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Gender difference in health benefits from taekwondo participation as a physical activity – meta-analysis

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Authors' Contribution:

A Study Design
B Data Collection
C Statistical Analysis
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E Funds Collection

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Abstract:

Background and Study Aim: Taekwondo is one of the most popular hand-to-hand combat systems, and therefore also physical activity and has been shown to be effective in improving a variety of physical abilities. Taekwondo is a comprehensive exercise program that combines physical training with mental discipline. It is known to be effective in improving cardiovascular health, strength and flexibility, and meets the WHO's physical activity recommendations. However, given that exercise interventions may have different effects on different genders, there is a need for systematic analyses of gender differences in the health effects of taekwondo practice. The cognitive purpose of this meta-analysis was knowledge about the health effects (associated with fitness) of participation in taekwondo training of men and women. The application goal is to provide recommendations for personalized exercise strategies that compensate for fitness components adapted to the gender of the taekwondo practitioner from the perspective of health benefits.

Material and Methods: We systematically searched the literature according to PRISMA guidelines and included 17 randomized controlled trials (RCTs) in our meta-analysis. Study-specific effect sizes were calculated using Hedges' g, and gender subgroup analyses were performed.

Results: Taekwondo practice has been shown to provide significant physical health benefits for both men and women, but gender differences in effectiveness have been observed in some fitness components. The meta-analysis showed that the male group had significantly higher effect sizes than the female group on agility and flexibility metrics (agility: $p<0.01$; flexibility: $p<0.05$). On the other hand, there was no significant difference between men and women for strength and muscular endurance.

Conclusions: Although taekwondo is an effective physical health promotion exercise for both men and women, gender differences in agility and flexibility improvements were found. Men showed greater improvements in agility and flexibility, which could be attributed to differences in baseline fitness levels and the neuromuscular adaptive nature of taekwondo training. However, there were no gender differences in strength and muscular endurance, suggesting that taekwondo provides equal musculoskeletal benefits to both genders. These results suggest that a gender-specific approach to taekwondo program design is required. In particular, more intensive and differentiated training strategies are required to improve agility in women, while for men, taekwondo can be an effective way to compensate for their relative lack of flexibility.

Keywords: agility, cardiovascular health, flexibility, muscular strength, physiological benefits, public health

Dictionary:

Hedges' g – is a statistic used to measure the **effect size** in a two-group comparison, indicating the magnitude of the difference between the means. It is similar to Cohen's d but includes a **correction factor for small sample sizes** (typically less than 20) to reduce bias. To calculate Hedges' g, you divide the difference between the two sample means by the pooled standard deviation of the samples.

I² – an imaginary number is the product of a real number and the imaginary unit i, which is defined by its property $i^2 = -1$.The square of an imaginary number bi is $-b^2$. For example, $5i$ is an imaginary number, and its square is -25. The number zero is considered to be both real and imaginary.

df – degrees of freedom.

Agility – *noun* a combination of physical speed, suppleness and skill [41].

Flexibility – *noun* **1.** the amount or extent to which something can be bent **2.** the extent to which something can change or respond to a variety of conditions or situations [40].

Cardiovascular – adjective relating to the heart and the blood circulation system [40].

Public health – noun the study of illness, health and disease in the community → community medicine [40].

Muscle strength – essential and basic physical capacity in combat sports by which the body moving status is modified [41].

Muscle endurance – is the ability of a muscle to maintain submaximal force level for extended periods [42].

1. Introduction

The World Health Organization (WHO) recommends implementing regular physical activity from the age of five as a critical strategy for preventing non-communicable diseases (NCDs) [1]. Research has demonstrated that engaging in consistent physical activity can reduce the likelihood of developing a variety of chronic conditions, such as cardiovascular disease, type 2 diabetes, site-specific cancers, and premature mortality [2]. Furthermore, it is a critical element of disease control in individuals with asthma, as well as in the alleviation of respiratory diseases, including chronic obstructive pulmonary disease [3]. In addition, observational cohort studies suggest that engaging in regular physical activity during midlife can extend one's health span (number of disease-free years) [4].

Physical inactivity has been identified as a leading risk factor for NCDs, whereas regular physical activity is well-known to provide broad health benefits [1]. Within this context, while various forms of exercise provide health benefits and particularly, taekwondo – have emerged as a unique option that combines physical training with cultural traditions [5]. Moreover, taekwondo – a traditional Korean Olympic sport – stands out as a structured physical activity that holistically develops physical fitness.

Budo such as taekwondo provide a comprehensive workout, and regular practice can significantly improve cardiovascular health, muscular strength, and flexibility [6]. Studies have reported that taekwondo practitioners achieve significant gains in muscular strength, endurance, and flexibility through training [7-9].

According to WHO guidelines, adults should perform a minimum of 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic exercise each week, plus muscle-strengthening exercises for two or more days [1]. The aerobic high-intensity sparring, kicking drills, and strength conditioning in a typical taekwondo training program (multiple sessions per week) meet these recommendations [10, 11]. Therefore, from a physiological perspective, taekwondo can be considered an effective exercise to prevent NCDs as it usually leads to better cardiovascular and metabolic health [12].

For example, a randomized trial involving hypertensive older adults demonstrated that 12 weeks of taekwondo training significantly reduced blood pressure, improved body composition, and enhanced overall cardiovascular risk factors [13]. Such physiological responses indicate that taekwondo training can have a significant role in reducing chronic disease risk for conditions, such as heart disease and type 2 diabetes [14]. In summary, taekwondo is a multifaceted physical exercise in line with international health recommendations that offers comprehensive physiological benefits.

