BMJ Paediatrics Open

Physical function in children/adolescents with chronic kidney disease and the impact of exercise intervention: a protocol for systematic review and meta-analysis

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To cite: Sun Q, Huang L, Wang H, *et al*. Physical function in children/adolescents with chronic kidney disease and the impact of exercise intervention: a protocol for systematic review and meta-analysis. *BMJ Paediatrics Open* 2023;**7**:e002151. doi:10.1136/bmjpo-2023-002151

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjpo-2023-002151).

Received 22 June 2023
Accepted 5 September 2023

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ABSTRACT

Introduction Impaired physical function is relatively common in children/adolescents with chronic kidney disease (CKD), affecting not only patients' daily lives but also the efficiency of later treatment and rehabilitation. Exercise is a recognised intervention to improve physical function and quality of life in adult patients with CKD. However, implementing this strategy in paediatric/adolescent populations remains relatively limited. For exercise training to be widely delivered as part of paediatric public health policy, a better understanding of the physical function and the impact of exercise interventions in children/adolescents with CKD is needed.

Methods and analysis A systematic review and meta-analysis will be conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to compare physical function in children/adolescents with CKD with healthy controls and the impact of exercise interventions on their outcomes. The systematic review will search the following databases: PubMed, Embase, Scopus and Web of Science. We will use the Risk Of Bias In Non-Randomised Studies-of Interventions and the second edition of the Cochrane Risk of Bias to assess the quality of the literature. Where feasible, we will conduct random effects meta-analyses where appropriate. If possible, we will conduct subgroup analyses to explore potential sources of heterogeneity.

Ethics and dissemination Due to the nature of the protocol, ethical approval is not required. We will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines to disseminate the study results through publication and conference presentations.

PROSPERO registrationnumber CRD42023416208.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Kidney disease can impair physical functioning in children/adolescents, affecting their daily life and the outcome of later treatments. Exercise is an effective non-pharmacological therapy to improve physical function. However, programmes to implement exercise interventions in children/adolescents populations are still limited.

WHAT THIS STUDY HOPES TO ADD

⇒ This systematic review and meta-analysis will quantify the extent of physical functioning in children/adolescents with chronic kidney disease (CKD) relative to matched healthy controls.
⇒ This study will cover various exercise types to assess the evidence-based outcomes of this non-pharmacological therapy for physical function in children/adolescents with CKD.
⇒ The level of evidence may be limited by the number of studies available and some studies may be at high risk of bias.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This systematic review and meta-analysis will further clarify the therapeutic role of exercise interventions on physical functioning in children/adolescents with CKD to guide clinical practice.

INTRODUCTION

Chronic kidney disease (CKD) is a major health problem that affects approximately 9.5% of adults worldwide.[1] Although the prevalence of CKD in children/adolescents ranges from 3.0 to 17.5 cases per million,[2] CKD in this population is associated with an increased risk of poor growth, cardiovascular disease and mortality, imposing a significant psychological and social burden on the child's family.[3 4]

Physical function is intrinsic to maintaining children/adolescents' learning activities and daily life and is a dimension of health-related quality of life assessment.[5] However, the effects of kidney disease often result in children/adolescents having functional limitations and suffering activity-related injuries. Improving impaired physical function and preventing its decline is a crucial goal for maintaining the health and well-being of a wide range of adult patients with CKD and applies to the children/adolescent population.[6]

Increasing evidence suggests that exercise interventions are strongly associated with improvements in physical function and

health-related quality of life in adult patients with CKD.[7] In recent years, exercise-based non-pharmacological therapies have also been gradually extended to the children/adolescent CKD population to improve their prognosis.[6] However, there is insufficient evidence for exercise interventions as the preferred strategy to improve physical function in children/adolescents with CKD. Therefore, the objectives of this systematic review and meta-analysis study included (1) to conduct a meta-analysis to systematically compare physical function between paediatric/adolescent patients with CKD and healthy controls and (2) to assess the role of exercise training on physical function in children/adolescents patients with CKD.

