Effects of physical exercise on aerobic capacity and quality of life in patients diagnosed with asthma: A systematic review and meta-analysis

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Summary

Introduction: Nowadays, asthma is a disabling disease with no cure, and the development of effective non-pharmacological treatments which can alleviate side effects of drugs and pathological symptoms is urgent. Some studies have shown that physical exercise may have beneficial effects in patients with asthma, but results were controversial and inconsistent. More evidence is needed to ensure exercise as possible effective treatment in people with asthma.
Objectives: To examine the effects of physical exercise on aerobic capacity and quality of life in patients with asthma. Also, we analyze the possible moderation effects of the selected covariates. As a final aim, we verified if a correlation exists between benefits on aerobic capacity and those obtained on quality of life.
Material and method: We followed the PRISMA statement to search for randomized controlled trials that used physical exercise as intervention to improve aerobic capacity or quality of life in patients diagnosed with asthma. After data extraction, we conducted a random-effects meta-analysis model with moderation analysis. Then, we inspected the correlation between both outcomes through a multivariate approach. Finally, we performed some additional analyses: methodological quality analysis through the PEDro scale, publication bias analysis through funnel asymmetry tests and funnel plot visualization, and sensitivity analyses by outliers and influential cases detection.
Results: Physical exercise had positive effects on aerobic capacity and quality of life. None of the covariates showed a significant moderation effect. We found a positive correlation between the effects of exercise on aerobic capacity and those caused on their quality of life.
Conclusions: Our meta-analysis reports information that supports the use of physical exercise as part of the management and treatment of asthma. However, more specific studies are needed to find optimal type and dose of physical activity for those patients.

Key words:
Physical exercise. Aerobic capacity. Quality of life. Asthma. Meta-analysis.

Efectos del ejercicio físico en la capacidad aeróbica y la calidad de vida en pacientes diagnosticados con asma: revisión sistemática y meta-análisis

Resumen

Introducción: Actualmente, el asma es una enfermedad incapacitante sin cura, y urge el desarrollo de tratamientos no farmacológicos eficaces que puedan aliviar los efectos secundarios de los fármacos y los síntomas patológicos. Algunos estudios han demostrado que el ejercicio físico puede tener efectos beneficiosos en pacientes con asma, pero los resultados fueron controvertidos e inconsistentes. Se necesita más evidencia para garantizar que el ejercicio sea un posible tratamiento eficaz en personas con asma.
Objetivos: Examinar los efectos del ejercicio físico sobre la capacidad aeróbica y la calidad de vida en pacientes con asma. Además, analizamos los posibles efectos de moderación de las covariables seleccionadas. Como objetivo final, verificamos si existe una correlación entre los beneficios en la capacidad aeróbica y los obtenidos sobre la calidad de vida.
Material y método: Seguimos la declaración PRISMA para buscar ensayos controlados aleatorios que utilizaran el ejercicio físico como intervención para mejorar la capacidad aeróbica o la calidad de vida en pacientes con diagnóstico de asma. Después de la extracción de datos, realizamos un modelo de meta-análisis de efectos aleatorios con análisis de moderación. Luego, inspeccionamos la correlación entre ambos resultados a través de un enfoque multivariado. Finalmente, realizamos algunos análisis adicionales: análisis de calidad metodológica a través de la escala PEDro, análisis de sesgos de publicación a través de pruebas de asimetría de embudo y visualización de gráficos de embudo, y análisis de sensibilidad mediante la detección de 'outliers' y de casos influyentes.
Resultados: El ejercicio físico tuvo efectos beneficiosos en la capacidad aeróbica y en la calidad de vida. Ninguna de las covariables presentó un efecto moderador significativo. Encontramos una correlación positiva entre los efectos del ejercicio sobre la capacidad aeróbica y los provocados en la calidad de vida.
Conclusiones: Nuestro meta-análisis presenta información que respalda el uso del ejercicio físico como parte del manejo y tratamiento del asma. Sin embargo, se necesitan estudios más específicos para encontrar qué tipo y qué dosis de actividad física son los óptimos para estos pacientes.

Palabras clave:
Ejercicio físico. Capacidad aeróbica. Calidad de vida. Asma. Meta-análisis.

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Introduction

Asthma is a major non-communicable disease whose symptoms (i.e., any combination of cough, wheeze, shortness of breath and chest tightness) affect an estimated 300 million people[1], causing approximately 500,000 deaths[1]. Also, asthma is the most common chronic disease among children[1], which increases a) the global impact of this disease on vital outcomes (e.g., aerobic capacity, quality of life, or activities of daily-living)[2] and b) the urgency to discover new possible treatments and refine those that currently exist[3].

Although there is no definitive treatment for asthma[3], existing evidence shows that the most effective pharmacological treatments against the symptoms of the disease seem to be strategies with combined inhaled corticosteroids and long-acting β agonists[4]. Nonetheless, drug treatment has associated side effects such as weight gain or stress[5], which is detrimental to the quality of life of these patients. Scientific literature shows that physical exercise could be an effective non-pharmacological intervention to reduce these side effects and cope the symptoms of the disease[6], such as the inflammation of the small airways[7]. Several meta-analyses[6,8–10] showed a possible preventive effect of exercise on asthma development[6], and positive effects on asthma control[8,9], aerobic capacity[10], lung function[9], and quality of life[10].

