality assessment, two investigators (I.L. and H.J.) independently reviewed the included studies from international databases while other two investigators (M.J.K. and J.P.) independently reviewed the selected papers from Korean databases. Discrepancies in scoring were addressed through discussion between the investigators until a consensus was reached.

6. Level of evidence and strength of recommendation

The Strength of Recommendation Taxonomy (SORT) was used to assess the study quality and the body of evidence (Ebell et al., 2004). Selected studies for this meta-analyses could be classified as Level 1, 2, or 3 evidence. We considered level 1 evidence to be high-quality (D&B checklist ≥ 70%), level 2 evidence to be moderate-quality (40%〈D&B checklist〈70%), level 3 evidence to be poor-quality (D&B checklist ≤ 40%). We also graded a strength of recommendation for the pooled body of evidence based on following criteria (Ebell et al., 2004): (1) grade A is considered as consistent, good quality, or patient-oriented evidence; (2) grade B is considered as inconsistent or limited quality, or patient-oriented evidence; and (3) grade C is considered as consensus, or disease-oriented evidence.

7. Statistical analysis

A fixed-effects model was used when homogeneity was followed while a random-effects model was used for outcome variables without homogeneity. The R software (v. 3.6.1., R Core Team, 2019) was used for analyses. The significant level was set at .05.

Ⅲ. Results

1. Study selection

The QUORUM flow chart showing the selection process of this review was shown in 〈Figure 1〉. A total of

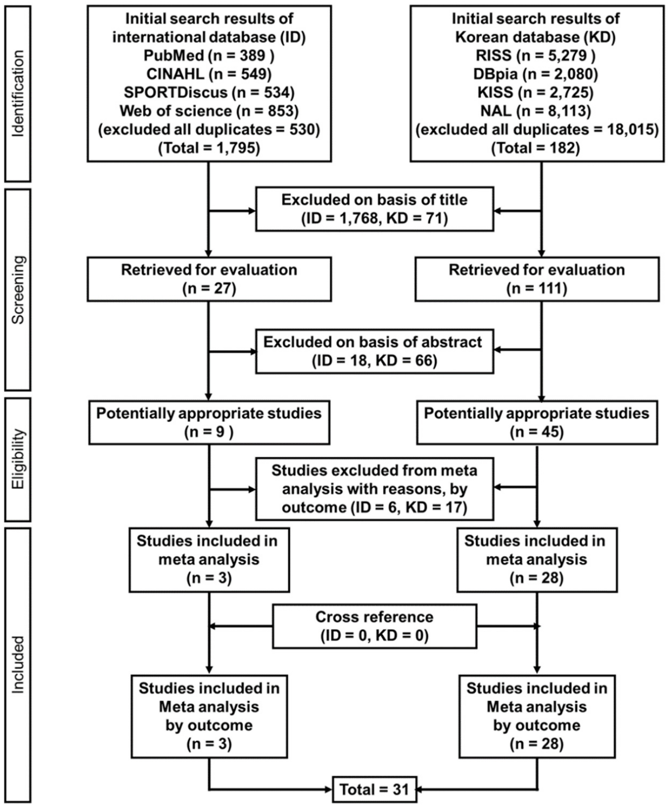

Figure 1. A QUORUM flow chart for the selection process of the systematic review and meta-analysis.

Abbreviation: international database, ID; Korean database, KD.

2,325 papers were searched from international databases including PubMed, SPORTDiscus, CINAHL, and Web of Science while a total of 18,197 papers were identified from Korean databases including RISS, DBpia, KISS, and National Assembly Library. 530 and 18,015 of the total papers were removed respectively due to duplicates. 1,768 and 71 papers were excluded after the title screening and 18 and 66 papers were excluded respectively by screening abstracts. 6 and 17 papers were excluded after full-text review respectively based on inclusion and exclusion criteria of this study. As a result of the identification of reference lists of selected studies, there were no additional papers which were found by cross reference. Therefore, a total of 31 papers (Cromwell, Meyers, Meyers & Newton, 2007; Choi & Lee, 2015; Cho & Roh, 2019; Jeong, Park, Park, Kim, & Kwon, 2015; Jeong, Ryu, Jung, Kim, & Park, 2018; Jeong & Jung, 2019; Jeong, Jung, & Ryu, 2019; Jeong & Jung, 2019a, 2019b; Jung, Seo, Kim, Kim, & Song, 2017; Kang, 2002; Kang, Jung, Kim, & Song, 2012; Kim & Park, 2012; Kim, 2013; Kim et al., 2014; Kim & Park, 2018; Kwon, Park, Kim, Jin, & Jang, 2011a; Kwon et al., 2011b; Lee, 2015; Lee, Kim, & Park, 2018; Lee & Lee, 2019; Moon & Kwon, 2010; Oh & Lee, 2006; Shin, Youm, Moon, Kim, & Park, 2008; Shin & Kim, 2009; Shin, 2010; Van Dijk, Lenssen, Leffers, Kingma, & Lodder, 2013; Woo, Han, & Lee, 2009; Youm, Lee, & Seo, 2011) were included for this systematic review and meta-analysis. The summary of all selected studies was shown in 〈Table 1〉.

