

Review article

Is pilates better than other exercises at increasing muscle strength? A systematic review



Júlia Ribeiro Pinto^a, Cleyton Salvego Santos^a, Wuber Jefferson Souza Soares^b,
Ana Paula Silveira Ramos^c, Robson Dias Scoz^{a,d,*}, André Filipe Teixeira de Jádice^d,
Luciano Maia Alves Ferreira^d, José João Baltazar Mendes^d, César Ferreira Amorim^{a,d,e,f}

^a Masters and Doctoral Program in Physiotherapy, University City of Sao Paulo (Unicid), São Paulo, Brazil

^b Secretary of Health, Cuiaba, Mato Grosso, Brazil

^c Doctoral Program of Human Movement Science, University of Santa Catarina State (UDESC), Florianópolis, Brazil

^d Laboratory of Physical and Functional Assessment in Physiotherapy (LAFFFi), Interdisciplinary Center of Investigation Egas Moniz (CiiEM), Caparica, Setubal, Portugal

^e R9 Biomechanic Analysis Laboratory, Corinthians Football Club, Sao Paulo, Brazil

^f Physical Therapy Department, Research Laboratory BioNR, Quebec University, Saguenay, Canada

ARTICLE INFO

Keywords:
Pilates
Strength
Exercise
Muscle

ABSTRACT

Our objective was to verify the effectiveness of Pilates method compared against other exercise modalities for muscle strength increase, balance and flexibility.

Method: Databases used and its respective results were: CENTRAL (n = 456), CINAHL (n = 291), EMBASE (n = 313), PEDro (n = 176), PUBMED (n = 236), SCIELO (n = 98), SPORTDiscus (n = 197) e Web of Science (n = 150). It included randomized controlled studies using Pilates and others exercise modalities that measured muscle strength.

Results: Eleven studies were included for analysis. The mean methodological quality score of these studies, evaluated by the PEDro scale, was 6 ± 1 . For the primary outcome, not being observed this difference for dynamic force (SMD = -0.29; 95%IC -0.69; 0.10), isometric (SMD = 0.20; 95%IC -0.06; 0.47) or resistance (SMD = -0.19; 95%IC -0.46; 0.07). For secondary outcomes, there was no difference for balance and flexibility.

Conclusion: In conclusion, there is very low to low evidence that there is no difference between Pilates and other exercise modalities for dynamic strength, isometric strength, resistance strength, balance and flexibility.

1. Introduction

Pilates was created by Joseph Pilates initially as “Contrology” for outdoor practice and aiming to increase muscle strength through body weight [1]. It is currently considered a method of physical conditioning to improve physical fitness through the balance between body, mind, and spirit [1, 2]. The execution of its exercises, both on the floor or with machines, must be carried out following its principles such as concentration, control, centralization, fluidity, precision, and breathing [1, 2, 3]. Despite the objective of initially working on strength, today Pilates is best known for improving flexibility, balance, motor coordination, posture, and mental health [4, 5, 6].

There are many reviews have researched to showing de benefits of Pilates practice on body composition like decrease weight, body fat

percentage, circumference, increase muscle mass [7], or improving flexibility, dynamic balance and muscular endurance [5] for pain and quality of life seems great too [8]. Low back pain is one of the most studied outcomes and Pilates is more effective than minimal interventional, but when Pilates compared with other exercises there are not difference [9]. Despite many studies presenting the benefits of the Pilates method, the practice of the Pilates method to increase strength is still little known.

The increase in muscle strength through the practice of exercises is considered an important factor for the maintenance of the population's health [10, 11]. Muscle strength can be trained under Pilates Method using the practitioner's own body weight or machines equipped with springs and elastic bands [1]. Although muscle strength is an important factor for a healthy body, little is known about Pilate's effectiveness in

* Corresponding author.

E-mail address: robsonscosz@hotmail.com (R.D. Scoz).

<https://doi.org/10.1016/j.heliyon.2022.e11564>

Received 14 June 2022; Received in revised form 25 October 2022; Accepted 7 November 2022

2405-8440/© 2022 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

increasing muscle strength. As Pilates is usually used towards flexibility or balance training, those have been the common outcomes studied by researchers [5, 12, 13].

Therefore, the objective of this systematic review was to verify the effectiveness of Pilates method compared to other exercise modalities in increasing muscle strength in healthy individuals.

2. Materials and methods

2.1. Protocol and registration

A protocol of this systematic review was registered in The International Prospective Register of Systematic Reviews – PROSPERO (CRD420202940). The study followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). There was no patient or public involvement in the conceptualization or development of this study.

2.2. Eligibility criteria

Only randomized controlled trials published in peer-reviewed journals were included in this review. Studies described with quasi-randomized allocation were not considered. There was no restriction on language or year of publication.

2.2.1. Inclusion

It included participants without musculoskeletal limitations to perform the exercises and without age restrictions. We selected studies that directly named at least one group among the comparisons as Pilates or Contrology; and studies that compared the muscle strength outcome, pre- and post-intervention between Pilates and other physical exercise modalities.

2.2.2. Exclusion

It was excluded from this review studies that combined Pilates with any other type of exercise in the same study group, studies that included participants with some contraindication for performing physical exercise, pregnant women, more serious diseases such as cancer, fracture, inflammatory or degenerative diseases.

2.3. Data search and selection

The search was executed on August 2020 on the following databases: CENTRAL, CINAHL, EMBASE, PEDro, PUBMED, SCIELO, SPORTDiscus and Web of Science. The search keywords were combined in two blocks: Intervention and Study Type. The full search strategy is presented as Supplementary Material.

Two independent reviewers were responsible for data selection and extraction. The initial selection was through reading the title and abstract and then the full text. Any disagreement between the reviewers was resolved by consensus. Information about the studies and characteristics of the interventions was collected.

As the main outcome, we considered dynamic muscle strength, strength resistance and isometric strength. As secondary outcomes, flexibility and balance were considered. For the extraction of outcome data, the mean, pre- and post-intervention standard deviation and sample size were considered. When presented in graphical format, an approximate extraction was performed using the WebPlotDigitizer Software. When approximate extraction was not possible, we contacted the authors by electronic mail requesting study data.

2.4. Risk of bias

The methodological quality of all studies was evaluated using PEDro Scale [14]. The scale has 11 items generating a maximum grade of 10 points (the first item does not generate a point). The higher the grade, the

less risk of bias. Studies with high (grade 6 or more) and low (grade 5 or less) methodological quality were considered in this review [15]. The complete information is presented as Supplementary Material.

2.5. Certainty of evidence

The certainty of evidence was reported according to the Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) [16]. It was classified as High, Moderate, Low or Very Low according to the following lowering factors: (1) Risk of Bias – more than 25% of all selected studies have a high risk of bias; (2) Inconsistency – I² higher than 50%; (3) Indirect Evidence – 50% or more of all participants are not included in the main group under analysis; (4) Imprecision – the final comparison has less than 400 participants; (5) publication bias. The complete information is presented as Supplementary Material.

2.6. Data synthesis and analysis

In this review, a comparison was made between pilates method and other modalities of physical exercise with a subgroup analysis by type of exercise. For the main outcome (muscle strength) a comparison was performed for each type of muscle strength manifestation (i) dynamic, (ii) isometric and (iii) resistance. For secondary outcomes, (iv) balance and (v) flexibility using the sit-and-reach test, and (vi) flexibility using the behind-back test were performed.