However, the current evidence is scarce, low-quality, and imprecise[11]. A point we must consider is that most of the meta-analyses that have inspected the effects of exercise in asthmatic patients only focused on aerobic exercises (e.g., swimming, walking, leisure biking and hiking)[6,9], being a knowledge gap the potential effects on quality of life and asthma control of other types of physical exercise such as multicomponent or strength. We also found discrepancy on the results (e.g., positive effects[10] vs. null[12] on quality of life), which combined with some methodological concerns (e.g., unexplained high levels of heterogeneity, differences in the age groups studied, or a clear definition of the analyzed variable), makes the information about physical exercise effects on asthmatic patients inconsistent[11]. Everything points that this lack of robustness may hamper the application of physical exercise as an effective non-pharmacological treatment to manage asthma symptoms. Therefore, we analyzed the effects of physical exercise on aerobic capacity (i.e., the maximum oxygen consumption during physical activity) and quality of life, both clinically important outcomes in patients suffering from asthma. We also examined the possible interactions between covariates selected for their evidence in the literature[6] and the effects on the study outcomes. Finally, we inspected the correlation between aerobic capacity and quality of life to detect potential associations between the effects caused in this target population.

Material and method

This systematic review with meta-analysis was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[13].

Search strategy

Guided by the PICOS framework, we performed a systematic search in the databases PubMed (MEDLINE), Scopus, Web of Science and SportDiscus from inception to April 2021. The search strategy was based on combining all terms related to the same cluster (e.g., participants or interventions) with OR and finally to combine all clusters with AND. Terms related to the search were "asthma patients", "exercise", "physical therapy", "aerobic capacity", "quality of life" and "randomized controlled trial".

Study selection

We searched for and included: (1) Randomized controlled trials in which (2) aerobic capacity or quality of life were studied in (3) patients who were five years old or older diagnosed with asthma[14] (4) that received an intervention based on aerobic or multicomponent physical exercises as the main element of the intervention (5) compared with non-exercise treatments or another exercise intervention.

As an exclusion criterion, we determined that interventions that consisted in physical exercise plus another healthy lifestyle intervention (e.g., diet) and patients diagnosed with an obstructive pulmonary disease other than asthma were excluded.

Data extraction

All data corresponding to trial patients' characteristics (e.g., sample size, age, sex), descriptive statistics (i.e., pre- and post-sample size, means, standard deviations of experimental and control groups) and outcome description were extracted into a self-made data extraction spreadsheet in Excel. If information was missing, the corresponding author was requested to supply the information or data for inclusion in the analyses.

Data synthesis

As we anticipated considerable between-study heterogeneity, a random-effects meta-analysis model was used to pool effect sizes, which were calculated as standardized mean differences (SMD; Hedges' g[15]). The restricted maximum likelihood estimator[16] was used to calculate the heterogeneity variance tau^2. We used Knapp-Hartung adjustments[17] to calculate the confidence interval (CI) around the pooled effect. We also estimated the prediction intervals (PI) as accurate measures. Then, we conducted a moderation analysis to find possible interaction effects between the pooled effects and the selected covariates (i.e., age, type of exercise, and duration of the intervention) identified by existing evidence[6]. Lastly, assuming a moderate correlation coefficient of 0.41[18], we estimated the correlation between pooled effects using a multivariate approach to find potential associations between aerobic capacity and quality of life in these patients.

All analyses were performed in R statistical software (version 4.0.3)[19]. We used the 'esc' package[20] to calculate the effect sizes (Hedges' g), the *'dmetar'* package[21] contains utility functions to facilitate the conduction of a random-effects meta-analysis model, and the 'meta' package[22] to evaluate biases in meta-analysis (i.e., outliers detection, influential cases analysis, and publication bias).

Additional analyses

Methodological quality

The score extracted from the Physiotherapy Evidence Database was used to evaluate the methodological quality of each trial and avoid the risk of bias[23]. When the score of an article was not shown in the PEDro website, reviewers agreed on a rating of this study following the criteria stipulated by the PEDro scale. Total PEDro scores of 0–3 are considered 'poor', 4–5 'fair', 6–8 'good', and 9-10 'excellent'. However, for trials evaluating complex interventions (e.g., exercise) a total PEDro score of 8/10 is optimal[24].