While the physiological benefits of taekwondo are increasingly being documented [15]1, one key dimension that needs further investigation is the differential expression of these benefits by gender. Exercise interventions, particularly taekwondo, can have varying impacts on different demographic groups [16, 17]. Thus, the efficacy of taekwondo in terms of gender differences in health benefits remains a topic of debate. Additionally, the potential influence of variables such as gender-specific participant characteristics, intervention duration, and exercise intensity on the differential effectiveness of taekwondo between men and women is yet to be conclusively determined.

For women in particular, specific health issues such as osteoporosis prevention and sarcopenia management after menopause become important at different stages of the life cycle, and research is needed to understand how effectively taekwondo can manage these unique health issues. For men, a more specific and detailed approach is needed to understand how taekwondo training provides differential effects on strength gains, muscle hypertrophy and cardiovascular health. Future research should consider these physiological differences between the men and women to develop more precise and gender-optimised taekwondo training protocols and health promotion guidelines.

To address this, a meta-analytic approach was employed to quantitatively synthesize existing research on gender differences in the health impacts of taekwondo. The cognitive purpose of this meta-analysis was knowledge about the health effects (associated with fitness) of participation in taekwondo training of men and women. The application goal is to provide recommendations for personalized exercise strategies that compensate for fitness components adapted to the gender of the taekwondo practitioner from the perspective of health benefits.

2. Materials and Methods

Study design

This meta-analysis, including the selection of articles, followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines [18].

Search strategy

We identified studies through a three-step process: First, we conducted a search of Google Scholar, Research Information Sharing Service, Korean Studies Information Service System, and Database Periodical Information Academic for relevant papers. The initial search was conducted on January 13, 2025, followed by a subsequent search on March 13, 2025, and included studies at the peer review stage to ensure that this review incorporated the most recent evidence. The search query employed the following phrases: Taekwondo OR Physical health OR Physical fitness OR Physiological benefits OR Metabolic health OR Cardiovascular health, Strength OR Endurance OR Flexibility. Second, we reviewed the references of relevant systematic reviews and meta-analyses. Third, we performed backward searches for all articles.

We included studies if (a) they included participants who were either female or male practicing taekwondo; (b) the intervention involved regular taekwondo classes conducted in-person, characterized by structured practice periods and intensities; (c) the study was a randomized controlled trial with an inactive control condition (i.e., no treatment) or an active control condition involving usual physical activities or general exercise programs; and (d) outcomes were measured using validated physiological and physical fitness assessment methods.

Quality assessment

The quality of the selected literature was evaluated using seven items of the Cochrane Risk of Bias (RoB) tool in the Review Manager program (RevMan 5.4, Cochrane Collaboration, Oxford, UK). The specific evaluation items were as follows [19]: (a) bias arising from the randomization process, (b) bias due to deviations from intended interventions, (c) bias due to missing outcome data, (d) bias in the measurement of the outcome, and (e) bias in the selection of the reported result. The items were rated as having a low risk, unclear, or high RoB. The RoB was ranked into three levels according to the number of evaluation items rated as having a high RoB in the experiment: high risk (five or more), medium risk (three or four), and low risk (two or less). Two researchers separately performed the quality assessment, rating the seven items in terms of low RoB (+), unclear RoB (?), and high RoB (−). In cases of disagreement, a consensus was reached through discussion between the researchers.

Data analysis

We selected 17 randomized controlled trials (RCTs) studies for inclusion in this review and extracted information on the characteristics of the participants and interventions. We coded the data according to the coding framework to describe the characteristics of each study and provide a basis for the analysis of heterogeneity in effect size. We separately extracted information on the statistical measures presented in each study, including pre- and post-test means, standard deviations, and sample sizes.

Effect sizes for all outcomes were calculated as Hedges' g using the Comprehensive Meta-Analysis (CMA 3.3) software. Given the expectation of heterogeneity across studies, a random-effects model was employed to pool the effect sizes. Heterogeneity was assessed using the I^2 statistic, with a value between 50% and 90% indicating significant heterogeneity. When heterogeneity was detected among the studies (I^2 statistic >50%), a random-effects model was used because the included studies used pre-post designs. To explore potential moderators of the effects, subgroup analyses (meta-analysis of variance) were performed. Finally, potential publication bias was examined through corresponding analytical tests to ensure the robustness of the meta-analytic findings.

3. Result

Study selection and characteristics

The full texts of all relevant articles were collected. The inclusion criteria were rigorously applied. The authors reviewed the full texts, and a total of 17 studies that satisfied the criteria for intervention studies were ultimately included in the analysis (Figure 1, Table 1).

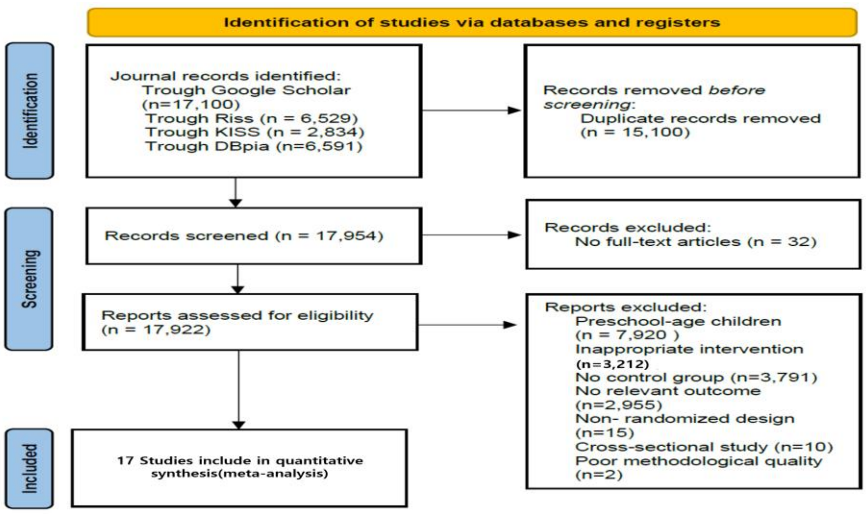

Figure 1. Flowchart of literature search and selection process.