The combined data was presented in a meta-analysis through forest plot for each comparison of outcomes. For comparisons with a high heterogeneity ($I^2 > 80\%$), a sensitivity analysis was performed considering two aspects: methodological quality of the study (excluding studies with high risk of bias, PEDro scale score <6) or studies with high heterogeneity (excluding studies causing of high heterogeneity). All analyzes were performed using the Review Manager Software (RevMan 5.3).

To carry out the meta-analysis, the mean data and post-intervention standard deviation of each study were used. Studies that presented multiple data for the same outcome were combined to form a single data. The combination of these data was performed according to the guidance described in chapter 6; section 6.5.2.10 of the Cochrane handbook [16]. For studies that compared pilates method with more than one group, the sample size of the Pilates group was divided by the number of comparisons in the study [16].

The analysis method considered was the random effect model, difference between standardized means and 95% confidence interval (95% CI). Studies that did not present data, or that it was not possible to extract the approximate data or did not return our contact were excluded from the meta-analysis, however, they were included in the descriptive analysis.

The evaluation of heterogeneity was performed by visually inspecting the forest graph (confidence interval overlap) and by I^2 test result. Heterogeneity was considered low if <50%, moderate between 50-80% and high if >80%.

3. Results

The search resulted in 1917 potential studies. After reviewing the title, abstract and full text 16 studies were part of this review. Eleven studies were included in the meta-analysis. The complete study selection flowchart is shown in Figure 1.

Of the studies included in this review, 3 studies were written in Persian [17, 18, 19]. Contact with the authors, requesting the data, was necessary for 7 studies [17, 18, 20, 21, 22, 23, 24]. Of these studies, only 1 returned data [23] and two other studies [20, 22] approximate data were used. The remaining studies [17, 18, 21, 22, 25] were included in the descriptive analysis, however, they were not used in the metanalysis. The reason for the exclusion of studies after reading the full text are presented s Supplementary Material.

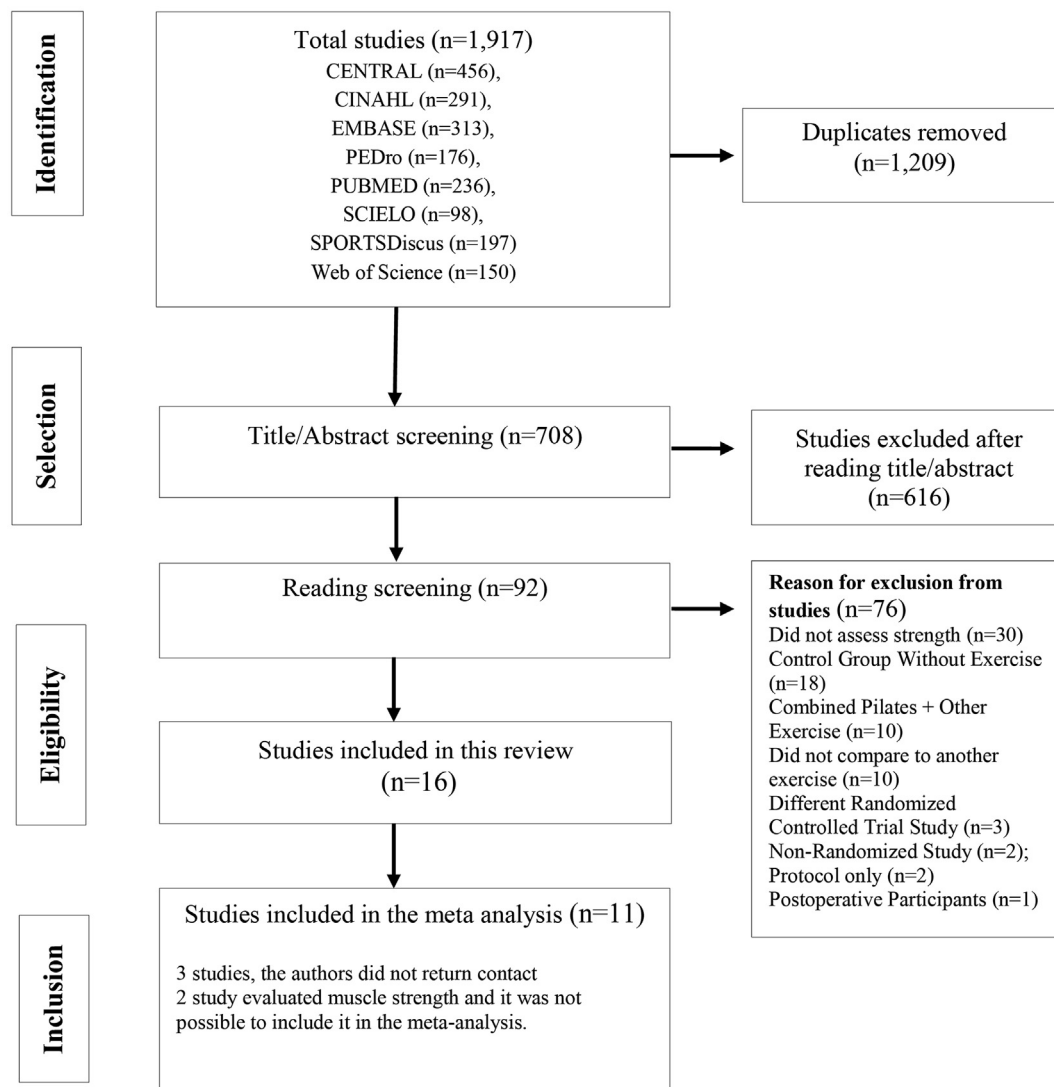


Figure 1. Flow of study selection.

Table 1. Intervention characteristics.

Data	Age (year)	Total Sample	Pilates Sample	Exercises Sample	Duration (weeks)	Freq.	% Δ Pilates	% Δ Exercises
Mean	60	43	22	21	12	3	27	21
±SD	19	23	18	14	7	1	16	24
Min.	56	30	14	16	4	2	0	-15
Max.	78	101	81	69	24	3	60	69

Notes: Freq.: Frequency, number of sessions during the week; % Δ: Percentage of difference between pre- and post-intervention mean for muscle strength outcome; SD: Standard deviation; Min.: Minimum; Max.: Maximum.

The general characteristics of all selected studies can be consulted in Table 1. The total number of participants in the studies was 689 (Pilates = 354 and Other Exercises = 335). The mean number of participants for each group was 43 ± 23 . The mean age of participants was 60 ± 19 years. The mean intervention period was 12 ± 7 weeks, with a minimum of 4 and a maximum of 24 weeks. The average frequency of sessions was 3 ± 1 sessions per week, with a minimum of 2 and a maximum of 3 sessions. Data on muscle strength, flexibility and balance outcomes can be consulted in Table 2.

The studies included in this review evaluated muscle strength in different ways, being divided into dynamic, isometric and resistance

strength. The types of assessment used to measure muscle strength were repetition maximum (RM) being 1RM and 10RM, elbow flexion test, load cell, sit and stand test, isokinetic dynamometer, trunk flexion test dynamic or isometric (abdominal), handgrip strength test, trunk extension and flexion in isometry and modified Sorensen test, peak pelvis strength test and test of descending flexed knees.

The types of exercises compared to Pilates in the studies were varied. Being, strength exercises, stretching, physical education class, balance, proprioceptive neuromuscular facilitation (PNF), physiotherapy, gymnastics, pool exercises, vibrating platform, elastic bands, and yoga. These data are presented in Table 2, as Supplemental Material.