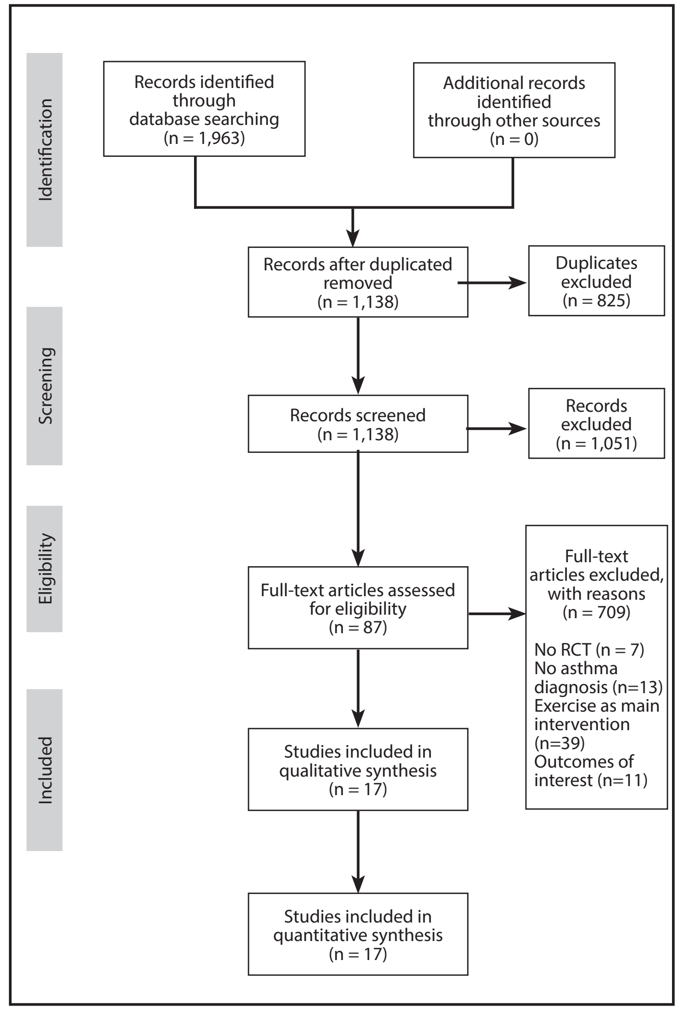
Publication bias

We used the visualization of the standard errors corresponding to each study and its effect size through a funnel plot per outcome. To quantify this possible asymmetry, we used the significance of the Eggers' test[25]. To support these results, we conducted the same analysis under Pustejovsky-Rodges approach[26], an option to conduct Eggers' test with the corrected standard error formula recommended for studies that used SMD as effect size[26].

Sensitivity analyses

To analyze the between-study heterogeneity, we inspected the studies with an extreme effect size (i.e., outliers) and those which heavily pushed the pooled effect of our analysis into one direction (i.e., influential cases). Furthermore, to support the influential cases analysis, we conducted a leave-one-out meta-analysis model[27], which reported the individual contribution to the pooled effect of a specific outcome and to heterogeneity levels (i.e., I^2). After removing the studies detected as outliers or influential cases, we conducted new meta-analytical models and plotted their corresponding forest plots to visualize models' comparison.

Figure 1. PRISMA flowchart of study selection.



Results

Included studies

We identified 1,963 registers through the initial searches. After screening citations by title and abstract, we considered 87 possible eligible studies for inclusion. After removing duplicates and applying the selection criteria, 17 studies[8,28-43] (1,329 patients; 29 effect sizes) were selected for inclusion in this meta-analysis (Figure 1).

The year of publication ranged from 2001 to 2020. A total of 627 (47.18%) of patients were women. The average age was 25.58±18.34 years old (range of 10 - 68.2). The average body mass index (BMI) was 23.11±3.54. The interventions had an average duration of 10.64±3.92 weeks. The interventions used in the included studies were aerobic exercises (n = 16) and multicomponent exercises (n = 13). All studies' characteristics referring to the intervention and control groups details, evaluation tools and main results are presented in Table 1.

Meta-analysis

Our results showed that exercise had positive effects on aerobic capacity in patients diagnosed with asthma (k = 15; Hedges' g = 0.73; 95% CI [0.16, 1.28]; p = 0.01). Also, significant effects were found for exercise on the quality of life of these patients (k = 14; Hedges' g = 0.69; 95% CI [0.26, 1.11]; p < 0.01). Forest plots are illustrated in Figure 2. None of the analyzed covariates showed a significant moderation effect.

For aerobic capacity, the between-study heterogeneity variance was estimated at tau^2 = 0.78 (95% CI: 0.37 - 2.43), with an I^2 value of 84% (95% CI: 75 - 90%). For quality of life, the between-study heterogeneity variance was estimated at tau^2 = 0.28 (95% CI: 0.11 - 1.51), with an I^2 value of 69% (95% CI: 45 - 82%). The prediction intervals ranged from g = –1.25 to 2.71 in aerobic capacity, and from g = –0.56 to 1.93 in quality of life, indicating that negative intervention effects cannot be ruled out for future studies.

Correlation between aerobic capacity and quality of life

We found a positive moderate correlation (r = 0.59) between aerobic capacity and quality of life, indicating that positive effects on aerobic capacity may cause positive effects on quality of life. The pooled effects and the association between outcomes are illustrated in Figure 3.

Table 1. Characteristics of the included studies.