Table 1. General characteristics of publications qualified for analysis (N/A indicates that the study design information was not reported in the original publication).

Author(year)	Participant	Study design	Duration	Outcome
Lee (2010) [20]	Obese women (mean age: ~36 years), Taekwondo training group (n=20), Control group (n=19)	N/A	12 weeks	Body composition, Physical (sit-up, sit-and-reach, hand grip strength)
Moon & Kwon (2010) [21]	Female (Training group: 7, Control group: 13)	N/A	12 weeks	Back strength; Sit-ups; LDL-C, TC; Body fat %
Kim et al (2012) [22]	Training group: 14, Control group: 13	Experimental, RCT	12 weeks	physical fitness for muscle endurance, flexibility, agility
Nam et al. (2013) [23]	Young adult women (mean age 20.7 ± 1.0 years; Training group: 7, Control group: 13)	Experimental, RCT	12 weeks	Back strength; Sit-ups; LDL-C and TC; Body fat %
Song et al. (2013) [24]	Male adolescents aged 13–14 (Training group: 12, Control group: 7)	Experimental, RCT	12 weeks	Bone maturity in TG; Fat-free mass (interaction); Health-related fitness or body fat %
Kim et al.(2014) [25]	Elderly women (mean age: 74.5 ± 5.1 years), Taekwondo training group (n=12), Control group (n=10)	Experimental, RCT	16 weeks	Activities of daily living (ADL), Depression, Psychological well-being
Kim (2015) [26]	Elderly women (mean age: ~67 years), Taekwondo training group (n=10), Control group (n=10)	Experimental, RCT	12 weeks	SFT physical fitness (chair stand, arm curl, 2-min step, chair sit-and-reach, back scratch, 8-foot up-and-go), Blood lipids
Lee & Choi (2015) [27]	Obese middle-aged women (Mean age ≈ 49–50; Exercise group: 10, Control group: 9)	N/A	12 weeks	Health-related fitness (Body weight, Body fat %, Strength, Endurance, Flexibility, PEI); Metabolic syndrome factors (Waist circumference, Systolic BP, TG); GH and IGF-1 levels
Clarke et al. (2016) [28]	Middle-aged men (mean age: 42.8 ± 2.1 years), Current Taekwondo group (TKDC: n=10), Former Taekwondo group (TKDS: n=10), Control group (CON: n=10)	Cross-sectional comparative study	N/A	BMD (Femoral neck, L4), Physical fitness (50m shuttle run, sit-ups), Body composition.
An et al. (2017) [29]	Middle-aged male smokers (mean age: ~40 years), Inspiratory muscle training and Taekwondo training group (n=7), Taekwondo training group (n=7), Control group (n=7)	Experimental, RCT	8 weeks	physical fitness (body composition, muscular strength, endurance, flexibility, cardiorespiratory) Pulmonary function (FEV1, FEV1/FVC) Isokinetic muscular function (peak torque %BW), CRP

Joo et al. (2017) [30]	Middle-aged obese women (mean age: ~43 years), Taekwondo combined exercise group (n=20), Control group (n=20)	Experimental, RCT	12 weeks	Body weight, Body fat percentage, Cardiorespiratory endurance (VO_2max), Muscular endurance, Flexibility, HDL-C, Triglyceride (TG)
Jeong et al. (2018) [31]	Menopausal obese women (mean age: ~61 years), Exercise group: 8, Control group: 9	Experimental, RCT	24 weeks	Physical fitness (muscular strength, endurance, aerobic fitness), daily step count, MVPA, body weight, BMI, body fat percentage, waist and hip circumference, depression (CES-D)
Lee et al. (2018) [32]	Hypertensive obese elderly women (≥65 years; Exercise group: 13, Control group: 13)	N/A	12 weeks	Body weight, Physical fitness (sit-up, one-legged stance, walking speed); Stroke volume, EF, E/A ratio; TC, LDL-C, hs-CRP
Cho & Roh (2019) [33]	Elderly women (mean age: ~69 years), Taekwondo training group (n=19), Control group (n=18)	Experimental, RCT	16 weeks	Lower body strength and flexibility, Aerobic endurance, Neurotrophic factors (BDNF, VEGF, IGF-1), Cognitive, function (Stroop Color-Word test), Cerebral blood flow
Lee (2020) [34]	Female : n=24, age : 46~60 years	Experimental, RCT	12 weeks	Muscle mass, %fat, muscular strength, flexibility
Mohammed, & Choi (2020) [35]	Male: n = 20, Female: n = 15, age: 13 ± 1 years	N/A	N/A	fat-free mass, skeletal muscle mass, energy intake
Kim et al. (2021) [36]	Elderly women with hypertension (mean age: ~72 years), Taekwondo group (n=10), Control group (n=10)	Experimental, RCT	12 weeks	Body composition, Blood pressur, HRPF (grip strength, flexibility, 2-min walk),

Quality assessment

In the quality assessment using the Cochrane RoB 2.0 tool, most studies showed a low risk of bias in the domains of ‘bias arising from the randomization process’, ‘bias due to deviations from intended interventions’, and ‘bias in measurement of the outcome’. However, the domains of ‘bias due to missing outcome data’ and ‘bias in the selection of the reported result’ revealed higher proportions of unclear or high RoB. The whole evaluation revealed a balanced distribution; approximately half of the studies had a low RoB, while the remaining studies exhibited serious issues or a high RoB. However, in the overall risk of bias visualization, the 'high risk' indicator dominates (Figure 2).