2. Methodologic quality

The results of the study quality assessment is shown in 〈Table 2〉. The average methodologic quality of included studies was 15.45 (range: 12-22). Overall, the results of QI% ranged from 38% to 70%, with a mean of 49.32%. The overall quality scores for each outcome variable are shown in 〈Table 3〉.

Table 1. A summary table of the selected studies

Author (year)	Study design	Sample size	Characteristics of participants	Intervention program	Results
Cromwell et al. (2007)	PC	20 (men:7, women:13), 20 (men:3, women:17)	TKD: 72.7 ± 6.1 CON: 73.8 ± 7.0	Duration: 11 wks Session volume: 60 min, 2 sessions/wk Elements: warm-up, stretching, blocking, striking, kicking, self-defense techniques, TKD form	1. Improved static balance (multidirectional reach test and single leg stance) 2. Improved agility (timed up & go) 3. Improved gait ability (walking velocity) 4. Improved LB flexibility (sit & reach)
Choi & Lee (2015)	PC	9 (women), 10 (women)	TKD: 149.20 ± 3.67 CON: 50.22 ± 4.26	Duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, physical training, TKD basic movement, kicking, Gyeorugi, cool-down & stretching	1. Decreased body weight, body fat 2. Improved UB strength (grip strength) 3. Improved UB endurance (sit up) 4. Improved LB flexibility (sit & reach)
Cho & Roh (2019)	RCT	20 (women), 20 (women)	TKD: 68.89 ± 4.16 CON: 69.00 ± 4.41	Duration: 16 wks Session volume: 60 min Elements: warm-up, 5 basic TKD movements, Poomsae chapter 1-4, Kicking, TKD gymnastic	1. Improved LB endurance (30s chair stand) and LB flexibility (sit & reach) 2. Improved aerobic endurance levels (2min step) 3. No significant differences in UB endurance (30s arm curl), UB flexibility (back scratch) and agility (2.44 m up-and-go)
Jeong et al. (2015)	PC	10 (women), 10 (women)	TKD: 72.38 ± 5.45 CON: 73.25 ± 6.39	Training duration: 24 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD training, band exercise, cool-down	1. Improved body composition (body mass, BMI, fat mass, WHR) 2. Improved UB strength (grip strength) 3. Improved LB endurance (chair sit & up) 4. Improved agility (timed up & go) 5. Improved aerobic endurance (2minn step) 6. Improved static balance (one leg standing)
Jeong et al. (2018)	PC	9 (women), 8 (women)	TKD: 61.05 ± 2.20 CON: 59.89 ± 4.86	Training duration: 24 wks Session volume: 90 min, 3 sessions/wk Elements: warm-up, TKD training, cool-down	1. Improved body composition (weight, BMI, body fat) 2. Improved walking ability (step count)
Jeong & Jung (2019)	PC	10 (women), 10 (women)	TKD: 72.20 ± 2.15 CON: 73.00 ± 3.01	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD training, band exercise, cool-down	1. No significantly difference in body composition (weight, BMI, body fat, WHR) 2. Improved static balance (one leg standing) 3. Improved aerobic endurance (2min walking) 4. Improved LB flexibility (sit & reach) 5. Improved walking ability (gait peed)
Jeong et al. (2019)	PC	10 (women), 10 (women)	TKD: 76.60 ± 4.30 CON: 76.00 ± 3.62	Training duration: 12 wks Session volume: 90 min, 3 sessions/wk Elements: warm-up, TKD training, band exercise, cool-down & stretching	1. Improved body composition (muscle mass, LBM) 2. Improved aerobic ability (2min walking) 3. Improved UB flexibility (back scratch) 4. Improved LB flexibility (sit & reach) 5. Improved UB endurance (dumbbell curl) 6. Improved LB endurance (chair sit & stand)
Jeong & Jung (2020a)	PC	9 (women), 9 (women)	TKD: 68.78 ± 1.99 CON: 68.33 ± 2.12	Training duration: 16 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, Physical training, TKD basic movement, Poomsae, kicking, TKD gymnastic, cool-down	1. Improved body composition (weight, BMI, body fat, muscle mass) 2. Improved UB endurance (arm curl, sit up) 3. Improved static balance (one leg standing) 4. Improved walking ability (10m maximal, normal walking speed)
Jeong & Jung (2020b)	PC	10 (women), 10 (women)	TKD: 68.80 ± 2.25 CON: 68.70 ± 1.89	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, Poomsae, TKD	1. No significantly difference in body composition (weight, BMI, body fat, WHR LBM)