METHODS

This systematic review protocol adheres to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P)[8] (online supplemental table S1). The results of this systematic review and meta-analysis will be reported following the PRISMA 2020 statement.[9] This systematic review protocol was registered with PROSPERO (registration number: CRD42023416208).

Patient and public involvement

Patients and/or the public were not involved in this research's design, conduct, reporting or dissemination plans.

Information sources and search strategy

Potentially eligible studies will be searched through the following scientific literature databases: PubMed, Embase, Scopus and Web of Science. The search strategy was proposed by the literature searcher after extensive reading of systematic reviews and articles on the topic and then refined with discussion by the third author. We used a combination of medical subject terms and keywords related to CKD, physical function and Boolean logic operators to develop a complete search strategy and slightly adapted the search syntax to the characteristics of each database. The search strategies for each database are shown in table 1 and online supplemental table S2. In addition, we will also manually search for records in the reference lists of previous systematic reviews. Literature downloaded from the databases will be imported into EndNote V.20 software for management. An updated search will be conducted 2 months before the publication

Table 1 Search detail for PubMed database

No.	Elements	Search detail
1	Population	"Renal insufficiency, chronic"[MeSH Terms] OR "Renal Insufficiency"[MeSH Terms] OR "Renal Replacement Therapy"[MeSH Terms] OR "Renal Insufficiency"[Title/Abstract] OR "Kidney Insufficiency"[Title/Abstract] OR "Kidney failure"[Title/Abstract] OR "Renal failure"[Title/Abstract] OR "Kidney disease"[Title/Abstract] OR "Renal disease"[Title/Abstract] OR "Predialysis"[Title/Abstract] OR "Pre-dialysis"[Title/Abstract] OR "End-Stage Kidney"[Title/Abstract] OR "End-Stage Renal"[Title/Abstract] OR "Endstage Kidney"[Title/Abstract] OR "Endstage Renal"[Title/Abstract] OR "Dialysis"[Title/Abstract] OR "Hemodialysis"[Title/Abstract] OR "Haemodialysis"[Title/Abstract] OR "Hemodiafiltration"[Title/Abstract] OR "Haemodiafiltration"[Title/Abstract] OR "Hemofiltration"[Title/Abstract] OR "Haemofiltration"[Title/Abstract] OR "Renal Transplantation"[Title/Abstract] OR "Kidney Grafting"[Title/Abstract] OR "Kidney Transplantation"[Title/Abstract]
2	Population	"Child"[Mesh] OR "Children"[Title/Abstract] OR "Child"[Title/Abstract] OR "Adolescent"[Mesh] OR "Adolescents"[Title/Abstract] OR "Adolescence"[Title/Abstract] OR "Teenagers"[Title/Abstract] OR "Teenager"[Title/Abstract] OR "Youth"[Title/Abstract] OR "Youths"[Title/Abstract] OR "Pediatric"[Title/Abstract]
3	Interventions	"Sports"[MeSH] OR "Exercise therapy"[MeSH] OR "Exercise"[MeSH] OR "Exercise Movement Techniques"[Mesh] OR "Resistance training"[Title/Abstract] OR "Endurance Training"[Title/Abstract] OR "Physical activity"[Title/Abstract] OR "Exercise"[Title/Abstract] OR "Yoga"[MeSH Terms] OR "Tai Ji"[MeSH Terms] OR "Tai Chi"[Title/Abstract] OR "Taiji"[Title/Abstract] OR "Tai Ji"[Title/Abstract] OR "T'ai Chi"[Title/Abstract] OR "Tai Chi Chuan"[Title/Abstract] OR "Running"[Title/Abstract] OR "Jogging"[Title/Abstract] OR "Swimming"[Title/Abstract] OR "Walking"[Title/Abstract] OR "Cycling"[Title/Abstract] OR "Qigong"[Title/Abstract] OR "Baduanjin"[Title/Abstract] OR "Yoga"[Title/Abstract] OR "Pilates"[Title/Abstract]
4	Outcomes	("Muscle Strength"[Mesh Terms] OR "Hand strength"[Mesh Terms] OR "Muscle Strength"[Title/Abstract] OR "Grip Strength"[Title/Abstract] OR "HGS"[Title/Abstract] OR "muscle power" [Title/Abstract] OR "muscular force"[Title/Abstract] OR "muscular power"[Title/Abstract] OR "muscular strength"[Title/Abstract]) OR ("Exercise test"[Mesh Terms] OR "Ergometry"[Mesh Terms] OR "Exercise tolerance"[Mesh Terms] OR "Physical fitness"[Mesh Terms] OR "Oxygen consumption"[Mesh Terms] OR "Walk test" [Mesh Terms] OR "Cardiorespiratory fitness" [Mesh Terms] OR "exercise tolerance"[Title/Abstract] OR "physical fitness"[Title/Abstract] OR "oxygen consumption"[Title/Abstract] OR "exercise test"[Title/Abstract] OR "Eurofit Test Batter*"[Title/Abstract] OR "EuroFit test" [Title/Abstract] OR "Arm Ergometry Test"[Title/Abstract] OR "fitness test"[Title/Abstract] OR "cardiopulmonary exercise test*"[Title/Abstract] OR "treadmill test"[Title/Abstract] OR "bicycle ergometry test"[Title/Abstract] OR "ergometr"[Title/Abstract] OR "oxygen consumption"[Title/Abstract] OR "VO2peak"[Title/Abstract] OR "VO2max"[Title/Abstract] OR "aerobic capacity"[Title/Abstract] OR "exercise capacity"[Title/Abstract] OR "cardiorespiratory fitness" [Title/Abstract] OR "aerobic fitness"[Title/Abstract] OR "cardiopulmonary fitness"[Title/Abstract] OR "walk test*"[Title/Abstract] OR "6-minute walk distance"[Title/Abstract] OR "six-minute walk distance"[Title/Abstract])
5	For study 1	#1 AND #2 AND #4
6	For study 2	#1 AND #2 AND #3