Table 2. Characteristics of studies and outcomes muscle strength, balance and flexibility, mean values and standard deviation.

Estudy	Group (n)	Assessment/Outcome	Pre mean ($\pm$ SD)	Post mean ($\pm$ SD)	Difference (IC95%)	PEDro Scale
Carrasco-Poyatos et al. 2019 [26]	Pilates (16) Strength (19)	Dynamic Force Comb. Isokinetic Dynamometer	45.03 (19.51) 39.07 (18.91)	51.48 (26.18) 50.19 (21.3)	6.45 (-1.63; 14.53) 11.12 (4.67; 17.58)	7
		Isometric Force Comb. Isokinetic Dynamometer	105.22 (72.23) 118.06 (83.83)	138.02 (92.5) 133 (88.82)	32.81 (3.77; 61.84) 14.94 (-12.74; 42.62)	
Carvalho et al. 2017 [20]	Pilates (21) PNF (21)	Isometric Force Comb. Load Cell	90.48 (41.98) 82.39 (47.32)	129.16 (65.54) 139.14 (60.59)	38.68 (14.79; 62.57) 56.75 (33.15; 80.34)	5
Culligan et al. 2010 [21]*	Pilates (28) Physiotherapy (24)	Dynamic Force MMII Peak Force Pelvis	N/R			5
Dashti et al. 2015 [17]*	Pilates (15) Elastic Band (15)	Resistance Force MMII Stand Chair Test	N/R			5
Donath et al. 2016 [22]	Pilates (17) Balance (16)	Isometric Force Comb. Trunk Flexion Test ACSM	96.87 (74.46) 115.57 (94.24)	123.46 (79.91) 144.53 (110.78)	26.59 (-10.81; 63.99) 28.96 (-22.44; 80.36)	4
		Resistance Force Dynamic Test Trunk Flexion	25.08 (12.04) 24.15 (9.75)	31.19 (17.96) 28.22 (12.8)	6.11 (-4.57; 16.79) 4.07 (-4.15; 12.29)	
		Balance Comb. Force Platform (COP)	4256.45 (1361.75) 3598.36 (1021.4)	5100.27 (1203.23) 5011.93 (1200.88)	843.82 (221.6; 1466.03) 1413.57 (856.48; 1970.66)	
		Balance Comb. Y Balance Test	73.41 (13.38) 87.79 (8.4)	73.11 (10.56) 81.54 (8.28)	-0.29 (-6.13; 5.54) -6.25 (-10.42; 2.08)	
Filho et al. 2016 [27]	Pilates (21) Gymnastics (23) Water Aerobics (24) Strength (22)	Dynamic Force Comb. 10RM.	13 (7.22) 12 (6.29) 14.25 (7.19) 13.25 (7.25)	17 (8.57) 16.75 (8.71) 16.5 (7.84) 20.75 (9.44)	4 (-0.25; 8.25) 4.75 (2.54; 6.96) 2.25 (0.11; 4.39) 7.5 (5; 10)	4
	Pilates (21) Gymnastics (23) Water Aerobics (24) Strength (22)	Flexibility MMII Test Sit Reach	1.64 (3.17) 1.55 (3.2) 1.48 (3.2) 1.56 (3.71)	2.21 (3.39) 1.99 (3.91) 1.91 (3.33) 1.95 (3.91)	0.57 (-3.25; 4.39) 0.44 (-1.68; 2.56) 0.43 (-1.47; 2.33) 0.39 (-1.93; 2.71)	
González-Gálvez et al. 2019 [25]*	Pilates (81) Physical Education (20)	Isometric Force Sørensen Test	147.98 (70.7) 139.4 (50.4)	182.75 (61) 114.5 (44.8)	34.77 (14.28; 55.26) -24.9 (-55.42; 5.62)	6
		Resistance Force Trunk Flexion	57.96 (34.5) 57.15 (35.1)	76.51 (37.9) 50.05 (26.3)	18.55 (7.3; 29.8) -7.1 (-26.95; 12.75)	
Irandoos & Taheri 2016 [18]	Pilates (20) Yoga (20)	Resistance Force MMII Stand Chair Test	6.2 (0.9) 6.4 (1.3)	9.9 (1.7) 10.1 (1.3)	3.7 (2.83; 4.57) 3.7 (2.87; 4.53)	4
		Balance Stork Test	14.9 (0.9) 14.8 (0.9)	14.6 (0.5) 16.8 (0.7)	-0.3 (-0.77; 0.17) 2 (1.48; 2.52)	
		FlexibilityTest Sit Reach	22 (1.8) 22.3 (2.1)	24.9 (1.9) 25.1 (1.9)	2.9 (1.72; 4.08) 2.8 (1.52; 4.08)	
Kovach et al. 2013 [28]	Pilates (22) Water Aerobics (17)	Resistance Force Comb. Elbow Curl Test	19.95 (5.21) 18.9 (5.14)	27.85 (5.69) 25.55 (5.02)	7.9 (5.59; 10.21) 6.65 (4.19; 9.11)	4
	Pilates (22) Water Aerobics (17)	Flexibility MMSS Back Reach Test	-0.86 (6.5) 1.3 (8.4)	-3.4 (5.6) -2.7 (8)	-2.54 (-6.23; 1.15) -4 (-9.73; 1.73)	
		Flexibility MMII Test Sit Reach	4.9 (8.7) 5 (8.7)	-8.3 (4.6) -8.3 (6.8)	-13.2 (-17.43; -8.97) -13.3 (-18.76; -7.84)	
Markovic et al. 2015 [29]	Pilates (14) Vibration Platform (16)	Dynamic Force MMSS 1RM	22.9 (6.7) 23 (4)	24.4 (6.8) 24.8 (4.4)	1.5 (-3.74; 6.74) 1.8 (-1.24; 4.84)	7
		Isometric Force Comb. Trunk Isometric (N)	305.25 (104.01) 288.25 (69.57)	314.5 (110.75) 369.75 (100.67)	9.25 (-30.99; 49.49) 81.5 (51.23; 111.77)	7
		Balance Force Platform (COP)	37.5 (8) 37.7 (4.6)	37.7 (8.4) 35.3 (5.4)	0.2 (-6.17; 6.57) -2.4 (-6.02; 1.22)	
Oliveira et al. 2015a [30]	Pilates (16) Stretching (16)	Dynamic Force Comb. Isokinetic Dynamometer	38.6 (7.43) 38 (8.74)	52.3 (8.53) 37.43 (9.3)	13.7 (10.9; 16.5) -0.58 (-3.73; 2.58)	5
Oliveira et al. 2015b [24]*	Pilates (16) Stretching (16)	Dynamic Force Comb. Isokinetic Dynamometer	N/R			7
Oliveira et al. 2017 [31]	Pilates (16) Stretching (16)	Dynamic Force Comb. Isokinetic Dynamometer	60.45 (25.36) 61 (25.74)	77.6 (25.41) 61.35 (27.94)	17.15 (8.27; 26.03) 0.35 (-9.05; 9.75)	8
Oliveira et al. 2018 [32]	Pilates (17) Vibration Platform (17)	Dynamic Force Comb. Isokinetic Dynamometer	63.08 (29.82) 54.53 (23.18)	68.33 (29.32) 56.73 (23.01)	5.25 (-4.78; 15.28) 2.2 (-5.63; 10.03)	8
Sahebozamani et al. 2016 [19]*	Pilates (16) Mackenzie (15)	Lumbar Dynamic Force Test Bent Knee Down	67.18 (11.37) 62.66 (12.92)	58.37 (10.95) 59.86 (13.05)	-8.81 (-16.87; -0.75) -2.8 (-12.51; 6.91)	4