Study	Participants	Age (average)	BMI	Protocol duration	Intervention parameters	Control parameters	Evaluation tools	Main results
Abdelbasset, 2018	38 (23 females)	10	21.8	10 weeks 3 sessions/ week 40 min/session	Intensity: 50-70% HR_{max} Type: Walking	Conventional treatment	VO_{2max} 6-MWT PAQLQ	10 weeks of physical exercise had beneficial effects on pulmonary functions, aerobic capacity, and quality of life in children with asthma
Andrade, 2014	33 (12 females)	10	19.8	6 weeks 3 sessions/ week ~40 min/ session	Intensity: 70-80% HR_{max} Type: Treadmill	Usual care	6-MWT PAQLQ	An improvement was found in functional capacity, maximal respiratory pressure, quality of life and asthma-related symptoms
Basaran, 2006	62 (22 females)	10.4	18.3	8 weeks 3 sessions/ week 60 min/session	Intensity: NA Type: Calisthenics + submaximal basketball training	Home respiratory exercises	6-MWT PAQLQ	8-weeks of regular submaximal exercise has benefitial effects on quality of life and exercise capacity in asthmatic children
Coelho, 2018	37 (32 females)	46	28.6	12 weeks 5 sessions/ week 30 min/session	Intensity: moderate Type: Walking	Usual care	6-MWT AQLQ	Participants of the intervention group increased their exercise capacity and their daily steps
Dogra, 2011	36 (22 females)	34.1	24.7	24 weeks 3-5 sessions/ week NA min/ session	Intensity: 70-85% HR_{max} Type: outdoor jogging, treadmill, recumbent, or upright cycling, and ellitical or rowing machines	Usual care	VO_{2max} Mini-AQLQ	A structured exercise intervention can improve asthma control
Fanelli, 2007	38 (NA females)	10.5	18.1	16 weeks 2 sessions/ week 90 min/session	Intensity: 70% RM Type: Cycling and/ or treadmill and endurance exercises	Educational program	VO_{2max} PAQLQ	Supervised exercise training might be associated with benefitial effects on disease control and quality of life in children
França-Pinto, 2015	43 (34 females)	42	26.4	12 weeks 2 sessions/ week 30 min/session	Intensity: Vigorous (anaerobic threshold) Type: Yoga breathing exercises + treadmill	Yoga breathing exercises + sham intervention	VO_{2max} AQLQ	Adding exercise as an adjunct therapy to pharmacological treatment could improve the main features of ast
Jaakkola, 2019	89 (70 females)	39.7	24.9	24 weeks 3 sessions/ week ~30 min/ session	Intensity: NA Type: Aerobic exercise + muscle training	Usual care	VO_{2max}	Regular exercise improves asthma control
Mendes, 2010	101 (79 females)	39.3	24.8	12 weeks 2 sessions/ week 30 min/session	Intensity: 60-70% VO_{2max} Type: Yoga breathing exercises + aerobic exercises	Educational program	VO_{2max} AQLQ	Aerobic training can play an important role in the clinical management of patients with persistent asthma
Moreira, 2008	31 (14 females)	12.7	20.4	12 weeks 2 sessions/ week 50 min/session	Intensity: submaximal. Type: Aerobic exercises + strength training + balance adn coordination exercises	Usual care	AQLQ	There is no reason to discourage asthmatic children with controlled disease to exercise
Refaat, 2015	68 (37 females)	37.1	22.5	6 weeks 3 sessions/ week 30 min/session	Intensity: 60-80% HR_{max} Type: Cycling, step ups, wall squats and upper limb endurrance exercises	Usual care	AQLQ	Physical training can improve quality of life and pulmonary function in patients with moderate and severe bronchial asthma

(continúa)

Study	Participants	Age (average)	BMI	Protocol duration	Intervention parameters	Control parameters	Evaluation tools	Main results
Sanz-Santiago, 2020	53 (29 females)	11.5	NA	12 weeks 3 sessions/ week 60 min/session	Intensity: moderate. Type: Cycling + resistance exercises	Usual care	VO_{2max} PAQLQ	Combined exercise training improved cardiorespiratory fitness and muscle strength in children
Shaw, 2011	44 (32 females)	21.9	27.1	8 weeks 3 sessions/ week 30 min/session	Intensity: 60% HR_{max} Type: Walking and/or jogging	Usual care	VO_{2max}	Aerobic exercise plus diaphragmatic inspiratory resistive breathing might be useful as an adjunct therapy in asthmatic patients
Turner, 2011	35 (19 females)	67.8	27.7	6 weeks 3 sessions/ week 80-90 min/ session	Intensity: 80% of the average walking speed + Borg scale Type: Walking + cycling + endurance exercises	Usual care	6-MWT AQLQ	Supervised exercise training improves symptoms and quality of life in these patients
Van Veldhsen, 2001	47 (13 females)	10.6	18.5	12 weeks 2 sessions/ week 60 min/session	Intensity: NA. Type: Fitness training + different physical activities	Usual care	VO_{2max}	Physical exercise program not only enhanced physical fitness, but also improved coping behavior with asthma
Wang, 2009	30 (10 females)	10	20	6 weeks 3 sessions/ week ~50 min /session	Intensity: 65% HR peak Type: Swimming	Usual care	VO_{2max}	Swimming may be an effective non-pharmacological intervention for the children or adolescent with asthma
Weisgerber, 2008	45 (24 females)	10.3	23	9 weeks 3 sessions/ week 30 min/session	Intensity: High (8-10 METs) Type: Swimming	Golf intervention	VO_{2max} AQLQ	Results suggest a potentially beneficial role for moderate to vigorous physical activity in childhood asthma