Table 2 Eligibility criteria for the systematic review

	Study 1	Study 2
Population	Diagnosed with CKD, including predialysis, peritoneal dialysis, haemodialysis and kidney transplant recipients younger than 19 years old.	
Intervention	Not applicable	Exercise training, including aerobic exercise, resistance training, combined exercise, Tai Chi and Qigong (eg, Baduanjin and yoga), will also be included.
Comparator	Healthy controls	Usual care, no exercise intervention or stretch.
Outcomes	Muscle strength (isometric, dynamic or isometric muscle strength as assessed by repetitive maximal assessment tests on free weight machines, hand-held or isometric dynamometers or ground reaction force plates), (b) aerobic capacity expressed as VO_{2max} or peak VO2 and assessed by maximal exercise tests or total distance estimates from submaximal exercise tests or walk test results, and (c) assessment results obtained by short physical performance battery, timed up and go test.	
Study design	Case–control designs, cohort studies, cross-sectional studies.	Randomised controlled trials, quasi-experimental studies with controls and single-arm precontrolled and postcontrolled trials.

CKD, chronic kidney disease.

of the review or before the final analysis to ensure that any relevant studies are included to the extent possible.

Eligibility criteria

The inclusion criteria are specified according to Population (P), Intervention (I), Comparator (C) and Outcomes (O) (table 2). Exclusion criteria: (1) Patients affected by acute kidney failure. (2) Reviews, case reports, book chapters, conference abstracts, methodological papers, editorials, opinion papers, qualitative studies, research protocols and animal studies.

Study selection

Two authors will independently review the literature for eligibility, and any conflicts will be determined through discussion. A third author will resolve the issue when a consensus cannot be reached. Reasons for exclusion will be documented and summarised in a PRISMA flow chart (figure 1).