(continued on next page)

Table 2 (continued)

Estudy	Group (n)	Assessment/Outcome	Pre mean ($\pm$ SD)	Post mean ($\pm$ SD)	Difference (IC95%)	PEDro Scale
Taskiran et al. 2014 [23]	Pilates (18)	Dynamic Force	0.34 (0.12)	0.34 (0.12)	0 (-0.08; 0.08)	5
	Yoga (18)	Hand Grip Strength	0.29 (0.1)	0.32 (0.12)	0.03 (-0.04; 0.1)	
		Resistance Force Elbow Curl Test	13.2 (4.41)	13.85 (5.02)	0.65 (-1.57; 2.87)	
			12.35 (3.53)	13.2 (3.95)	0.85 (-0.91; 2.61)	

RM: Repetition Maximum; SD: Standard Deviation; n: Sample; IC: Interval Confidence; Pre = Pre Intervention; Post = Post Intervention; PNF: Proprioceptive Neuromuscular Facilitation; ACSM: American College of Sports Medicine; N: Newton; MMSS: Superior Member; MMII: Inferior Member; Comb.: Data from the combined studies. COP: Pressure Center. Physical Education: Physical Education Classes. N/R: Not returned the data request by electronic mail.

* Studies that did not enter the meta-analysis because of the direction of results or not returned data request.

3.1. Risk of bias

The studies were considered to have moderate methodological quality, with a mean value of 6 ± 1 of a maximum score of 10. The maximum score achieved was 8 and the minimum score was 4. The main factors for reducing the maximum score were: blinding and analysis by intention to treat. The analysis was performed directly from PEDro website (<https://pedro.org.au/>). Six studies [17, 19, 21, 23, 24, 25] required a manual analysis. The evaluation of each study can be consulted as Supplementary Material.

3.2. Dynamic muscle strength

The comparison of dynamic muscle strength (Figure 2) was composed of a total sample of 958 participants (Pilates = 376 and Other Exercises = 582). Low certainty of evidence (two-level reduction, risk of bias and

inconsistency). The result shows that there was no statistically significant difference (SMD = -0.29; 95%CI -0.69; 0.10; $I^2 = 87\%$; $n = 958$).

A sensitivity analysis was performed due to the high heterogeneity presented $I^2 = 87\%$. With the exclusion of the two studies using stretching exercises [26, 27], with scores in the risk of bias analysis of 5 and 8 respectively, the heterogeneity was became low $I^2 = 36\%$. However, even with the reduction of heterogeneity (Figure 3) the result shows that there was no statistically significant difference (SMD = -0.06; 95%CI -0.27; 0.15; $I^2 = 36\%$; $n = 702$).

3.3. Isometric muscle strength

The comparison of isometric muscle strength (Figure 4) was composed of a total sample of 410 participants (Pilates = 196 and Other Exercises = 214). Low certainty of evidence (two-level reduction, risk of bias and

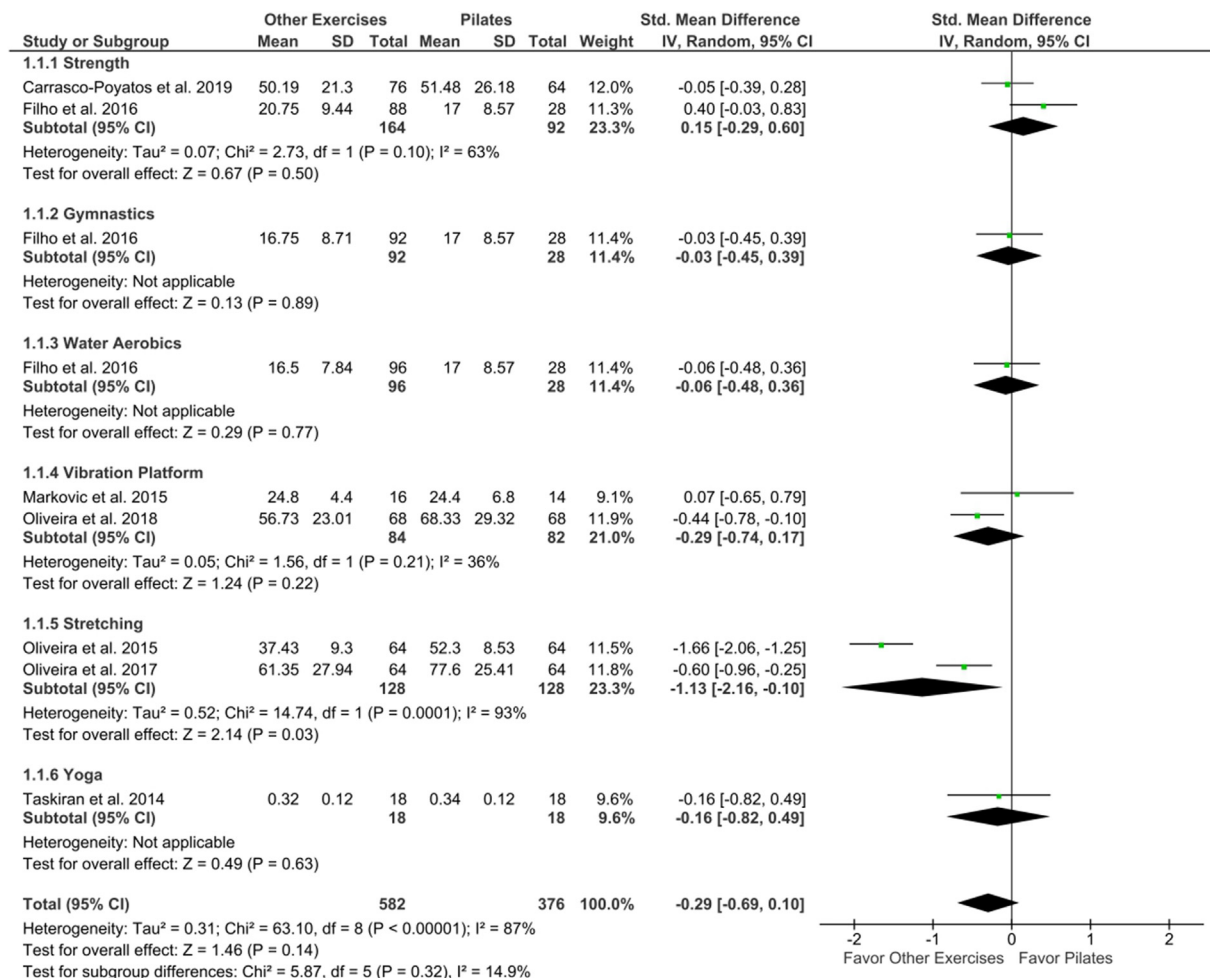


Figure 2. Forest plot of comparison Pilates versus Exercises. Outcome: dynamic muscle strength.