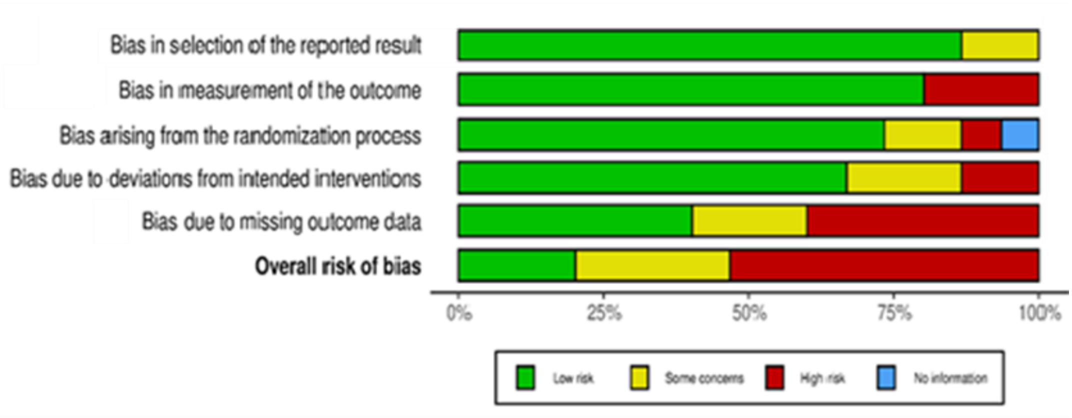

Figure 2. Quality assessment (ordinal variable from the highest proportion of the 'low risk' variable).

Effect size of taekwondo interventions: impacts of taekwondo training on agility in men and women

In a meta-analysis that examined the impact of taekwondo practice on agility in male and female adults, the taekwondo group had a significantly larger effect size for agility (Hedge's g = –0.570, 95% confidence interval (CI) = –1.045, –0.095, p = 0.019 than the control group based on a random-effects model. As shown in Table 2, agility was analysed in 7 of 17 studies. The research results exhibited inter-study heterogeneity (I^2 = 53.477).

Table 2. Effects size of taekwondo practice on agility.

Publication		Subgroup within study	Statistics indicators each study						
Year	Author(s)		Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
2013	Nam, et al. [23]	female	0.089	0.449	0.202	−0.791	0.970	0.198	0.843
2016	Kim [26]	female	−0.872	0.450	0.202	−1.754	0.010	−1.938	0.053
2016	Clarke, et al. [28]	male	−1.536	0.492	0.242	−2.501	−0.571	−3.120	0.002
2017	An, et al. [29]	male	−1.327	0.560	0.313	−2.424	−0.230	−2.370	0.018
2018	Jeong, et al. [31]	female	0.028	0.461	0.213	−0.876	0.932	0.062	0.951
2018	Lee, et al. [32]	female	−0.731	0.393	0.155	−1.501	0.040	−1.859	0.063
2019	Cho, & Roh [33]	female	−0.020	0.322	0.104	−0.650	0.611	−0.061	0.951
Fixed effect			**−0.505**	**0.162**	**0.026**	**−0.823**	**−0.188**	**−3.117**	**0.002**
Random effect			**−0.570**	**0.242**	**0.059**	**−1.045**	**−0.095**	**−2.350**	**0.0019**

Given the heterogeneity observed across studies, we calculated the average effect size (ES) separately for the two types of participants distinguished in the present study using subgroup analysis (male and female) to examine differences in agility. In women, the effect of taekwondo training compared to all control conditions was Hedge's g = −0.282, 95% CI = −0.635, 0.072, p = 0.119, I^2 = 17.061. In men, the effect of taekwondo training compared to all control conditions was Hedge's g = −1.445, 95% CI = −2.169, −0.720, p = 0.000, I^2 = 0.000 (Table 3). Furthermore, there was a significant difference between the female and male subgroups (x^2 = 7.995, df = 1, p = 0.005).

Table 3. Forest plot of gender differences in agility.

Publication		Statistics indicators for each study						
Year	Autor(s)	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
2013	Nam et al. [23]	0.089	0.449	0.202	−0.791	0.970	0.198	0.843
2016	Kim [26]	−0.872	0.450	0.202	−1.754	0.010	−1.938	0.053
2018	Jeong, et al. [31]	0.028	0.461	0.213	−0.876	0.932	0.062	0.951
2018	Lee et al. [32]	−0.731	0.393	0.155	−1.501	0.040	−1.859	0.063
2019	Cho, & Roh [33]	−0.020	0.322	0.104	−0.650	0.611	−0.061	0.951
Fixed effect	**Female**	**−0.282**	**0.180**	**0.033**	**−0.635**	**0.072**	**−1.561**	**0.119**
2016	Clarke et al. [28]	−1.536	0.492	0.242	−2.501	−0.571	−3.120	0.002
2017	An, et al. [29]	−1.327	0.560	0.313	−2.424	−0.230	−2.370	0.018
Fixed effect	**Male**	**−1.445**	**0.370**	**0.137**	**−2.169**	**−0.720**	**−3.908**	**0.000**
Fixed effect	Overall	**−0.505**	**0.162**	**0.026**	**−0.823**	**−0.188**	**−3.117**	**0.002**

Effect size of taekwondo interventions: impacts of taekwondo training on flexibility in men and women

In a meta-analysis that examined the impact of taekwondo practice on agility in male and female adults, the taekwondo group had a significantly larger effect size for flexibility (Hedge's g = 0.534, 95% CI = 0.332, 0.736, p = 0.000) than the control group based on a random-effects model (Table 4), flexibility was analysed in 14 of the 17 studies. The research results exhibited inter-study heterogeneity, as indicated by I^2 = 54.729.