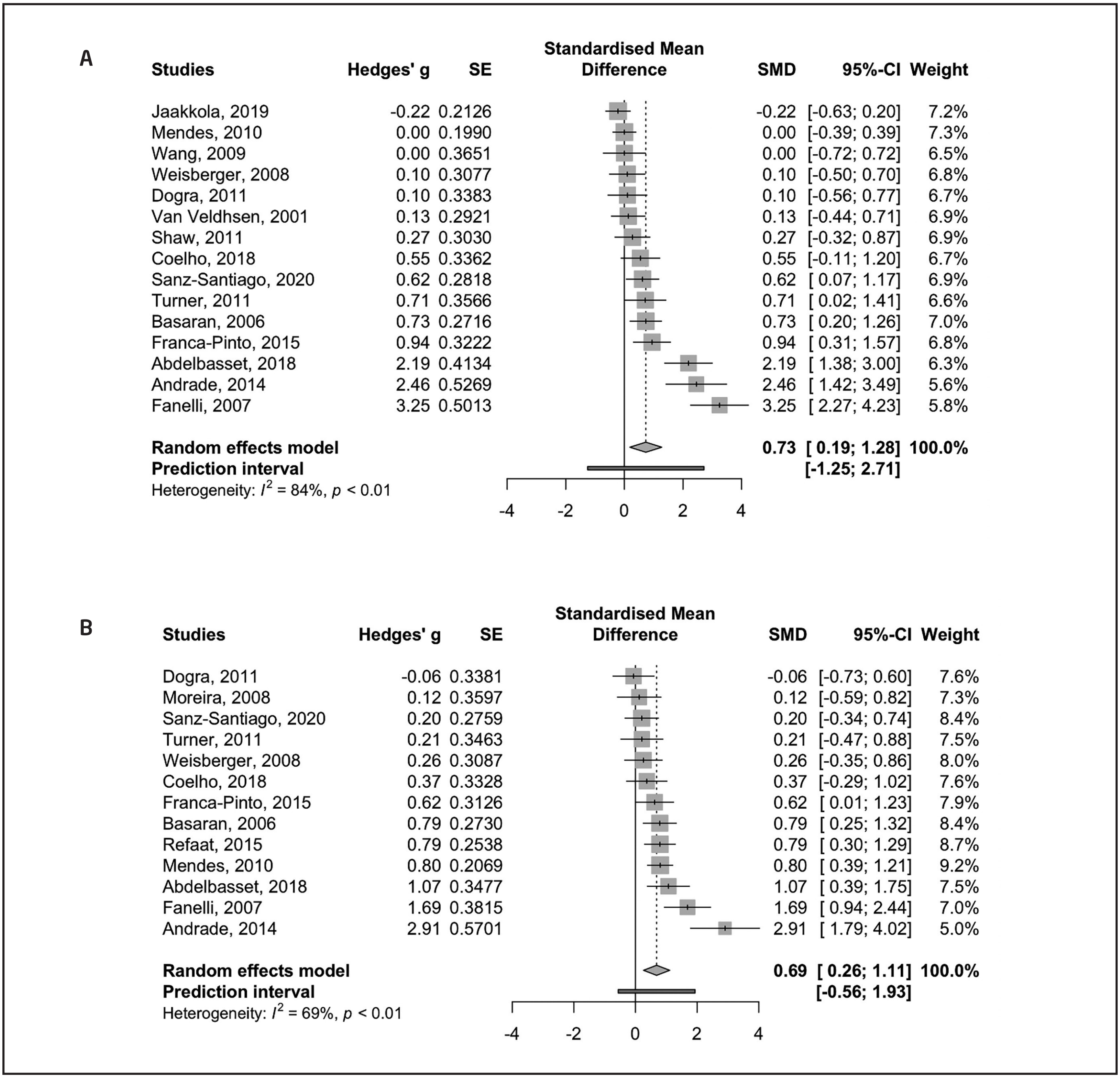
HR_{max}: Maximal Heart Rate; 6-MWT: 6-Minutes Walking Test; PAQLQ: Pediatric Asthma Quality of Life Questionnaire; AQLQ: Asthma Quality of Life Questionnaire.

Table 2. PEDro scale scores of the included studies.

Study	Eligibility criteria*	Random allocation	Concealed allocation	Baseline comparison	Blinded subjects	Blinded therapists	Blinded assessors	Adequate follow -up	Intention to-treat analysis	Between group comparison	Point estimates and variability	Overall
Abdelbasset, 2018	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7
Andrade, 2014	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6
Basaran, 2006	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Coelho, 2018	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Dogra, 2011	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	5
Fanelli, 2007	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5
França-Pinto, 2015	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	5
Jaakkola, 2019	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Mendes, 2010	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Moreira, 2008	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Refaat, 2015	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Sanz-Santiago, 2020	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6
Shaw, 2011	No	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6
Turner, 2011	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Van Veldhoven, 2001	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Wang, 2009	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Weisgerber, 2008	Yes	Yes	No	Yes	No	No	No	No	No	No	No	2

*Invalid criterion for final score.

Figure 2. Effect sizes for exercise on study outcomes. Studies are ordered according to their effect sizes. A) Aerobic capacity; B) Quality of life.



Methodological quality of included studies

We found that 6 studies[31,35,38,41–43] presented a good methodological quality, 10 studies[8,28–30,33,34,36,37,39,40] obtained a fair methodological quality score and only 1 study[32] presented a poor methodological quality. In summary, we can determine the methodological quality of our study as fair-good. All scores of the included studies are presented in Table 2.

Publication bias analysis

Eggers' test does not indicate the presence of funnel asymmetry (Table 3). After performing sensitivity analysis with the Pustejovsky-Rodges approach, our results also did not show the presence of funnel asymmetry, which indicates data consistency. To visualize the funnel symmetry, the funnel plots of both outcomes are illustrated in Figure 4.