				gymnastic, cool-down, practice	
Ji et al. (2011)	PC	7 (women), 8 (women)	TKD: 69.75 ± 1.83 CON: 70.87 ± 2.69	Training duration: 12 wks Session volume: 90 min, 3 sessions/wk Elements: warm-up, TKD training, weight training, cool-down & stretching	1. Improved UB strength (chest press, lat pull down, shoulder press, arm curl) 2. Improved LB strength (leg extension, leg curl, hip abduction) 3. Improved UB endurance (arm curl) 4. Improved LB endurance (30 sec chair stand) 5. Improved UB flexibility (back scratch)
Jo (2012)	PC	13 (women), 13 (women)	TKD: 69.00 ± 2.00 CON: 68.62 ± 2.18	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, poomsae, cool-down & stretching	Decreased body weight, body fat
Jung et al. (2017)	PC	8 (women), 8 (women)	TKD: 73.5 ± 3.89 CON: 73.1 ± 5.54	Training duration: 16 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD training, weight training, stretching	1. No significant difference in body composition (body fat, fat mass, lean mass) 2. Interaction effect in LB endurance (30s chair stand), agility (2.44m up & go), aerobic agility (2 min step) 3. Improved LB strength (extensor and flexor peak torque in 60°/sec, extensor and flexor total work in 180°/sec)
Kang (2002)	PC	40(men)	69.5 ± 4.19	Training duration: 12 wks Session volume: 2 sessions/wk Elements: TKD-based exercise program (warm-up, balance training, cool-down)	1. No significance difference in static balance (Functional Reach Test)
Kang et al. (2012)	PC	15 (women), 15 (women)	TKD: 71.31 ± 3.82 CON: 71.89 ± 4.37	Training duration: 12 wks Session volume: 50 min, 2 sessions/wk Elements: warm-up, hand motion, kicking, standing, cool-down 10 min	1. No significant difference in UB (grip strength), % body fat 2. Interaction effect in fat-free mass 3. Improved UB endurance (upper arm flexion), LB flexibility (sit & reach), agility (2.44m up & go), aerobic endurance (walking for 6 min)
Kim & Park (2012)	PC	17 (no information)	75.58 ± 0 .58	Training duration: 6 wks Session volume: 3 sessions/wk Elements: warm-up, kicking, punch, Poomsae, cool-down	Improved dynamic balance (Berg's balance scale, maximum oscillation velocity)
Kim (2013)	PC	8 (women), 8 (women)	TKD-Poomsae: 65.54 ± 2.24 TKD-aerobic: 68.14 ± 3.02 Weight training: 67.99 ± 2.43	Training duration: 12 wks Session volume: 20 ~ 40 min, 3 sessions/wk Elements: warm-up, TKD training, cool-down	Decreased BMI in both TKD Poomsae group and TKD aerobic group
Kim et al. (2014)	PC	15 (women), 15 (women)	TKD: 65.1 ± 3.1 CON: 66.7 ± 3.1	Training duration: 16 wks Session volume: 120 min Elements: warm-up, kicking, TKD training, music sign language, cool-down	1. Decreased body composition (weight) 2. Improved UB strength (both of grip strength), UB endurance (arm curl), dynamic balance (3m tandem walk, 5m brisk walking, 5m walking), agility (figure of 8 walking, sit & stand, standing up from a supine position, timed up & go), dynamic balance (functional reach)
Kim & Park (2018)	PC	12 (women)	74.4 ± 3.05	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, kicking, TKD basic movement, cool-down	1. Improved UB strength (both of grip strength), LB endurance (chair sit & up), aerobic endurance (2 min standing walking), agility (timed up & go, figure of 8 walking)
Kwon et al. (2011a)	PC	8 (women), 8 (women)	TKD: 72.50 ± 2.20 CON: 73.38 ± 2.45	Training duration: 12 wks Session volume: 40 min, 3 sessions/wk Elements: warm-up, TKD basic movement, Poomsae, cool-down	1. Improved body composition (total muscle mass) 2. Improved aerobic endurance (VO_2max), UB endurance (push-up), LB flexibility (sit & reach), static balance (one leg standing)