Table 4. Effects size of taekwondo practice on flexibility.

Publication		Subgroup within study	Statistics indicator for each study						
Year	Author(s)		Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
2010	Lee [20]	female	0.235	0.315	0.099	−0.382	0.852	0.746	0.456
2010	Moon & Kwon [21]	female	0.936	0.375	0.141	0.201	1.672	2.495	0.013
2012	Kim et al. [22]	male	0.769	0.388	0.150	0.008	1.529	1.982	0.048
2013	Nam, et al. [23]	female	−0.021	0.449	0.202	−0.902	0.859	−0.048	0.962
2016	Kim [26]	female	0.110	0.429	0.184	−0.730	0.951	0.258	0.797
2016	Clarke et al. [28]	male	0.997	0.456	0.208	0.102	1.891	2.184	0.029
2017	Joo et al. [30]	female	0.497	0.361	0.130	−0.211	1.205	1.377	0.169
2018	Jeong, et al. [31]	female	−0.213	0.463	0.214	−1.119	0.694	−0.459	0.646
2018	Lee, et al. [32]	female	0.625	0.485	0.236	−0.326	1.577	1.288	0.198
2019	Cho & Roh [33]	female	0.159	0.322	0.104	−0.473	0.791	0.493	0.622

Publication		Subgroup within study	Statistics indicator for each study						
Year	Author(s)		Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
2020	Lee [34]	female	1.020	0.421	0.177	0.195	1.844	2.424	0.015
2020	Mohammed & Choi [35]	male	0.903	0.248	0.061	0.418	1.389	3.645	0.000
2021	Kim et al. [36]	female	0.643	0.423	0.179	−0.186	1.473	1.520	0.128
Fixed effect			**0.536**	**0.100**	**0.010**	**0.340**	**0.733**	**5.352**	**0.000**
Random effect			**0. 534**	**0.103**	**0.011**	**0.332**	**0.736**	**5.174**	**0.000**

Given the heterogeneity observed across studies, we calculated the average ES separately for the two types of participants distinguished in the present study using subgroup analysis (male and female) to examine differences in flexibility. In women, the effect of taekwondo training compared with all control conditions was Hedge's g = 0.401, 95% CI = 0.170, 0.632, p = 0.001, I^2 = 0.000. In men, the effect of taekwondo training compared to all control conditions was Hedge's g = 0.887, 95% CI = 0.515, 1.259, p = 0.000, I^2 = 0.000 (Table 5). Furthermore, there was a significant difference between the female and male subgroups (x2 = 4.731, df = 1, p = 0.030).

Table 5. Forest plot of gender differences in flexibility.

Publication	Author(s)	Statistics indicators for each study						
Year		Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
2010	Lee [20]	0.235	0.315	0.099	−0.382	0.852	0.746	0.456
2010	Moon & Kwon [21]	0.936	0.375	0.141	0.201	1.672	2.495	0.013
2013	Nam et al. [24]	−0.021	0.449	0.202	−0.902	0.859	−0.048	0.962
2016	Kim [27]	0.110	0.429	0.184	−0.730	0.951	0.258	0.797
2017	Joo et al. [30]	0.497	0.361	0.130	−0.211	1.205	1.377	0.169
2018	Jeong et al. [31]	−0.213	0.463	0.214	−1.119	0.694	−0.459	0.646
2018	Lee et al. [32]	0.625	0.485	0.236	−0.326	1.577	1.288	0.198
2019	Cho & Roh [33]	0.159	0.322	0.104	−0.473	0.791	0.493	0.622
2020	Lee [34]	1.020	0.421	0.177	0.195	1.844	2.424	0.015
2021	Kim et al. [36]	0.643	0.423	0.179	−0.186	1.473	1.520	0.128
Fixed effect	**Female**	**0.401**	**0.118**	**0.014**	**0.170**	**0.632**	**3.397**	**0.001**
2012	Kim et al. [22]	0.769	0.388	0.150	0.008	1.529	1.982	0.048
2016	Clarke et al. [28]	0.997	0.456	0.208	0.102	1.891	2.184	0.029
2020	Mohammed & Choi [35[	0.903	0.248	0.061	0.418	1.389	3.645	0.000
Fixed effect	**Male**	**0.887**	**0.190**	**0.036**	**0.515**	**1.259**	**4.672**	**0.000**
Fixed effect	**Overal**	**0.536**	**0.100**	**0.010**	**0.340**	**0.733**	**5.352**	**0.000**

Effect size of taekwondo interventions: impacts of taekwondo training on muscle strength in men and women

In a meta-analysis that examined the impact of taekwondo practice on muscle strength in male and female adults, it was observed that the taekwondo group had a significantly larger effect size for muscle strength (Hedge's g = 0.450, 95% CI = 0.153, 0.747, p = 0.000) than the control group based on a random-effects model (Table 6), muscle strength was analysed in 15 of the 17 studies. The research results exhibited inter-study heterogeneity, as indicated by $I^2 = 50.555$.

Table 6. Effects size of taekwondo practice on muscle strength.