Figure 3. Effect sizes and confidence ellipses of both outcomes. The diamonds near the axes are the estimates of the effect size of our variables and the black arrows represent their 95% CI. The diamond in the center is the combined effect for both variables. The red ellipse represents the 95% CI ellipse of our combined effect size. The black ellipse is 95% PI for all effects of all studies under a random-effects model. Each point represents a study and the dashed line its 95% CI.

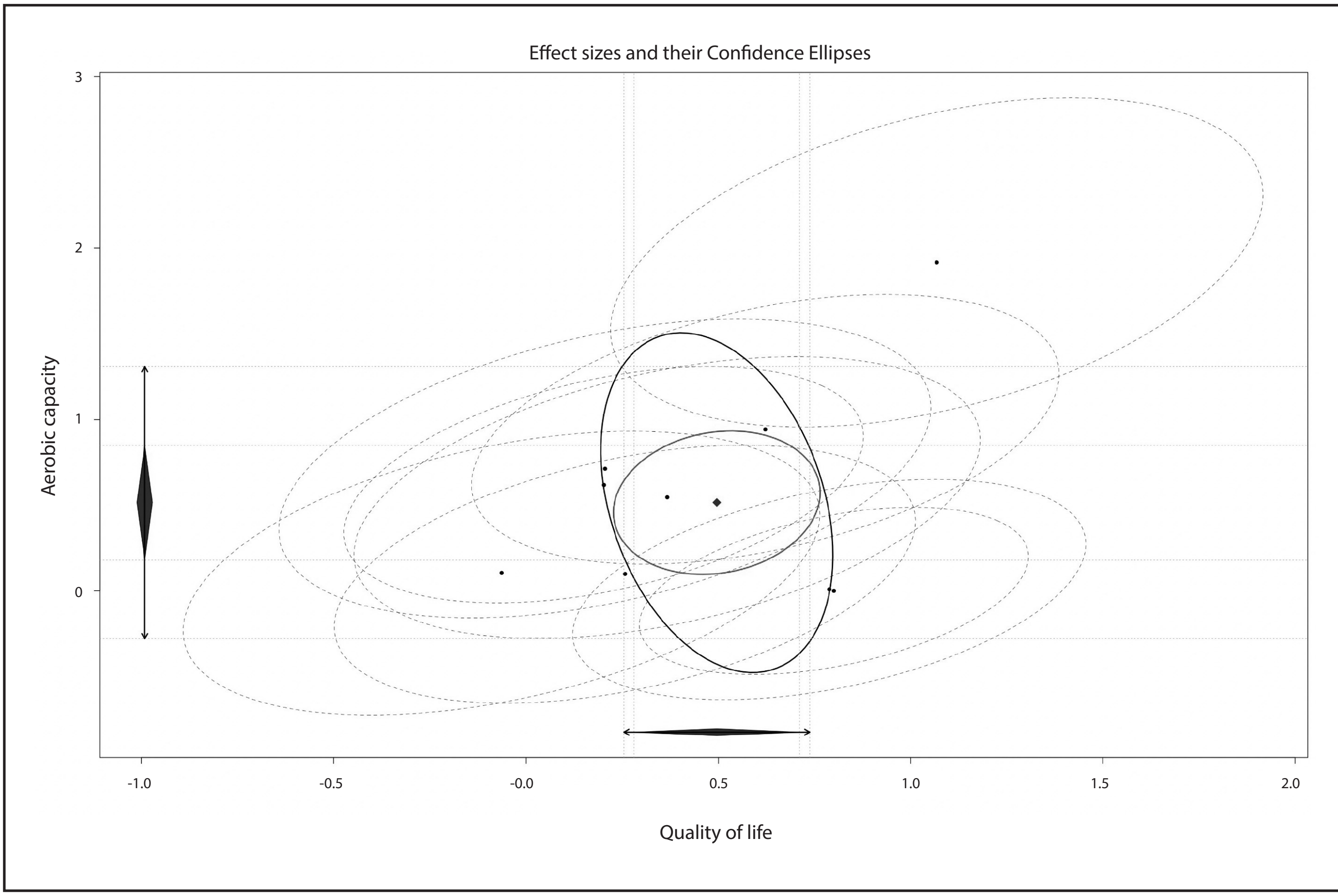


Figure 4. Contour-Enhanced Funnel Plots.