Kwon et al. (2011b)	PC	10 (women), 10 (women)	TKD: 71.70 ± 1.34 CON: 72.60 ± 1.43	Training duration: 12 wks Session volume: 50 min, 4 sessions/wk Elements: warm-up, TKD basic movement, Poomsae, TKD aerobic, cool-down	1. Decreased in body composition (BMI, body fat, body fat %, weight) 2. Improved aerobic endurance (VO_2max)
Lee (2015)	PC	20 (women), 20 (women)	TKD: 54.30 ± 2.52 CON: 53.1 ± 2.67	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD training, cool-down	1. Interaction effect in weight, LBM, body fat, WHR 2. Main effect of time in LBM, WHR
Lee et al. (2018)	PC	13 (women), 13 (women)	TKD: 69.85 ± 3.83 CON: 70.64 ± 4.55	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD basic movement, Poomsae, kicking, practice Gyeorugi, cool-down	1. Improved body composition (weight, BMI, body fat, WHR) 2. Improved UB endurance (arm curl, sit up) 3. Improved static balance (one leg standing) 4. Improved walking ability (10m maximal, normal walking speed)
Lee & Lee (2019)	PC	12 (women), 12 (women)	TKD: 50.9 ± 1.67 CON: 50.3 ± 3.74	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD training, cool-down	Improved body composition (body fat, LBM)
Moon & Kwon (2010)	PC	15 (women), 15 (women)	TKD: 72.13 ± 1.30 CON: 75.07 ± 3.24	Training duration: 12 wks Session volume: 40 min, 3 sessions/wk Elements: warm-up, standing, blocking, striking, kicking, cool-down	1. Decreased in body composition (weight, BMI, body fat) 2. Improved LBM, aerobic endurance (peak VO_2 max), flexibility (standing trunk flexion), UB endurance (sit up)
Oh & Lee (2006)	PC	20 (men:10, women:10), 20 (men:10, women:10)	TKD: Female 69.55 ± 4.32, Male 65.70 ± 2.86 CON: Female 67.29 ± 4.68, Male 68.40 ± 4.48	Training duration: 16 wks Elements: warm-up, TKD basic movement, kicking, Poomsae, Gyeorugi, cool-down	No significant difference in all variables compared to pre intervention
Shin et al. (2008)	PC	8 (women), 8 (women)	TKD: 69.8 ± 1.7 CON: 71.1 ± 4.4	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD training, cool-down	No significance difference in static balance (COP mean velocity)
Shin & Kim (2009)	PC	10 (women), 10 (women)	TKD: 69.7 ± 2.02 CON: 71.7 ± 4.39	Training duration: 12wks Session volume: 60 min, 3 sessions/wk 1. Warm-up 10 min 2. TKD 40 min 3. Cool-down 10 min	1. Decreased body fat, fat mass, LBM 2. Improved VO2 max, VO2max/BW
Shin (2010)	PC	7 (women), 7 (women)	TKD: 70.86 ± 4.3 CON: 71.68 ± 4.26	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD training, cool-down	1. Increased LBM in Poomsae group 2. Decreased % fat in Poomsae group 3. Improved aerobic endurance (peak VO_2max, peak VO_2max/BW)
Van Dijk et al. (2013)	PC	24 (men: 12, women: 12)	Men: 58.9 ± 6.1 Women: 51.8 ± 6.2	Training duration: 1 year, 40 lessons Session volume: 60 min Elements: warm-up, TKD techniques, Poomsae, self-defense TKD techniques Additionally recommended program: balance training for about 5-10 minutes	1. Improved static balance 2. No significance difference in power (one leg hop)
Woo et al. (2009)	PC	20 (women), 20 (women)	TKD: 69.78 ± 15.0 CON: 74.93 ± 6.55	Training duration: 12 wks Elements: warm-up & meditation, TKD basic movement, kicking, Poomsae, cool-down	1. Improved UB strength (back strength), UB endurance (push up) 2. Improved upper (trunk extension), LB flexibility (sit & reach)
Youm et al. (2011)	PC	10 (women), 10 (women)	TKD: 69.4 ± 5.8 CON: 70.6 ± 4.8	Training duration: 12 wks Session volume: 60 min, 3 sessions/wk Elements: warm-up, TKD training, cool-down	1. No significant difference in body composition (weight, BMI) 2. Decreased static balance (COP ML velocity)

Abbreviation: ADL, activities of daily living; AP, anteroposterior; BMI, body mass index; CON, control; COP, center of pressure; EC, exclusion criteria; IC, inclusion criteria; LB, lower body; LBM, lean body mass; ML, mediolateral; PC, prospective cohort study; RCT, randomized controlled trial; TKD, Taekwondo; UB, upper body; WHR, waist-hip ratio.