Publication		Subgroup within study	Statistics indicators for each study						
Year	Author(s)		Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
2010	Lee [20]	female	0.660	0.323	0.104	0.028	1.292	2.046	0.041
2010	Moon & Kwon [21]	female	0.671	0.366	0.134	−0.045	1.388	1.836	0.060
2013	Nam et al. [23]	female	0.462	0.455	0.207	−0.429	1.354	1.016	0.310
2013	Song et al. [24]	male	0.880	0.433	0.187	0.031	1.728	2.033	0.042
2014	Kim et al. [25]	female	1.366	0.461	0.212	0.463	2.268	2.966	0.003
2015	Kim [26]	female	0.981	0.456	0.208	0.089	1.874	2.154	0.031
2015	Lee & Choi [27]	female	−1.238	0.483	0.233	−2.183	−0.292	−2.564	0.010
2016	Clarke et al. [28]	male	0.057	0.428	0.184	−0.782	0.897	0.133	0.894
2017	An et al. [29]	male	0.166	0.501	0.251	−0.817	1.148	0.330	0.741
2017	Joo et al. [30]	female	0.539	0.362	0.131	−0.171	1.248	1.488	0.137
2018	Jeong et al. [31]	female	−0.109	0.462	0.213	−1.014	0.796	−0.236	0.813
2018	Lee et al. [32]	female	0.069	0.380	0.144	−0.676	0.814	0.181	0.856
2019	Cho & Roh [33]	female	0.063	0.322	0.104	−0.568	0.693	0.194	0.846
2020	Lee [34]	female	1.185	0.430	0.185	0.343	2.027	2.757	0.006
2021	Kim et al. [36]	female	0.867	0.432	0.187	0.020	1.714	2.006	0.045
Fixed effect			**0.453**	**0.105**	**0.011**	**0.247**	**0.659**	**4.302**	**0.000**
Random effect			**0.450**	**0.151**	**0.023**	**0.153**	**0.747**	**2.972**	**0.003**

Given the heterogeneity observed across studies, we calculated the average ES separately for the two types of participants distinguished in the present study using subgroup analysis (male and female) to examine differences in muscle strength. In women, the effect of taekwondo training compared with all control conditions was Hedge's g = 0.467, 95% CI = 0.241, 0.692, p = 0.000, $I^2 = 57.929$. In men, the effect of taekwondo training compared to all control conditions was Hedge's g = 0.384, 95% CI = −0.126, 0.894, p = 0.140, $I^2 = 4.010$ (Figure 1). However, there was no significant difference between the female and male subgroups ($x^2 = 0.049$, df = 1, p = 0.824).

Table 7. Forest plot of gender differences in muscle strength.

Publication		Statistics indicators for each study						
Year	Author(s)	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
2010	Lee [20]	0.660	0.323	0.104	0.028	1.292	2.046	0.041
2010	Moon & Kwon [21]	0.671	0.366	0.134	−0.045	1.388	1.836	0.066
2013	Nam et al. [23]	0.462	0.455	0.207	−0.429	1.354	1.016	0.310
2014	Kim et al. [25]	1.366	0.461	0.212	0.463	2.268	2.966	0.003
2015	Kim [26]	0.981	0.456	0.208	0.089	1.874	2.154	0.031
2015	Lee & Choi [27]	−1.238	0.483	0.233	−2.183	−0.292	−2.564	0.010
2017	Joo et al. [30]	0.539	0.362	0.131	−0.171	1.248	1.488	0.137
2018	Jeong et al. [31]	−0.109	0.462	0.213	−1.014	0.796	−0.236	0.813
2018	Lee et al. [32]	0.069	0.380	0.144	−0.676	0.814	0.181	0.856
2019	Cho & Roh [33]	0.063	0.322	0.104	−0.568	0.693	0.194	0.846
2020	Lee [34]	1.185	0.430	0.185	0.343	2.027	2.757	0.006
2021	Kim et al. [36]	0.867	0.432	0.187	0.020	1.714	2.006	0.045
Fixed	**Female**	**0.467**	**0.115**	**0.013**	**0.241**	**0.692**	**4.052**	**0.000**
2013	Song, et al. [24]	0.880	0.433	0.187	0.031	1.728	2.033	0.042
2016	Clarke et al.[28]	0.057	0.428	0.184	−0.782	0.897	0.133	0.894
2017	An et al.[29]	0.166	0.501	0.251	−0.817	1.148	0.330	0.741
Fixed	**Male**	**0.384**	**0.260**	**0.068**	**−0.126**	**0.894**	**1.475**	**0.140**
Fixed	**Overall**	**0.453**	**0.105**	**0.011**	**0.247**	**0.659**	**4.302**	**0.000**

Effect size of taekwondo interventions: impacts of taekwondo training on muscular endurance in men and women

In a meta-analysis that examined the impact of taekwondo practice on muscular endurance in male and female adults, the taekwondo group had a significantly larger effect size for muscular endurance (Hedge's g = 0.506, 95% CI = 0.114, 0.898, p = 0.011) than the control group, based on a random-effects model. Muscular endurance was analysed in 12 of the 17 studies (Table 8). The research results exhibited inter-study heterogeneity (I^2 = 63.200).

Table 8. Effects size of taekwondo practice on muscular endurance.

Publication		Subgroup within study	Statistics indicators for each study						
Year	Author(s)		Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-value	p-value
2010	Lee [20]	female	0.116	0.314	0.099	−0.499	0.732	0.371	0.711
2010	Moon & Kwon [21]	female	0.673	0.366	0.134	−0.043	1.390	1.841	0.066
2012	Kim et al. [22]	male	0.834	0.390	0.152	0.069	1.599	2.136	0.033
2013	Nam et al. [23]	female	−0.977	0.475	0.225	−1.908	−0.047	−2.058	0.040
2015	Kim [26]	female	1.721	0.507	0.257	0.726	2.716	3.391	0.001
2015	Lee & Choi [27]	female	0.175	0.440	0.193	−0.688	1.037	0.397	0.692

2016	Clark, et al. [28]	male	1.623	0.499	0.249	0.644	2.602	3.251	0.001
2017	An et al. [29]	male	0.215	0.502	0.252	−0.769	1.199	0.429	0.668
2017	Joo et al. [30]	female	1.117	0.383	0.147	0.365	1.868	2.913	0.004
2019	Cho & Roh [33]	female	−0.030	0.473	0.223	−0.957	0.897	−0.064	0.949
	Fixed effect		0.492	0.120	0.014	0.257	0.726	4.109	0.000
	Random effect		**0.506**	**0.200**	**0.040**	**0.114**	**0.898**	**2.532**	0.011

Given the heterogeneity observed across studies, we calculated the average ES separately for the two types of participants distinguished in the present study using subgroup analysis (male and female) to examine differences in muscular endurance. In women, the effect of taekwondo training compared with all control conditions was Hedge's g = 0.389, 95% CI = 0.125, 0.653], p = 0.004, I^2 = 65.373. In men, the effect of taekwondo training compared to all control conditions was Hedge's g = 0.883, 95% CI = 0.369, 1.397, p = 0.001, I^2 = 49.768 (Table 9). However, no significant difference was observed between the female and male subgroups (x^2 = 1.125, df = 1, p = 0.289).