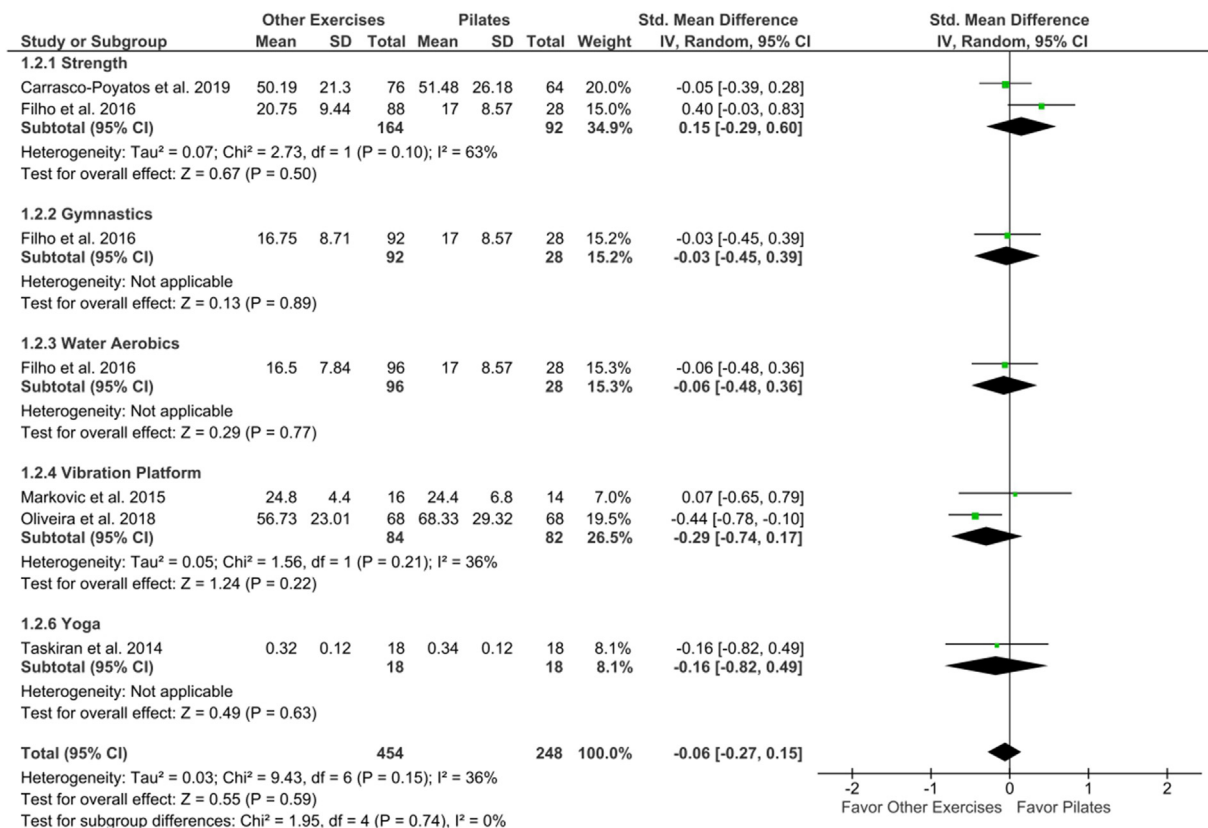


Figure 3. Forest plot of comparison Pilates versus Exercises with sensitivity analysis. Outcome: dynamic muscle strength.

inconsistency). The result shows that there was no statistically significant difference (SMD = 0.20; 95%CI -0.06; 0.47; $I^2 = 43\%$; $n = 410$).

3.4. Muscle strength endurance

The comparison of strength resistance (Figure 5) was composed of a total sample of 223 participants (Pilates = 117 and Other Exercises = 106). Low certainty of evidence (two-level reduction, risk of bias and

imprecision). The result is that there was no statistically significant difference (SMD = -0.19; 95%CI -0.46; 0.07; $I^2 = 0\%$; $n = 223$).

3.5. Balance

The comparison of balance (Figure 6) was composed of a total sample of 202 participants (Pilates = 102 and Other Exercises = 100). Very low certainty of evidence (4-level reduction, risk of bias and inconsistency)

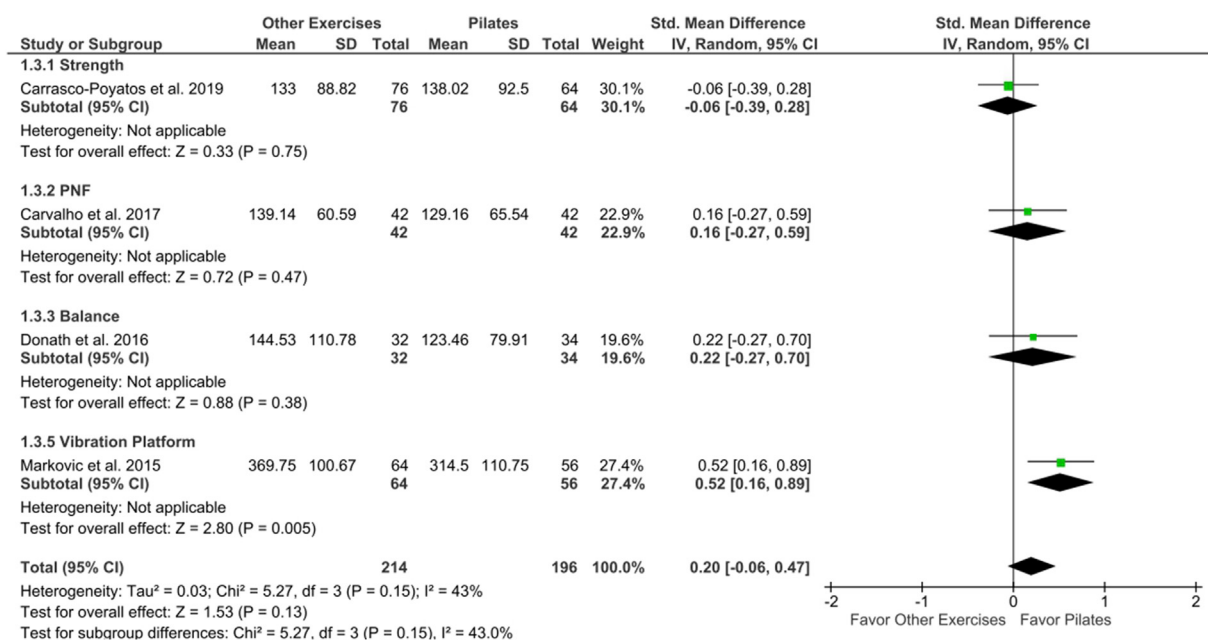


Figure 4. Forest plot of comparison Pilates versus Exercises. Outcome: isometric muscle strength.