Screening of eligible documents

The retrieved literature will be screened in EndNote V.20. First, we will use the find duplicates feature to remove duplicates. Duplicates that EndNote cannot identify will be manually screened. In the title/abstract filter, we will first use the search function to exclude irrelevant publication types. Documents with titles such as 'case report', 'review', 'meta', 'letter' and 'guide' will be excluded. Titles and abstracts will then be reviewed.

Records that cannot be determined to be relevant at the title/abstract screening stage will be eligible by

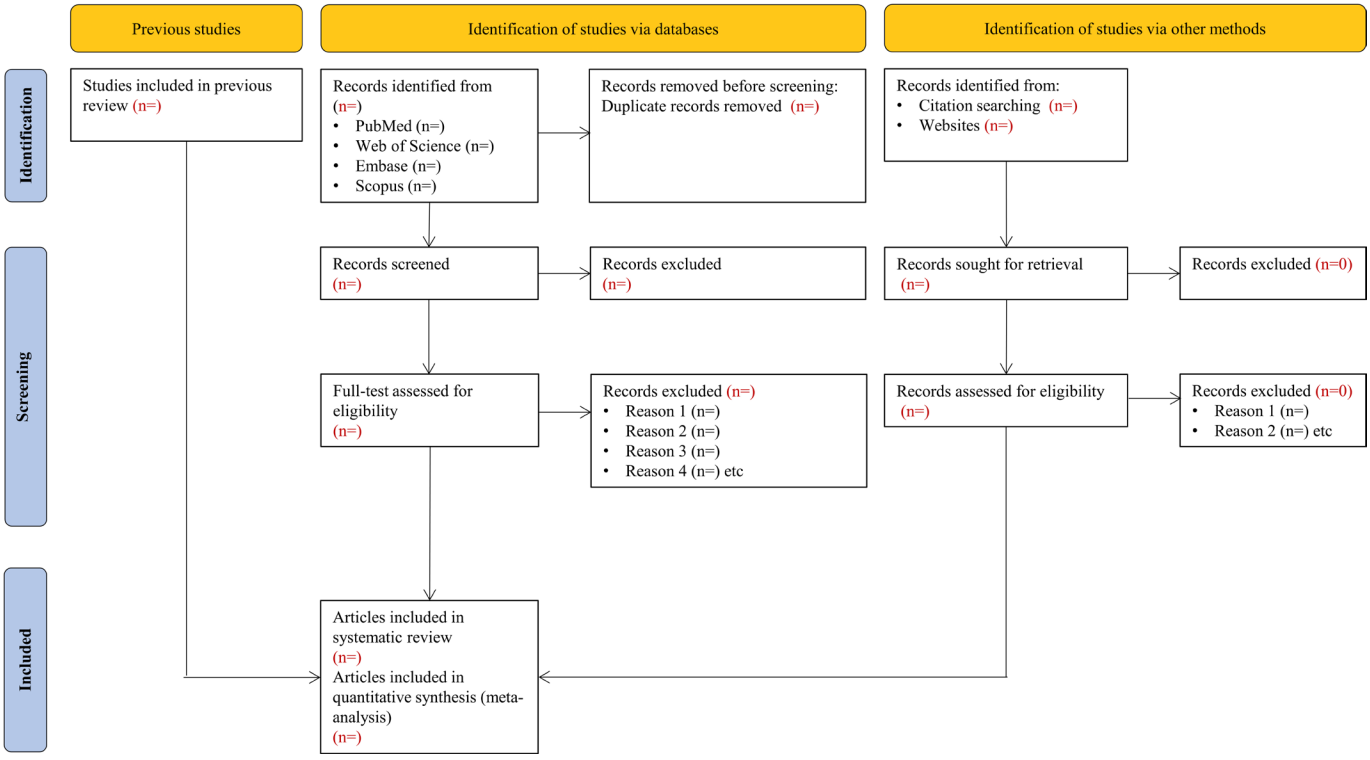

Figure 1 Flow chart of literature screening.