Table 2. Methodological quality score using the Down and Black scale of relevant studies

Author	Year	Down & Black scale							LE
		Report	EV	IV (bias)	IV (SB)	Power	Total	MQI%	
Cromwell et al.	2007	7	2	4	0	0	13	41	level 2
Choi & Lee	2015	8	0	5	1	0	14	45	level 2
Cho & Roh	2019	8	1	4	2	0	15	48	level 2
Jeong et al.	2015	8	0	5	2	0	15	48	level 2
Jeong et al.	2018	8	1	5	3	0	17	54	level 2
Jeong & Jung	2019	8	1	5	3	0	17	54	level 2
Jeong et al.	2019	8	1	5	3	0	17	54	level 2
Jeong & Jung	2020a	6	1	5	3	0	15	48	level 2
Jeong & Jung	2020b	7	1	5	3	0	16	51	level 2
Ji et al.	2011	7	0	4	1	0	12	38	level 2
Jo	2012	8	1	5	3	0	17	54	level 2
Jung et al.	2017	7	2	5	3	5	22	70	level 1
Kang	2002	9	1	5	3	0	18	58	level 2
Kang et al.	2012	6	1	4	2	0	13	41	level 2
Kim & Park	2012	7	0	4	1	0	12	38	level 3
Kim	2013	7	1	4	2	0	14	45	level 2
Kim et al.	2014	8	1	4	3	0	16	51	level 2
Kim & Park	2018	8	2	4	1	0	15	48	level 2
Kwon et al.	2011a	7	1	4	2	0	14	45	level 2
Kwon et al.	2011b	7	1	4	2	0	14	45	level 2
Lee	2015	8	1	5	3	0	17	54	level 2
Lee et al.	2018	8	0	4	3	0	15	48	level 2
Lee & Lee	2019	8	1	5	3	0	17	54	level 2
Moon & Kwon	2010	7	1	4	3	0	15	48	level 2
Oh & Lee	2006	7	1	4	2	0	14	45	level 2
Shin et al.	2008	7	1	4	2	0	14	45	level 2
Shin et al.	2009	7	1	4	3	0	15	48	level 2
Shin	2010	7	1	4	3	0	15	48	level 2
Van Dijk et al.	2013	8	2	4	2	5	21	67	level 2
Woo et al.	2009	7	1	5	3	0	16	51	level 2
Youm et al.	2011	7	1	4	2	0	14	45	level 2

Abbreviation: EV, external validity; IV, internal validity; LE, level of evidence; MQI, mean quality index; SB, selection bias

Table 3. The quality assessment and level of evidence for outcome variables

Variables	MQI%	Range	SR	Level 1 (n)	Level 2 (n)	Level 3 (n)
Body composition						
Body fat	50.25	41-70	B	1	19	0
Body mass index	48.94	45-54	B	0	16	0
Body weight	49.41	45-54	B	0	17	0
Fat-free mass	50.33	41-70	B	1	17	0
Waist hip ratio	51.86	48-54	B	0	7	0
Physical fitness						
Dynamic balance	46.25	38-51	B	0	4	0
Static balance	48.93	38-67	B	0	14	1
Flexibility of LB	48.93	38-67	B	1	12	1
Flexibility of UB	48.50	38-70	B	0	6	0

Aerobic capacity	48.88	38-70	B	1	14	1
Agility	49.46	38-70	B	1	11	1
Gait ability	50.33	41-54	B	0	6	0
ME of LB	50.25	38-70	B	1	6	1
ME of UB	49.21	38-70	B	1	12	1
Power	60.50	54-67	B	0	2	0
Strength of LB	54.00	38-70	B	1	0	1
Strength of UB	50.00	38-70	B	1	11	1

Abbreviation: LB, lower body; ME, muscular endurance; MQI, mean quality index; SR, strength of recommendation; UB, upper body.