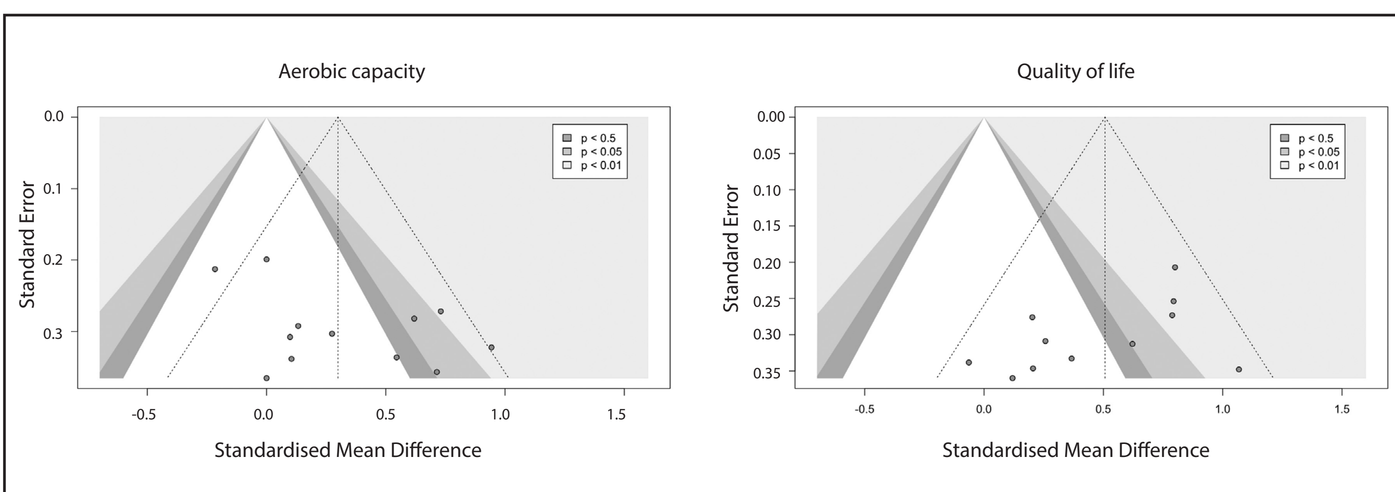


Figure 5. Leave-One-Out Meta-Analysis to identify the individual contribution to the heterogeneity and effect size. A) Aerobic capacity; B) Quality of life.

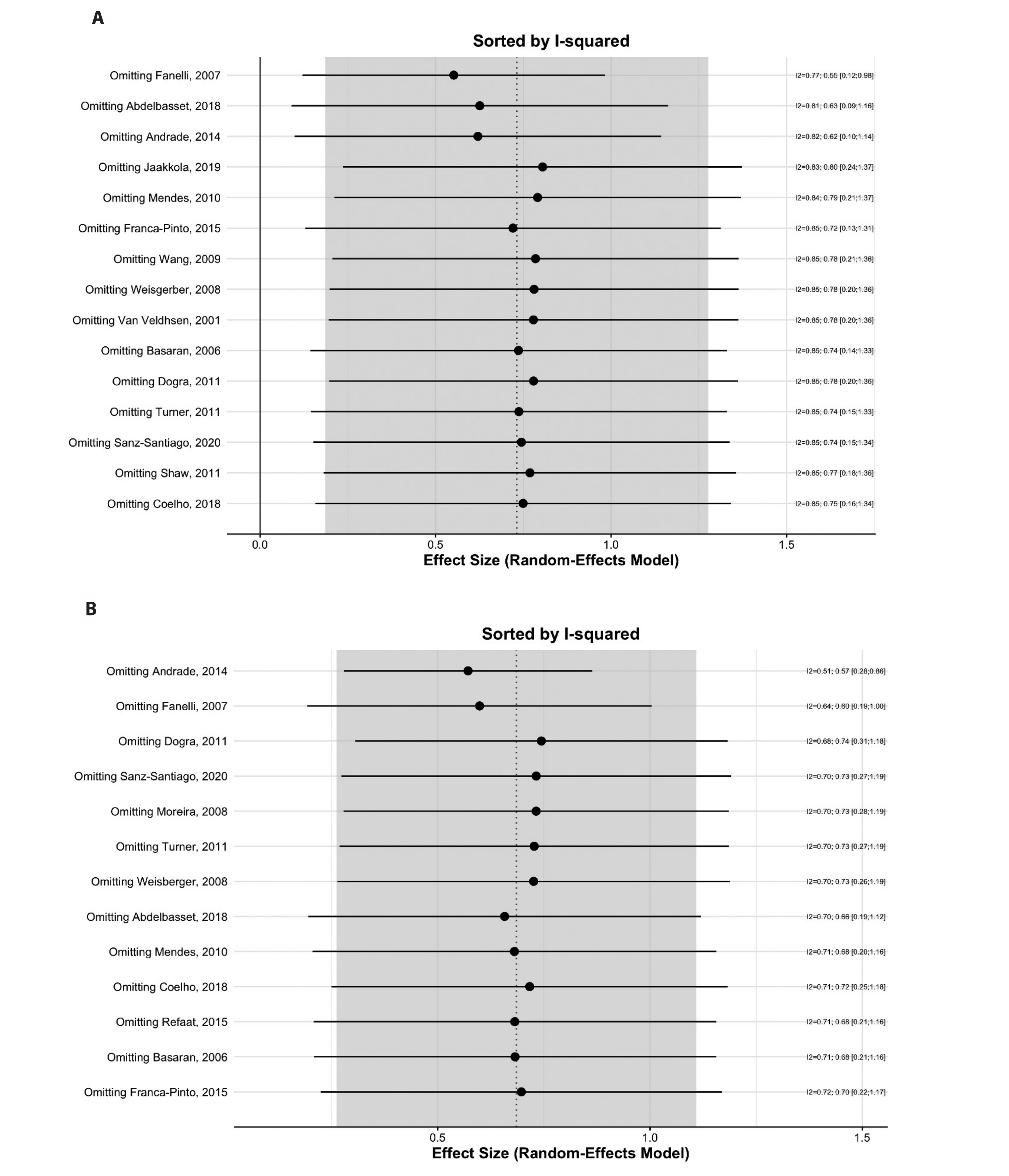


Table 3. Publication bias analysis results.