Table 3 Data extraction elements

Topic	Items
Articles	First authors and publication year.
Study details	Study designs and study locations (countries).
Subjects	Mean age, gender, stage of CKD.
Methods	Detail of interventions: exercise frequency, exercise intensity, exercise type, exercise time and intervention duration. Detail of outcome assessment.
Results	Results of physical function tests in the CKD group and healthy control group. Physical function test results at baseline and endpoint for participants in the Intervention and control groups.
Others	Declared conflicts of interest. Financial support.

CKD, chronic kidney disease.

reviewing the full text. A detailed list of excluded studies will be recorded in a table with reasons for exclusion (online supplemental table S3). The authors will be contacted to obtain the full text for records for which full text is unavailable. If it is still elusive, the paper will not be included in the meta-analysis, but the qualitative analysis will be performed.

We will identify a study by design, population and author affiliation if it is reported in multiple articles. When different original research datasets are reported in multiple articles, we will select the paper with the largest sample size reported. Disagreements between the two authors during the selection process will be resolved through discussion. If the discussion does not result in a consensus choice, a third reviewer will be involved and make the final decision.

Data extraction

Based on the predesigned information extraction table, the study feature information and the result data will be extracted by two authors independently. The information we will extract is shown in table 3. Any discrepancies will be resolved through discussion.

When the physical function was measured more than twice, baseline and final follow-up outcomes will be extracted. In studies comparing a particular intervention with usual care, when more than one intervention group of the same type was reported for a study (eg, resistance training vs aerobic exercise vs control), these intervention groups will be combined to avoid double counting the control group. If we encounter a study that presents results in the figure, we will use GetData software to extract the mean and SD.

To ensure correct and complete data extraction, we conducted a pilot extraction for five eligible studies (online supplemental tables S4 and S5), and the table will be subsequently revised as needed.

Quality assessment

The randomised controlled trials will be assessed by the Cochrane Collaborations' second version of the risk of bias tool for randomised trials[10] using the Excel macro tool (https://www.riskofbias.info/welcome). Quasi-experiment and single-arm trials were assessed using the Risk Of Bias In the Non-Randomised Studies-of Interventions tool.[11]

Handing missing data

For missing data that cannot be obtained from the text, we will contact the corresponding author, and if we do not hear back within 1 month, we will consider the contact a failure. Without a response, we will calculate effect estimates using the available data as described in the Cochrane Handbook,[12] where possible. In the case of studies reporting data format of (1) median, first and third quartiles or minimum, and maximum; (2) mean, 95% CI; (3) median with IQR or median±SD and (4) mean, SE, we will use the following corresponding reference equations to estimate the mean and SD.

(1) Mean±SD will be estimated using the method of Luo *et al*[13] and Wan *et al*.[14] Calculation results are available on the web (https://www.math.hkbu.edu.hk/~tongt/papers/median2mean.html).

(2) The formula A and B recommended by the Cochrane Handbook[12] will be used to calculate the mean±SD.

Formula A (sample size of each group ≥100): $SD = \frac{\sqrt{n} \times (\text{upper limit} - \text{lower limit})}{3.92}$

Formula B (sample size of each group <60): $SD = \frac{\sqrt{n} \times (\text{upper limit} - \text{lower limit})}{2 \times t}$

(3) Mean±SD will be estimated by the method of Hozo *et al*.[15] For studies with samples >25 per group, the mean was equal to the median, and the SD was calculated as IQR/4.

(4) SD=SE error $\times\sqrt{n}$.

Data analysis

Data synthesis

When data from at least two trials are available, we will perform a meta-analysis. Statistical analyses are based on the meta[16] package and metafor[17] package of R software (V.4.2.0). For each outcome, postintervention means±SD will be extracted, assessed with restricted estimation maximum likelihood for pool analysis, and express as weighted mean differences or standardised mean differences. Statistical heterogeneity between studies will be assessed with I^2, a value greater than 50% will be considered to indicate substantial heterogeneity,[18] in which case a random effects model will be used, and otherwise, a fixed effects model. In the analysis, a $p<0.05$ will be considered statistically significant.