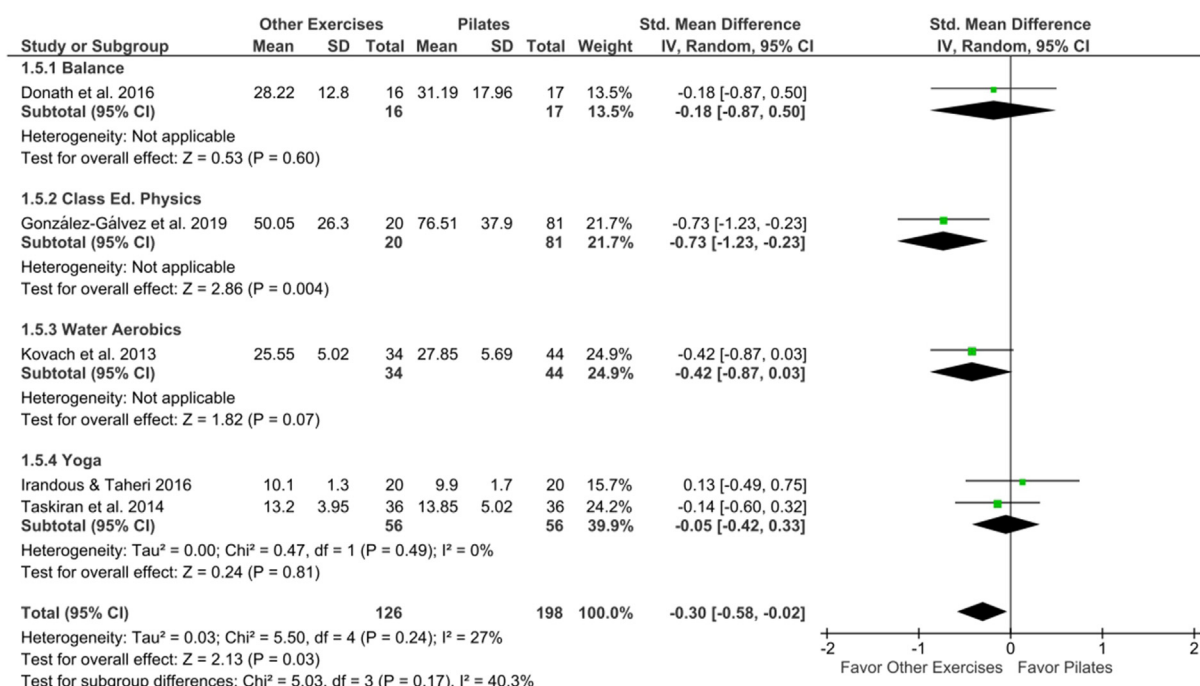


Figure 5. Forest plot of comparison Pilates versus Exercises. Outcome: muscle strength endurance.

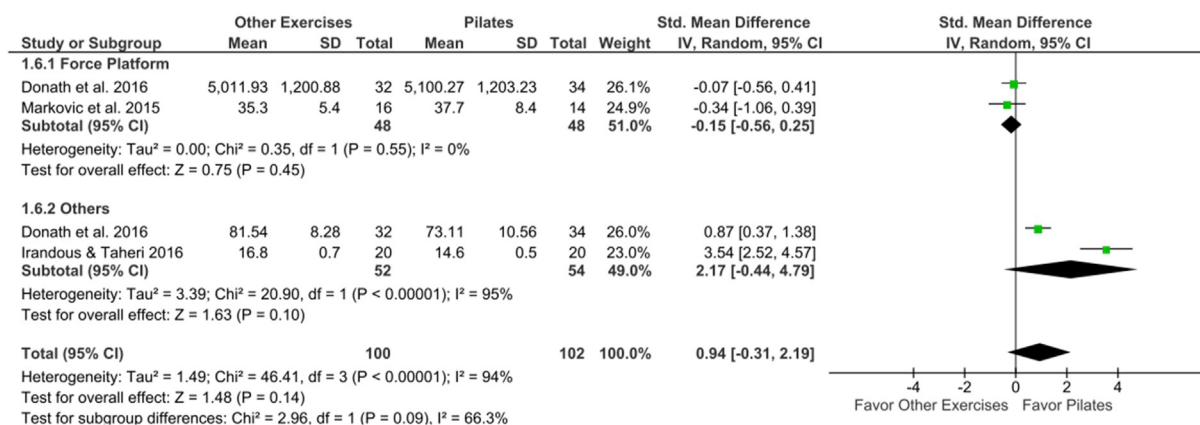


Figure 6. Forest plot of comparison Pilates versus Exercises Outcome: balance.

and imprecision). The result shows that there was no statistically significant difference (SMD = 0.94; 95%CI -0.31; 2.19; I² = 94%; n = 202).

A sensitivity analysis was performed due to the high heterogeneity presented I² = 94%. With the exclusion of the evaluation type (Balance Test Y18 and Test of Stork14), with a score in the risk of bias analysis of 4 for both studies, the heterogeneity become low I² = 0%. However, even with the reduction of heterogeneity (Figure 7) the result shows that there was no statistically significant difference (SMD = -0.15; 95%CI -0.56; 0.25; I² = 0%; n = 96).

3.6. Flexibility – sit and reach test

The comparison of flexibility evaluated through the sit and reach test (Figure 8) was composed of a total sample of 169 participants (Pilates = 63 and Other Exercises = 106). Very low certainty of evidence (three-level reduction, risk of bias and imprecision). The result shows that there was no statistically significant difference (SMD = -0.00; 95%CI -0.33; 0.33; I² = 0%; n = 169).

3.7. Flexibility – back scratch test

The comparison of flexibility evaluated through the test of reaching behind the back (Figure 9) was composed of a total sample of 129 participants (Pilates = 43 and Other Exercises = 86). Low certainty of evidence (two-level reduction, risk of bias and imprecision). The result shows that there was no statistically significant difference (SMD = 0.02; 95%CI -0.37; 0.41; I² = 0%; n = 129).

4. Discussion

Comparisons of the effectiveness of Pilates method against other exercise modalities for muscle strength, balance, and flexibility showed a low to very low quality of evidence. Mainly due to the low methodological quality of the studies and the small size of the studies, with an average of 43 ± 27 participants (minimum: 30 and maximum: 101). The studies presented different methods of intervention and evaluation of outcomes, resulting in a high heterogeneity, which we already expected

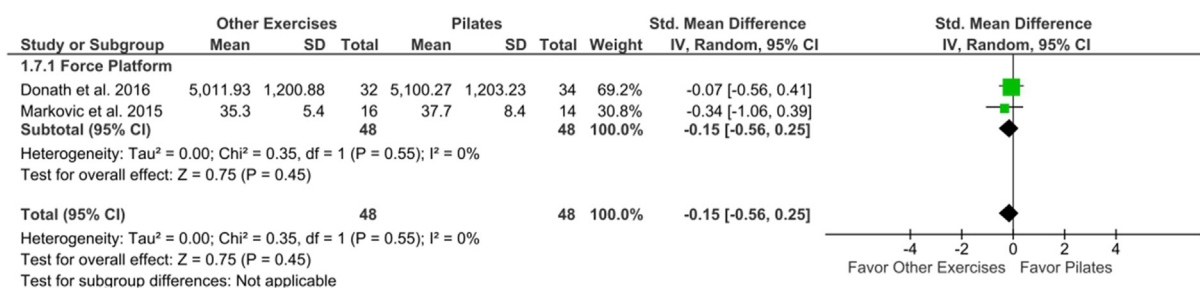


Figure 7. Forest plot of comparison Pilates versus Exercises with sensitivity analysis. Outcome: balance.