Table 9. Forest plot of gender differences in muscular endurance.

Publication		Statistics indicators for each study						
Year	**Author(s)**	**Hedges's g**	**Standard error**	**Variance**	**Lower limit**	**Upper limit**	**Z-value**	**p-value**
2010	Lee [20]	0.116	0.314	0.099	−0.499	0.732	0.371	0.711
2010	Moon & Kwon [21]	0.673	0.366	0.134	−0.043	1.390	1.841	0.066
2013	Nam et al. [23]	−0.977	0.475	0.225	−1.908	−0.047	−2.058	0.040
2015	Kim [26]	1.721	0.507	0.257	0.726	2.716	3.391	0.001
2015	Lee & Choi [27]	0.175	0.440	0.193	−0.688	1.037	0.397	0.692
2017	Joo, et al. [30]	1.117	0.383	0.147	0.365	1.868	2.913	0.004
2018	Lee et al. [32]	0.741	0.394	0.155	−0.030	1.512	1.884	0.060
2019	Cho & Roh [33]	−0.030	0.473	0.223	−0.957	0.897	−0.064	0.949
2020	Lee [34]	−0.034	0.394	0.155	−0.806	0.739	−0.085	0.932
Fixed	**Female**	**0.389**	**0.135**	**0.018**	**0.125**	**0.653**	**2.892**	**0.004**
2012	Kim et al. [22]	0.834	0.390	0.152	0.069	1.599	2.136	0.033
2016	Clarke et al. [28]	1.623	0.499	0.249	0.644	2.602	3.251	0.001
2017	An et al. [29]	0.215	0.502	0.252	−0.769	1.199	0.429	0.668
Fixed	**male**	**0.883**	**0.262**	**0.069**	**0.369**	**1.397**	**3.366**	**0.001**
Fixed	**Overall**	**0.492**	**0.120**	**0.014**	**0.257**	**0.726**	**4.109**	**0.000**

Publication bias assessment

We performed a funnel plot analysis to verify the validity of our results and examine publication bias among the selected studies. The funnel plot indicated exemplary symmetry, with each variable being somewhat balanced and uniformly distributed (Figure 3-6). The analysis of all factors revealed that publishing bias was comparatively modest

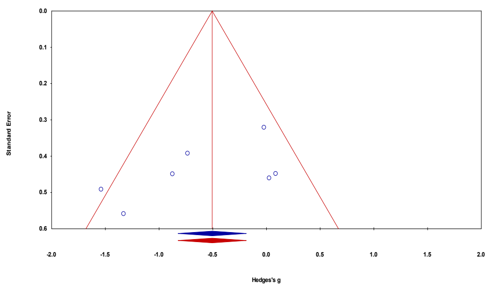

Figure 3. Funnel plot of standard error by Hedges's g for agility

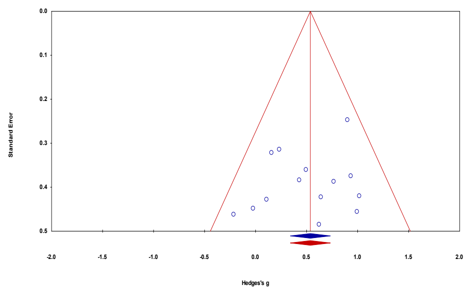

Figure 4. Funnel plot of standard error by Hedges's g for flexibility

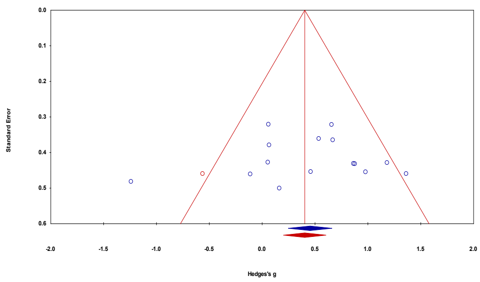

Figure 5. Funnel plot of standard error by Hedges's g for muscle strength

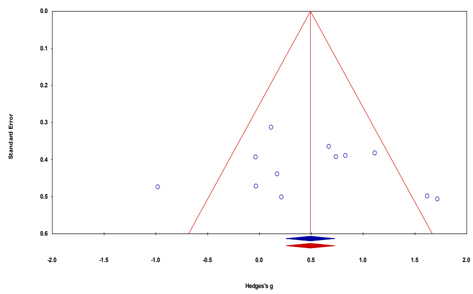

Figure 6. Funnel plot of standard error by Hedges's g for muscular endurance

4. Discussion

Examining the health-promoting effects of taekwondo from a gender perspective is important for modern exercise science and public health. Research has demonstrated that men and women have differences in physiology and lifestyle that can lead to different responses to the same exercise [37]. Considering these sex differences is essential to maximize the benefits of exercise interventions and to develop tailored health promotion strategies.