Subgroup analysis

When enough studies are available, subgroup analysis will be used to explore potential sources of heterogeneity. Interventions and disease stages will be considered

as possible sources of heterogeneity. We will investigate whether the effects of exercise interventions on physical function in children/adolescents with CKD are altered y (1) age (children, adolescents), (2) duration of exercise, (3) exercise type and (4) stage of disease (predialysis, peritoneal dialysis, haemodialysis and kidney transplant recipients). The results of the subgroup analysis will be presented in online supplemental table S6.

Publication bias

If at least 10 studies are included, we will assess publication bias by creating contour-enhanced funnel plots[19] and Egger's test.

Sensitivity analysis

We will perform a sensitivity analysis based on leaving one out, omitting each study consecutively, to explore its impact on the overall results.

Qualitative analysis

We will perform a narrative analysis to present the results for articles that meet the eligibility criteria set by this systematic review and meta-analysis, but for which meta-analysis is not possible (eg, incomplete data).

Grading of evidence assessment

We will assess the quality of evidence using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) methodology to determine the certainty of the evidence for the following five domains[20]:

1. Risk of bias: We will reduce the certainty of evidence if a sensitivity analysis shows significant differences between studies with low, medium or high bias.
2. Indirectness: If the research questions in the included studies are consistent with the PICO questions, the evidence level will not be downgraded.
3. Inconsistency: Unexplained heterogeneity will be a reason for downgrading, that is, I^2 greater than 50%.
4. Imprecision: Whether the CI corresponding to the effect estimate is narrow enough.
5. Publication bias: If publication bias is found by funnel plot or Egger's test, we will downgrade the evidence level of the domain.

The certainty of evidence will be rated as high, medium, low and very low by the GRADE tool. High means that further research is unlikely to change confidence in effect estimates; medium implies that further research is likely to have a significant impact on confidence in effect estimates; low means that further research is very likely to have an impact on confidence in effect estimates; and very low means that estimates of effects are very uncertain. The evidence summary table is provided in online supplemental table S7.

DISCUSSION

In adults with CKD, low physical function, such as low cardiorespiratory fitness and handgrip strength, is associated with various adverse health outcomes and is a widely recognised independent predictor of all-cause mortality risk.[21–24] In children and adolescents with CKD, the increased cardiovascular risk due to kidney disease, muscle atrophy/exhaustion after dialysis initiation and excessive weight gain observed after transplantation suggest that the healthcare team needs to work to optimise physical function by providing education, counselling and regular encouragement to participate in exercise interventions regularly.

Although some studies have shown a positive effect of exercise interventions on physical function improvement in children/adolescents with CKD, these studies have limited sample sizes and are not sufficiently representative. The results of this systematic review and meta-analysis will provide a scientific basis for managing exercise rehabilitation in children/adolescents with CKD. As data integration progresses, bias and significant heterogeneity may occur; therefore, subgroup and sensitivity analyses will be conducted as appropriate to explore the sources of heterogeneity as much as possible and ensure the results' reliability.

Contributors QS and LH contributed to the study protocol design and refinement. FZ developed the search strategy. FZ and HW conducted a review of the literature for this research topic. FZ wrote the first draft, which was revised by HZ and QS. All authors read and approved the final manuscript.

Funding This study is supported by Longhua Hospital Shanghai University of Traditional Chinese Medicine (YW.006.032), Budgeted projects in Shanghai University of Traditional Chinese Medicine (2021WK118), 2022 Talent Development Continuing Education (RSC2301), and Shanghai Modern Nursing Vocational Education Group Special Adjunct Faculty Program (hlzjtpgr202327).

Competing interests No, there are no competing interests.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as online supplemental information.