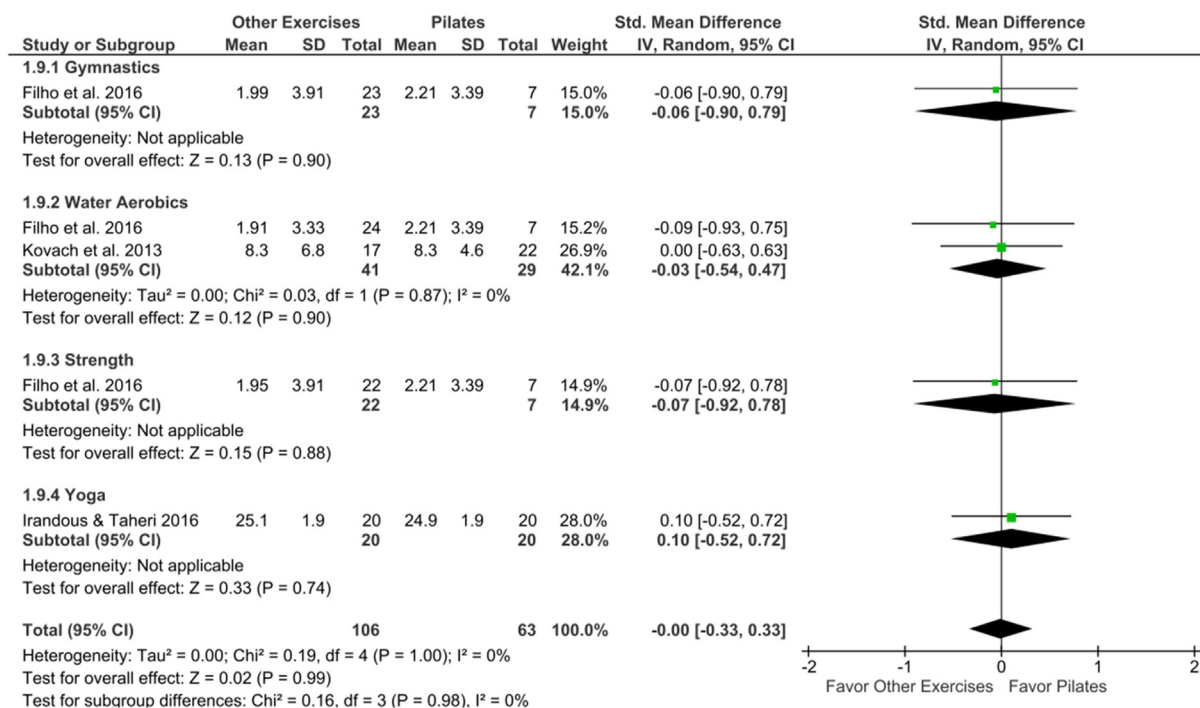


Figure 8. Forest plot of comparison Pilates versus Exercises through the sit and reach test. Outcome: flexibility.

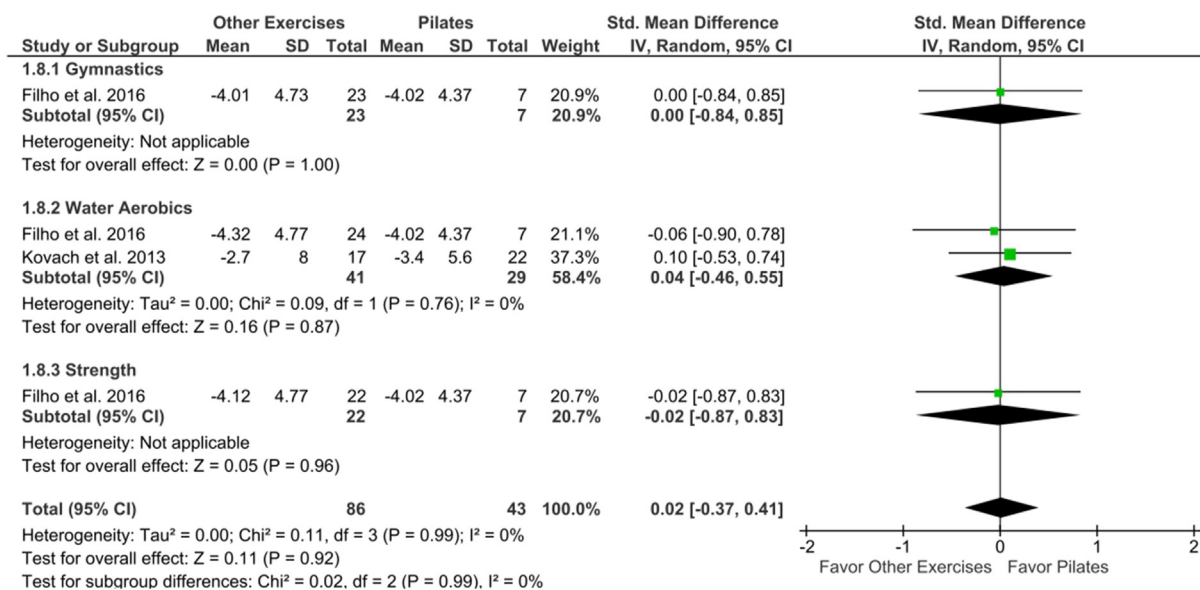


Figure 9. Forest plot of comparison Pilates versus Exercises through back scratch test. Outcome: flexibility.

due to the difference between the interventions. Among the comparisons of outcomes, only the comparison for the strength resistance outcome showed a statistically significant difference, favoring other exercise modalities. While other comparisons did not show any statistically significant difference.

4.1. Pilates vs other exercises

The first of our findings was that there was no statistically significant difference for muscle strength when compare Pilates method than exercises, however, the certainty of the evidence of this comparison was considered low, and further studies may change this result. However, the application of the Pilates method with an average frequency of 12 ± 7 weeks with a frequency of 3 ± 1 sessions per week, increased muscle strength by $27\% \pm 16$, when comparing pre and post intervention. This shows us that although we did not observe any difference for the muscle strength, Pilates is an option for increasing muscle strength considering pre and post intervention data.

The second finding of this review was that the secondary outcomes balance and flexibility showed no difference between Pilates and other types of exercise. However, the number of studies for this analysis was too small for balance ($n = 3$ studies) and flexibility ($n = 3$ studies). These comparisons also presented a very low certainty of evidence, mainly because these studies present a high risk of bias and a low total number of participants for comparison.

An already published systematic review [33] with elderly participants evaluated the effects of Pilates compared to no activity (control group). In their results for the muscle strength outcome, they showed a large effect size for lower limb strength $SMD = 1.13$ (0.30–1.96, 95% CI). And a mean effect size for the upper limb $SMD = 0.72$ (0.02–1.43, CI95%). Indicating that Pilates increases lower limb strength after intervention. For the flexibility outcome, it presented a large effect size for the hip and lumbar region $SMD = 1.22$ (0.39–2.04, CI95%) and upper limb $SMD = 1.16$ (0.70–1.63, CI95%). For balance outcome, the effect size was also considered large $SMD = 1.10$ (0.29–1.90, 95%CI).

In another systematic review [34] also comparing the effects of Pilates to no activity (control group). A large effect size of 1.23 (g of Hedges) (0.84–1.62 95% CI) was observed for muscle strength, favoring Pilates. However, this meta-analysis consisted of only three studies. When analyzing balance, they found a moderate effect size for static balance 0.34 (0.097–0.594, CI95%), and dynamic balance 0.77 (0.451–1.090, CI95%). When analyzing flexibility, there was no difference.

On another review [35] analyzing the benefits of Pilates in young people (aged ≤ 21 years), the authors observed a large effect size >0.8 (g of Hedges) favoring Pilates for the outcomes muscle strength and flexibility.

The data from these studies shows that Pilates may be effective for increasing muscle strength and improving flexibility and balance when compared to no activity. However, we also observed in our study an increase in post-intervention muscle strength. Our results shows that this increase in muscle strength and improvement in flexibility and balance are not superior to those presented by other types of exercise, showing no differences when comparing Pilates to other types of exercises.

To the best of our knowledge, this is the first systematic review considering the effectiveness of the Pilates method compared to other types of exercises for the muscle strength outcome. We performed a comprehensive search in the literature without language limitations, as many reviews are limited to considering only studies in the English language and we found studies in languages such as Persian, Portuguese and Spanish. Therefore, the health professional, when considering the needs of his client/patient, through his experience, should evaluate which exercise modality have the best evidence from the literature to determine the best intervention, increasing adherence and enhancing results.