Taekwondo is considered to have broad benefits for physical and mental health due to its combination of physical training and mental discipline. Additionally, it is reported to support the development of mental health in children and adolescents, as well as to improve obesity, metabolic disease, and cardiovascular risk factors in adults and older adults. Maximizing the public health value of taekwondo requires a closer understanding of the patterns and differences in its health effects between men and women. In the following sections, we (1) interpret key differences in the health effects of taekwondo practice by gender, (2) compare the observed effect sizes, and (3) discuss the limitations of existing studies in terms of gender analysis.

This meta-analysis found that some of the physical health benefits of practicing taekwondo differed by sex, with males showing significantly greater benefits than females in agility and flexibility, but no significant sex differences were observed in strength and muscular endurance. For agility, the male group showed a large effect size ($g = -1.45$), whereas the female group showed a relatively small effect size ($g = -0.28$), and the difference was statistically significant ($p<0.01$). Flexibility also showed a statistically significant larger effect for males ($g = 0.89$) than for females ($g = 0.40$), which was also statistically significant ($p<0.05$). However, for strength (female: $g = 0.47$, male: $g = 0.38$) and muscular endurance (female: $g = 0.39$, male: $g = 0.88$), there was no significant difference between the sexes ($p = 0.824$ and $p = 0.289$, respectively), although the effect was significant for both. These results suggest that taekwondo has a positive effect on physical health in men and women, but the relative effect size may vary by sex, depending on the specific fitness component.

Studies have explained the reasons for these sex differences. In general, men have a relatively higher baseline agility, which allows fast movement and explosive force, compared to women [38]. This might be attributable to the dynamic, high-intensity kicking and sparring forms of taekwondo, which facilitate neuromuscular adaptations in men. Conversely, the relatively small improvement in agility in the female group in this study may be because they were middle-aged or older, which may have limited their ability to improve their agility, or the program may not have sufficiently stimulated agility compared to the male group. This raises the need to increase the intensity or frequency of agility training or design training programs tailored to women to maximize agility.

The relatively large effect on flexibility seen in men may be due to differences in initial flexibility levels between the sexes. Generally, women tend to have higher baseline flexibility and more flexible muscle-tendon structures than men [39]. Therefore, there may be a ceiling effect on the extent to which women can increase their flexibility, and men may possess more potential to enhance their flexibility via training, such as repeated leg kicks and stretches in taekwondo, owing to their comparatively restricted beginning flexibility. This suggests that men can achieve greater flexibility gains through taekwondo, thus reducing existing gender differences.

Conversely, in this study, there were no significant sex-related differences in strength and muscular endurance. This may be attributable to the exercise characteristics of taekwondo training. It is not a weight-bearing exercise that focuses on maximal strength but consists of calisthenics and continuous muscular endurance exercises, which are characterized by improved neuromuscular efficiency and functional strength in men and women. The disparities in strength and muscular endurance improvements between the sexes may be negligible as taekwondo training mostly fosters neural changes and enhances motor efficiency [16]. This indicates that taekwondo training can provide an equally intense stimulus for men and women, inducing similar improvements in strength and muscular endurance.

The results of this study have important implications for the design and implementation of traditional budo exercise programs, such as taekwondo. The greater agility and flexibility gains in men emphasize the utility of taekwondo as an exercise that compensates for factors that they are more likely to lack. For women, the effects on strength and muscular endurance were relatively similar to those for men, suggesting that taekwondo is an effective exercise program for improving overall strength and endurance in women. Furthermore, more intensive training modalities or separate program designs should be considered to improve female trainers' agility.

This study has several limitations. First, the age, health status, and training intensity of the participants in the individual studies included in this review varied, which may have limited the generalizability of the results. In particular, the female group included mostly middle-aged and older adults, whereas the male group was relatively younger, which may have exaggerated the sex differences in age and baseline fitness. Another limitation is that the methodology for measuring agility and muscular endurance varied across studies, making it difficult to ensure the consistency of the results.

Future studies should use a more rigorous experimental design with male and female participants of similar age and baseline fitness conditions, performing the same taekwondo program, to identify sex differences more clearly. In addition, to better understand the causes of sex differences, studies should be conducted to explore the mechanisms of exercise adaptation between the sexes by measuring physiological factors, such as muscle fibre types and hormonal changes. This will allow the identification of sex-specific effects of taekwondo training more clearly and contribute to the design of personalized taekwondo exercise programs.

5. Conclusions

In conclusion, the present study confirmed that taekwondo is an effective physical health-promoting exercise for men and women and suggested that there are gender differences in some fitness factors. By understanding and utilizing these differences, the effectiveness of taekwondo programs can be maximized, which will allow for sex-specific customization and optimization of the exercises. Additionally, the use of taekwondo as a physical activity promotion form in community public health programs may contribute to improving the health of both males and females. However, for the fitness components that showed differential gains between sexes, such as agility and flexibility, customized strategies that consider sex characteristics when prescribing exercises are required. For example, adding exercises that compensate for fitness components that are less likely to improve in each sex can help ensure that all trainees achieve a well-rounded fitness level. Incorporating sex differences in exercise response into program design can help practitioners achieve maximum health benefits and improve the efficiency of exercise prescriptions.

Several areas for future research to further clarify gender differences among taekwondo practitioners exist. First, a study design that strictly controls for variables, such as age, initial fitness level, and training intensity, should be used to ensure that the observed differences between men and women are not driven by these factors. By comparing men and women under the same conditions, it will be possible to clearly identify sex differences in the effects of taekwondo. Second, to understand the physiological mechanisms of sex-specific exercise adaptation, studies that measure physiological indicators such as muscle fibre type and hormonal changes are needed. Such follow-up studies will strengthen the scientific evidence supporting the sex-specific effects of taekwondo practice and contribute to the development of tailored exercise recommendations and exercise programs for public health.

Data Availability Statement: The data supporting this study's findings are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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