3. Data synthesis

1) Body composition

The results of meta-analyses for body composition are shown in 〈Table 4〉. The following 5 variables about body composition were analyzed: body fat (BF; k=29), body mass index (BMI; k=19), body weight (BW; k=17), fat-free mass (FFM; k=26), and waist hip ratio (WHR; k=7). The overall effect size measures were calculated for BF (I^2=26.44%, Q(28)=47.09, p=.01), BMI (I^2=0%, Q(18)=7.95, p=.98), BW (I^2=24.91%, Q(16)=21.31, p=.17), FFM (I^2=0.00%, Q(25)=12.03, p=.99), and WHR (I^2=0%, Q(6)=0.59, p=1.00). Therefore, a fixed effect model was used to estimate the overall effect of Taekwondo training on BMI, BW, FFM, and WHR while a random effect model was used to estimate the overall effect of Taekwondo training on BF. The overall differences between pre and post intervention in BF, BMI, and BW were found to be statistically significant, indicating that there were significant effects of Taekwondo training on BF, BMI, and BW 〈Table 4〉.

2) Physical fitness

The results of meta-analyses for physical fitness are shown in 〈Table 5〉. The following 12 variables in 4 subcategories were analyzed: dynamic balance (DB; k=6), static balance (SB; k=24), flexibility of lower body (FLB; k=16), flexibility of upper body (FUB; k=7), aerobic capacity (AC; k=23), agility (k=18), gait ability (GA; k=7), muscular endurance of lower body (MELB; k=12), muscular endruance of upper body (MEUB; k=16), power (k=2), strength of lower body (SLB; k=8), and strength of upper body (SUB; k=22). For balance, the overall effect size measures were estimate for DB (I^2=97.22%, Q(5)=63.87, p〈.01) and SB (I^2=68.28%, Q(23)=64.28, p〈.01). Therefore, a random effect model was used to estimate the overall effect of Taekwondo training on DB and SB. The overall differences between pre and post intervention in SB were found to be statistically significant, indicating that there were significant effects of Taekwondo training on SB 〈Table 5〉. For flexibility, the overall effect size measures were estimate for FLB (I^2=0%, Q(15)=4.87, p=.99), FUB (I^2=0%, Q(6)=0.43, p=1.00). Therefore, a fixed effect model was used to es-

Table 4. The results of meta-analyses for body composition

Body composition	Model	SMD	*SE*	95% CI	*z*	*p*	MQI
Body fat	RE	0.43	0.09	0.25 to 0.62	4.60	〈.01**	15.84
Body mass index	FE	0.21	0.10	0.02 to 0.39	2.17	.03*	15.31
Body weight	FE	0.30	0.11	0.09 to 0.51	2.85	〈.01**	15.60
Fat free mass	FE	-0.15	0.08	-0.31 to 0.00	-1. 39	.05	15.78
Waist hip ratio	FE	0.13	0.16	-0.17 to 0.44	0.84	.40	16.29

Abbreviation: CI, confidence interval; FE, fixed effect model; MQI, mean quality index; RE, random effect model; SE, standard error; SMD, standardized mean difference.
*p〈.05, **p〈.01.

Table 5. The results of meta-analyses for physical fitness

Physical fitness	Model	SMD	*SE*	95% CI	*z*	*p*	MQI
Balance							
Dynamic balance	RE	2.09	1.18	-0.23 to 4.41	1.77	.08	14.50
Static balance	RE	-0.79	0.14	-1.07 to -0.51	-5.50	$<.01^{**}$	15.33
Flexibility							
Flexibility of LB	FE	-0.4	0.10	-0.6 to -0.19	-3.85	$<.01^{**}$	15.21
Flexibility of UB	FE	-0.23	0.16	-0.54 to 0.08	-1.47	.14	15.83
Movement ability							
Aerobic capacity	FE	-0.47	0.09	-0.65 to -0.29	-5.07	$<.01^{**}$	15.31
Agility	RE	0.60	0.15	0.31 to 0.89	4.03	$<.01^{**}$	15.54
Gait ability	FE	-0.93	0.16	-1.24 to -0.62	-5.84	$<.01^{**}$	15.83
Muscle function							
ME of LB	FE	-0.79	0.14	-1.05 to -0.52	-5.77	$<.01^{**}$	15.75
ME of UB	RE	-0.79	0.17	-1.11 to -0.47	-4.79	$<.01^{**}$	15.43
Power	FE	-0.19	0.28	-0.75 to 0.37	-0.67	.50	19.00
Strength of LB	FE	-1.02	0.19	-1.39 to -0.64	-5.35	$<.01^{**}$	17.00
Strength of UB	FE	-0.39	0.09	-0.56 to -0.21	-4.30	$<.01^{**}$	15.69

Abbreviation: CI, confidence interval; FE, fixed effect model; LB, lower body; ME, muscular endurance; MQI, mean quality index; RE, random effect model; SE, standard error; SMD, standardized mean difference; UB, upper body.