5. Study limitations

As a limitation, we can consider the lack of analysis by subgroup considering the age of the participants and the evaluation methods used for each outcome. We did not differentiate between Pilate's mat and its apparatus method, due to the difference in the sequence of exercises and stimuli, the responses to each outcome may be altered. In our analysis, we did not separate the use of the intervention as a method of physical training or physical therapy.

6. Conclusions

The data from this review show that there is very low to low certainty of evidence that there is no difference between Pilates and other types of exercises for dynamic strength, isometric strength, resistance strength, balance and flexibility.

Declarations

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Funding statement

This work was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior [001], Fundação para a Ciência e a Tecnologia [UIDB/04585/2020].

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at <https://doi.org/10.1016/j.heliyon.2022.e11564>.

References

- [1] P. Latey, The Pilates method: history and philosophy, *J. Bodyw. Mov. Ther.* (2001) 275–282.
- [2] C. Wells, et al., Defining Pilates exercise: a systematic review, *Compl. Ther. Med.* (2012) 253–262.
- [3] P. Latey, Updating the principles of the Pilates method—Part 2, *J. Bodyw. Mov. Ther.* (2022) 94–101.
- [4] K. Smith, E. Smith, Integrating pilates-based core strengthening into older adult fitness programs implications for practice, *Topi. Geriatr. Rehabil.* (2005) 57–67.
- [5] A. Cruz-Ferreira, et al., A systematic review of the effects of pilates method of exercise in healthy people, *Arch. Phys. Med. Rehabil.* (2011) 2071–2081.
- [6] J.A. Kloubec, Pilates for improvement of muscle endurance, flexibility, balance, and posture, *J. Strength Condit Res.* 24 (3) (2010) 661–6672010.
- [7] A.R. Aladro-Gonzalvo, et al., The effect of Pilates exercises on body composition: a systematic review, *J. Bodyw. Mov. Ther.* (2012) 109–114.
- [8] M. Mazzarino, et al., Pilates method for women's health: systematic review of randomized controlled trials, *Arch. Phys. Med. Rehabil.* (2015) 2231–2242.
- [9] T.P. Yamato, et al., Pilates for low back pain, *Cochrane Database Syst. Rev.* (2015), CD010265.
- [10] C.E. Garber, et al., American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise, *Med. Sci. Sports Exerc.* (2011) 1334–1359.
- [11] W.H. Organization, Global Recommendations on Physical Activity for Health, 2010. <https://www.ncbi.nlm.nih.gov/books/NBK305057/>.
- [12] R.O. Bueno De Souza, et al., Effects of mat pilates on physical functional performance of older adults: a meta-analysis of randomized controlled trials, *Am. J. Phys. Med. Rehabil.* (2018) 414–425.

- [13] H. Kamioka, et al., Effectiveness of Pilates exercise: a quality evaluation and summary of systematic reviews based on randomized controlled trials, *Compl. Ther. Med.* (2016) 1–19.
- [14] C.G. Maher, et al., Reliability of the PEDro scale for rating quality of randomized controlled trials, *Phys. Ther.* (2003) 713–721.
- [15] A.G. Cashin, Mcauley J.H. Clinimetrics, *Physiotherapy Evidence Database (PEDro) Scale Journal of Physiotherapy*, 2020, p. 1.
- [16] J. Higgins, et al., *Cochrane Handbook for Systematic Reviews of Interventions Version 6.2*. Cochrane, 2022. Available from, www.training.cochrane.org/handbook2011.
- [17] P. Dashti, et al., Comparison of the effects of two selected exercises of Theraband and Pilates on the balance and strength of lower limb in elderly women, *Iranian J. Obstet. Gynecol. Infert.* (2015) 1–9.
- [18] K. Irandoust, M. Taheri, The impact of Yoga and Pilates exercises on older adults, *Salmand* (2016) 152–161.
- [19] M. Sahebozamani, et al., Comparing the effects of Pilates training and McKenzie exercises on core muscles cross-sectional area and strength in patients with chronic non-specific low back pain: a clinical trial, *J. Maz. Univ. Med. Sci.* (2016) 48–61.
- [20] F.T.d. Carvalho, et al., Pilates and proprioceptive neuromuscular facilitation methods induce similar strength gains but different neuromuscular adaptations in elderly women, *Exp. Aging Res.* (2017) 440–452.
- [21] P.J. Culligan, et al., A randomized clinical trial comparing pelvic floor muscle training to a Pilates exercise program for improving pelvic muscle strength, *Int. Urogyn. J.* (2010) 401–408.
- [22] L. Donath, et al., Pilates vs. Balance training in health community-dwelling seniors: a 3-arm, randomized controlled trial, *Int. J. Sports Med.* (2016) 202–210.
- [23] Ö.Ö. Taskiran, et al., Do pilates and yoga affect quality of life and physical performance of elderly living in a nursing home a preliminary study, *Turkish J. Geriatr.* (2014) 262–271.
- [24] L.C.d. Oliveira, et al., The Pilates method improves the relationship agonist-antagonist flexor and extensor knee in elderly: a randomized controlled trial, *Manual Therapy, Posturol. Rehabil.* (2015) 1–7.
- [25] N. Gonzalez-Galvez, et al., Pilates training induces changes in the trunk musculature of adolescents, *Revista Brasileira de Medicina do Esporte* (2019) 235–239.
- [26] M. Carrasco-Poyatos, et al., Pilates versus resistance training on trunk strength and balance adaptations in older women: a randomized controlled trial, *Peer J.* 7 (2019) e7948.
- [27] M.L.M. Filho, et al., Avaliação de diferentes programas de exercícios físicos na força muscular e autonomia funcional de idosos, *Motricidade* (2016) 124–133.
- [28] M. Vécseyne Kovách, et al., Effects of Pilates and aqua fitness training on older adults' physical functioning and quality of life, *Biomed. Hum. Kinet.* (2013) 22–27.
- [29] G. Markovic, et al., Effects of feedback-based balance and core resistance training vs. Pilates training on balance and muscle function in older women: a randomized-controlled trial, *Arch. Gerontol. Geriatr.* (2015) 117–123.
- [30] L.C.d. Oliveira, et al., Effects of Pilates on muscle strength, postural balance and quality of life of older adults: a randomized, controlled, clinical trial, *J. Phys. Ther. Sci.* (2015) 871–876.
- [31] L.C.d. Oliveira, et al., Pilates increases the isokinetic muscular strength of the knee extensors and flexors in elderly women, *J. Bodyw. Mov. Ther.* (2017) 815–822.
- [32] L.C. Oliveira, et al., Effects of the Pilates exercise compared to whole body vibration and no treatment controls on muscular strength and quality of life in postmenopausal women: a randomized controlled trial, *Isokinet. Exerc. Sci.* (2018) 149–161.
- [33] R.O. B.d. Souza, et al., Effects of mat pilates on physical functional performance of older adults: a meta-analysis of randomized controlled trials, *Am. J. Phys. Med. Rehabil.* (2018) 414–425.
- [34] V. Bullo, et al., The effects of Pilates exercise training on physical fitness and wellbeing in the elderly: a systematic review for future exercise prescription, *Prev. Med.* (2015) 1–11.
- [35] E. Hornsby, L.M. Johnston, Intervention on physical function of children and youth: a systematic review. *Archives of physical medicine and rehabilitation* 2020, *Eur. J. Investig. Health Psychol. Educ.* 12 (2022) 317–328.