Method	Intercept	95% CI	t-value	p
Egger	–3.49	–7.10 – 0.12	–1.896	0.0904
Pustejovsky-Rodges	–1.28	–4.12 – 3.13	0.95	0.366

Sensitivity analysis

Observing the variance in effect sizes and heterogeneity through leave-one-out meta-analysis method, we detected 3 studies[30,38,41] for aerobic capacity outcome and 2 studies[30,38] for quality of life outcome that could have influenced the pooled effects. The individual contributions to the effect size and heterogeneity are illustrated in Figure 5. Removing the observed influential studies, the pooled effects of both outcomes decreased, but we obtained a significant reduction in the heterogeneity level and more accurate confidence and prediction intervals, suggesting significant positive effects of physical exercise on quality of life of these patients. All data referred to sensitivity analysis appeared in Table 4.

Discussion

To our knowledge, our meta-analysis, with a final representation of 1,329 patients with asthma (17 studies; 29 effect sizes), was the first-ever in reporting a significant correlation between aerobic capacity and quality of life effects in patients diagnosed with asthma. Furthermore, we found significant positive effects of physical exercise on aerobic capacity and quality of life in these patients. A point we must consider is that prediction intervals of both outcomes included zero in our main analyses. However, when we removed the influential studies, we obtained clear improvements on aerobic capacity and quality of life (i.e., prediction intervals did not include zero), a significant decrease in the heterogeneity levels, and more accurate intervals (i.e., confidence and prediction). In contrast, we also observed an effect size shrinking in that process. Lastly, we found a moderate positive correlation between both outcomes, suggesting that beneficial effects on quality of life may have been caused by benefits on aerobic capacity.

The results obtained in our meta-analysis are in line with other reviews[6,8–10], supporting the beneficial effects of exercise in asthmatic patients. Asthma is an inflammatory disease, and exercise and/or physical activity can play an important role in controlling its symptoms: improving the aerobic capacity of these patients may provide a reduction in exercise-induced bronchoconstriction (i.e., airway muscles contraction)[44], which is the main cause of the notorious sedentary behavior of people diagnosed with asthma[45], and a better physical exercise tolerance[46]. Hence, these benefits could be reflected on the overall quality of life of people with asthma, since the greater impact on any asthma symptom, the better their quality of life[47], which may partially explain the found correlation between both outcomes.

This research adds consistent evidence on the usefulness of physical exercise in the management and treatment of asthma. Considering our data and the current evidence[48], we hypothesize that physical exercise could improve some pathologies which share symptoms with asthma disease such as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), from common symptoms (e.g., cough) to severe ones (e.g., difficulty breathing, shortness of breath, or loss of movement), taken in account all pathology symptoms, the context, and patient status. However, in order to transfer this knowledge to clinical practice, we need to fill in the existing gaps in the literature about the optimal type and dose for these patients[49]. International organizations recommend keeping a healthy and active life, encouraging people with asthma to engage in regular physical activity[49], at least 30 minutes of moderately intense physical activity or structured physical exercise every day[49], resulting in global recommendations, not specifications. In order to establish optimal physical exercise for these people, there is limited evidence which suggests that aquatic activities (e.g., swimming) are more beneficial by reducing the airborne particles exposure[47], and that moderate-vigorous intensity activities could result in greater benefits[47]. This information scarcity could explain that we do not detect moderation effects differentiating by type of physical exercise (i.e., aerobic vs. multicomponent), although significant interactions could be hidden by lack of available data.

In this point, we can identify several key strengths to our study. Our meta-analysis is the first one that has been able to explain part of the benefits caused on quality of life by aerobic capacity improvements. Sensitivity analyses allow us to explain large amounts of heterogeneity given in the main analyses. Included studies presented a fair-good methodological quality. Additional analysis did not show the presence of publication bias. Conversely, we also detected some limitations. We have only focused on exercise, but future meta-analyses should include different types of physical activities (e.g., body-mind or aquatic activities).

Table 4. Sensitivity analysis results

Outcome	Analysis	Hedges' g	95% CI	p	95% PI	I^2	95% CI
Aerobic capacity	Main Analysis	0.73	0.16 - 1.28	0.01	–1.25 - 2.71	84%	75 - 90
	Infl. Cases Removed	0.30	0.06 - 0.54	0.002	–0.31 - 0.91	43%*	13 - 72
Quality of life	Main Analysis	0.69	0.26 - 1.11	0.004	–0.56 - 1.93	69%	45 - 82
	Infl. Cases Removed	0.51	0.27 - 0.74	< 0.001	0.03 - 0.98*	28%*	0 - 64

[1]Removed as outliers: Abdelbasset, 2018; Andrade, 2014; Franelli, 2007
[2]Removed as outliers: Andrade, 2014; Franelli, 2007
*Significanrt changes between models

Moreover, we had a low number of studies to observe moderation subgroup effects (e.g., evidence support that children may benefit more from physical exercise than older adults[50], and we did not detect it), which limits the differentiation on the effects.

Conclusions

This work contributes to broadening the horizon in the management and treatment of asthma, proposing physical exercise as a non-pharmacological treatment to improve the aerobic capacity and, consequently, the quality of life of people with asthma. Our meta-analysis has demonstrated that physical exercise is an intervention which deserves further analysis to lay the foundations for specific and efficient recommendations (i.e., optimal type and dose of physical activity) to improve the lives of these patients who suffer a disease that currently has no cure.

Conflict of interest

The authors do not declare a conflict of interest.

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