$^{**}p<.01$.

timate the overall effect of Taekwondo training on FLB and FUB. The overall differences between pre and post intervention in FLB were found to be statistically significant, indicating that there were significant effects of Taekwondo training on FLB 〈Table 5〉. For movement ability, the overall effect size measures were calculated for AC (I^2=0%, Q(22)=14.88, p=.87), agility (I^2=52.81%, Q(17)=35.49, p<.01), and GA (I^2=0%, Q(6)=2.87, p=.83). Therefore, a fixed effect model was used to estimate the overall effect of Taekwondo training on AC and GA while a random effect model was used to estimate the overall effect of Taekwondo training on agility. The overall differences between pre and post intervention in AC, agility, and GA were found to be statistically significant, indicating that there were significant effects of Taekwondo training on AC, agility, and GA 〈Table 5〉. For muscle function, the overall effect size measures were calculated for MELB (I^2=43.65%, Q(11)=19.52, p=.05), MEUB (I^2=55.61%, Q(15)=34.50, p<.01), power (I^2=0%, Q(1)=0.18, p=.68), SLB (I^2=0%, Q(7)=5.04, p=.66), and SUB (I^2=30.41%, Q(21)=30.18, p=.09). Therefore, a fixed effect model was used to estimate the overall effect of Taekwondo training on MELB, power, SLB, and SUB while a random effect model was used to estimate the overall effect of Taekwondo training on MEUB. The overall differences between pre and post intervention in MELB, MEUB, SLB, and SUB were found to be statistically significant, indicating that there were significant effects of Taekwondo training on MELB, MEUB, SLB, and SUB 〈Table 5〉.

4. Risk of bias

The likelihood of risk of bias was assessed using funnel plots and Egger's regression. Based on the results from Egger's regression, 7 outcome variables including BF, DB, MELB, MEUB, SB, SLB, and SUB have publication bias. Therefore, we conducted additional analyses using the trim-and-fill method and the results indicated that publication bias has not affected the overall results.

5. Level of evidence and strength of recommendation

Based on criteria of this study on the classification of levels of study quality, the only one study of total studies was level 1 while twenty-nine studies and the other were level 2 and 3, respectively. In addition, because most study design of total selected studies were prospective cohort study except for one randomized controlled design, all outcome variables have limited quality (Ebell et al., 2004). Therefore, we observed grade B evidence for all outcome variables ⟨Table 3⟩.

Ⅳ. Discussion

The aim of this systematic review and meta-analysis was to identify the effects of Taekwondo training on physical fitness in adults aged 50 yeas and older. Our major findings showed that Taekwondo training had positive effects on body composition and physical fitness in the elderly population. The strength of recommendation of all outcome variables was grade B, which indicated inconsistent or limited quality, or patient-oriented evidence.

Because many previous studies identified whether exercise programs make positive effects on gait performance, cognitive function, hypertension in adults older than 50, we focused on effects of the Taekwondo training on physical fitness in the population. The Taekwondo training showed significantly positive effects on decrease in BF, BMI, and BW with grade B evidences. The elderly population suffers from aging. Aging is defined as condition increasing risk of chronic diseases with muscular atrophy, increased BF, and decreased physical fitness such gait ability, strength, muscular endurance, flexibility, and aerobic capacity (Brukner & Khan, 2019). Because increased body fat and muscular atrophy have negative effects on individual's health and activities of daily living in older people, those components should be treated properly. According to our findings, the Taekwondo training intervention decrease BF, BW, and BMI without decreased FFM. It may imply that well-designed Taekwondo training results in healthier body composition and decrease risk of chronic diseases such as cancer, diabetes, hypertension, obesity (Brukner & Khan, 2019; Warburton, Nicol & Bredin, 2006). Because people from children to older can participate in Taekwondo without any constraint such as equipment and time-space restrictions, the Taekwondo training should be considered as physical education for lifelong and sports for all.