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REFERENCES

1 ISN global kidney health Atlas. 2023. Available: https://www.theisn.org/wp-content/uploads/media/ISN%20Atlas_2023%20Digital.pdf [Accessed 04 May 2023].
2 Shi XM, Liu BN, Zhong XH, *et al*. Epidemiology of chronic kidney disease in children. *Zhonghua Er Ke Za Zhi* 2019;57:721–4.

3 VanSickle JS, Warady BA. Chronic kidney disease in children. *Pediatr Clin North Am* 2022;69:1239–54.
4 Harada R, Hamasaki Y, Okuda Y, *et al*. Epidemiology of pediatric chronic kidney disease/kidney failure: learning from registries and cohort studies. *Pediatr Nephrol* 2022;37:1215–29.
5 Faigenbaum AD, Rebullido TR, MacDonald JP. Pediatric inactivity triad: a risky PIT. *Curr Sports Med Rep* 2018;17:45–7.
6 Wilkinson TJ, O'Mahoney LL, Highton P, *et al*. Physical activity and the 'pediatric inactivity triad' in children living with chronic kidney disease: a narrative review. *Ther Adv Chronic Dis* 2022;13:20406223221109971.
7 Zhang F, Bai Y, Zhao X, *et al*. Therapeutic effects of exercise interventions for patients with chronic kidney disease: an umbrella review of systematic reviews and meta-analyses. *BMJ Open* 2022;12:e054887.
8 Shamseer L, Moher D, Clarke M, *et al*. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ* 2015;350:g7647.
9 Page MJ, Moher D, Bossuyt PM, *et al*. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ* 2021;372:n160.
10 Sterne JAC, Savović J, Page MJ, *et al*. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* 2019;366:l4898.
11 Sterne JA, Hernán MA, Reeves BC, *et al*. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ* 2016;355:i4919.
12 Cochrane handbook for systematic reviews of interventions (version 6.3, 2022). Available: https://training.cochrane.org/handbook/current [Accessed 04 May 2023].
13 Luo D, Wan X, Liu J, *et al*. Optimally estimating the sample mean from the sample size, median, mid-range, and/or mid-quartile range. *Stat Methods Med Res* 2018;27:1785–805.
14 Wan X, Wang W, Liu J, *et al*. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Methodol* 2014;14:135.
15 Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. *BMC Med Res Methodol* 2005;5:13.
16 Schwarzer G. *Meta: an R package for meta-analysis, 7*. 2007: 40–5.
17 Viechtbauer W. Conducting meta-analyses in R with the Metafor package. *J Stat Softw* 2010:36.
18 Higgins JPT, Thompson SG, Deeks JJ, *et al*. Measuring inconsistency in meta-analyses. *BMJ* 2003;327:557–60.
19 Duval S, Tweedie R. Trim and fill: a simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics* 2000;56:455–63.
20 Guyatt GH, Oxman AD, Vist GE, *et al*. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008;336:924–6.
21 Zhang F, Wang H, Bai Y, *et al*. Handgrip strength and all-cause mortality in patients with chronic kidney disease: an updated systematic review and meta-analysis of cohort studies. *Int Urol Nephrol* 2023;55:2857–65.
22 Alexandrou M-E, P Theodorakopoulou M, Boutou A, *et al*. Cardiorespiratory fitness assessed by cardiopulmonary exercise testing between different stages of pre-dialysis chronic kidney disease: a systematic review and meta-analysis. *Nephrology (Carlton)* 2021;26:972–80.
23 Pella E, Boutou A, Boulmpou A, *et al*. Cardiopulmonary exercise testing in patients with end-stage kidney disease: principles, methodology and clinical applications of the optimal tool for exercise tolerance evaluation. *Nephrol Dial Transplant* 2022;37:2335–50.
24 Hwang S-H, Lee DH, Min J, *et al*. Handgrip strength as a Predictor of all-cause mortality in patients with chronic kidney disease undergoing dialysis: a meta-analysis of prospective cohort studies. *J Ren Nutr* 2019;29:471–9.