The Taekwondo trianing had significant effects on improvement of SB, FLB, AC, agility, GA, MELB, MEUB, SLB, and SUB with grade B evidences. Gait including walking and running is one of the fundamental movement motor skills and essential ability for health-related quality of life and independent life in older people. However, aging results in decreased gait velocity, which was relative to reduction in life expectancy (Stanaway et al., 2011). The results from this study showed that the Taekwondo training improved GA as well as several variables of physical fitness. SB is needed to maintain postural balance, while SLB, SUB, and FLB are needed to generate joint torques enough to walk as well as joint mobility. Additionally, MELB and MEUB are also important to repeat gait cycles and agility is necessary to react the environmental condition. As gait uses aerobic system as known as oxidative phosphorylation, AC is an important physical fitness to perform gait. Therefore, SB, FLB, AC, agility, MELB, MEUB, SLB, and SUB are interacted each other to perform gait and Taekwondo may be a good exercise program for independent life in older people.

To improve cognitive function, oxygenation to brain is crucial. Improvements of oxygenation resulted from increased AC and muscular strength (Gajewski & Falkenstein, 2016). Taekwondo may have positive effects on improvements of congitive function directly and indirectly, as it showed enhanced AC and physical fitness of whole body. Although medication is used to recover congitnive function, it has some side-effects. For that reason, physical activity was considered as an alternative because of low-cost and no side-effect. Given aforementioned reasons, Taekwondo may be a good exercise for improving cognitive function. However, because there are few evidences, future studies on this topic are needed.

There were some limitation to interpret findings. First, only one paper was considered as high quality research with level 1. Furthermore, all outcome variables had only grade B evidence but not grade A evidence. Therefore, high quality randomized controlled trials (RCT) should be conducted for future studies to improve research quality, level of evidence, and strength of recommendation. Second, most of selected research had small sample size, which may cause difficult in determining significant difference between pre- and post-intervention. Third, intervention periods of all research were different with a range of 6 weeks to 1 year (6 weeks, 1 paper; 11 weeks, 1 paper; 12 weeks, 21 papers; 16 weeks, 5 papers; 24 weeks, 2 papers; 1 year, 1 paper). Because these different period may affect the results, future studies should consider details of study design.

Ⅴ. Conclusion

Based on our findings, the Taekwondo training may be effective exercise in elderly people. Therefore, more details on Taekwondo training for the elderly people such as exercise intensity, volume, contents, and orders should be developed to apply to individual-specific exercise programs after assessment of their physical fitness. In addition, well-designed RCTs are needed to achieve the goal mentioned above.

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50세 이상 성인의 태권도 수련이 체력을 향상시키는가?
: 체계적 문헌 고찰 및 메타 분석

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요 약

목적 본 체계적 문헌고찰 및 메타분석 연구의 목적은 태권도 수련이 50세 이상 성인의 체력 향상에 미치는 영향을 평가하는 것이다.

방법 1967년 1월부터 2020년 3월까지 '태권도', '체력'을 한국어 또는 영어로 키워드로 PubMed, CINAHL, SPORTDiscus, Web of Science, 학술연구정보서비스, 국가과학기술정보센터, 한국학술정보에서 문헌검색을 실시하였다. 연구 간 비교를 위해 이들 변수에 대해 표준화된 평균 차이(SMD)와 95% 신뢰구간을 사용한 효과 크기를 산출하였다.

결과 31편의 연구가 최종 메타분석에 포함되었다. 태권도 수련이 체지방(SMD=0.43), 체질량지수(SMD=0.21), 체중(SMD=0.30), 정적 균형(SMD=-0.79), 하체 유연성(SMD=-0.40), 유산소성 능력(SMD=-0. 47), 민첩성(SMD=0.60), 보행 능력(SMD=-0.93), 하체 근지구력(SMD=-0.79), 상체 근지구력(SMD=-0.79), 하체 근력(SMD=-1.02), 상체 근력(SMD=-0.39)에서 유의한 긍정적인 효과가 관찰되었다. 반면, 제지방량, 허리-엉덩이 비율, 동적 균형, 상체의 유연성, 파워에서는 통계적으로 유의미한 차이가 나타나지 않았다.

결론 본 연구결과를 바탕으로 태권도가 50세 이상 성인의 체력에 긍정적인 영향을 미칠 수 있다는 것을 뒷받침할 수 있다. 논의된 제한 사항으로 인해 현재 연구 결과를 검증하기 위해 향후 연구에서 잘 설계된 무작위-대조군 연구와 다양한 수준의 태권도 중재 연구가 요구된다.

주제어 노인, 운동, 건강, 무도, 시니어

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