



# Aerobic exercise in adults with chronic kidney disease (CKD): a meta-analysis

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## Abstract

**Purpose** Patients with chronic kidney disease (CKD) are frail and have high risk of cardiovascular disease. This study was performed to assess the effects of aerobic exercise training in adults with CKD.

**Methods** MEDLINE, EMBASE, CENTRAL, Web of Science were searched up to December 2018 to identify eligible randomized controlled trials (RCTs) that studied aerobic exercise in adults with CKD. Primary outcomes include oxygen consumption at peak exercise ( $VO_2$  peak), exercise capacity, blood pressure, heart rate, and health-related quality of life (HRQoL). Statistical analysis was performed using Review Manager 5.2.1 software.

**Results** Thirty-one trials, containing 1305 adults with CKD, were included. The most used aerobic exercise program was characterized as moderate intensity (15/31), 3 times/week frequency (22/31), 30 min duration (9/31) and 3 months follow-up (12/31). Significant improvement was observed in cardiorespiratory function ( $VO_2$  peak) ( $P < 0.0001$ ), exercise duration ( $P < 0.0001$ ), HDL-C ( $P = 0.03$ ) and pain ( $P = 0.007$ ), physical role ( $P = 0.03$ ), general health ( $P = 0.007$ ) of HRQoL after aerobic exercise in patients with CKD. A marginal difference was observed in HR max ( $P = 0.07$ ). However, no statistical difference was noticed in exercise capacity, blood pressure, resting heart rate, serum lipid and serum creatinine between aerobic training group and control. No subgroup differences were altered in all outcomes when studies were divided based on intensity of exercise training, the treatment of dialysis or the length of intervention.

**Conclusions** Aerobic exercise training could benefit adult CKD patients in increasing cardiorespiratory function, exercise duration, HDL-C level and improve health quality of life.

**Keywords** Aerobic exercise training · Chronic kidney disease · Meta-analysis

## Introduction

Incidence and prevalence of chronic kidney disease (CKD) is increasing world widely. Patients with CKD have an obvious loss of aerobic power and functional capacity compared with healthy individuals of the same age group [1], which caused by several factors, including renal anemia, malnutrition, uremic toxins, acidosis, vitamin D deficiency and

altered potassium metabolism [2]. As a result, CKD patients are more susceptible to poor health outcomes, including disability, hospitalization and high mortality [3]. Although exercise training maybe a promising solution, the effect of aerobic exercise training in CKD patients has not yet been completely clarified. Previous studies have shown that aerobic exercise could effectively improve cardiopulmonary capacities, health-related quality of life (HRQL), blood pressure (BP) in CKD patients [4]. However, other clinical studies showed no significant benefit [5]. Therefore, a meta-analysis was performed to clarify the effect of aerobic exercise training on CKD patients.

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## Materials and methods

### Search

Two reviewers independently and systematically searched for studies evaluated aerobic exercise in CKD patients published in English up to December 2018. The following databases were searched: MEDLINE, EMBASE, The Cochrane Central Register of Controlled Trials (CENTRAL) in The Cochrane Library, Web of Science. The search terms used were: [(aerobic exercise) OR (exertion) OR (exercise therapy) OR (physical education and training) OR (physical fitness) OR (exercise training)] AND [(Chronic Kidney Failure) OR (Kidney Transplantation) OR (hemodialysis) OR (haemodialysis) OR (dialysis) OR (renal disease) OR (kidney disease) OR (CKD or CKF or CRD or CRF or ESKD or ESRD or ESKF or ESRF)] AND [(random\*) OR (randomized controlled trial\*) OR (RCT)]. The reference lists of review articles and studies included were hand searched for other potentially eligible studies.

### Selection

Two independent reviewers selected articles according to the inclusion and exclusion criteria. Disagreements were resolved in consultation with a third reviewer. The inclusion criteria were as follows: (a) adults ( $\geq 18$  years) with CKD (2–5 days stage) were enrolled; (b) the intervention was aerobic exercise training versus non-exercise control OR aerobic exercise training plus co-intervention versus co-intervention; (c) exercise program should include: intensity, frequency and duration ( $> 2$  months); (d) primary outcomes—oxygen consumption at peak exercise ( $VO_2$  peak), exercise duration, muscular endurance (sit-to-stand-to-sit test), serum creatinine, health-related quality of life (HRQoL); secondary outcomes—walking capacity (6-min walk), systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate, serum albumin, pre-albumin, triglycerides, total cholesterol, low-density lipoprotein cholesterol (LDL-C) and high-density lipoprotein cholesterol (HDL-C); (e) randomized controlled trial (RCT) and quasi-RCT. The exclusion criteria were as follows: studies in acute kidney injury (AKI) or kidney transplant patients, children, without detailed training plan. Full texts of selected articles were carefully read to determine whether they were eligible. Studies with unobtainable and unusable data were also excluded.

### Data extraction and quality assessment

Data extraction was carried out independently by two reviewers using standard data extraction forms. Quality of

the studies were assessed using the Tool to Assess Risk of Bias in Randomized Controlled Trials (Contributed by the CLARITY Group at McMaster University) [6], in which each assessed item received a “Definitely Yes (low risk of bias)”, “Definitely No (high risk of bias)”, “Probably No”, or “Probably Yes”. All disagreements were resolved by discussion or by a third researcher.

### Statistical analysis

Review Manager (5.2.1) was used to estimate the effect of the outcomes. All outcomes were analyzed using fixed or random effects model. Heterogeneity across studies was analyzed using  $I^2$  statistic method. When there was no heterogeneity ( $I^2 \leq 50\%$ ,  $P > 0.05$ ), fixed effect meta-analyses were performed. Otherwise random-effect model was applied. Funnel plots were used to examine the potential publication bias. Subgroup analysis was performed for the length of exercise intervention ( $< 6$  months,  $\geq 6$  months), the treatment of dialysis and intensity of exercise training (low, moderate, high) when there were sufficient data.

## Results

### Search results

A total of 1863 reports were screened and 161 studies were read in detail. 130 studies were excluded according to exclusion criteria: duplication ( $n = 6$ ); abstract ( $n = 27$ ); other exercise ( $n = 23$ ); wrong control group ( $n = 30$ ); not RCT ( $n = 2$ ); no adequate data ( $n = 34$ ); protocol ( $n = 8$ ). Finally, 31 trials [7–37] and 1305 patients were included in the current study (Fig. 1).

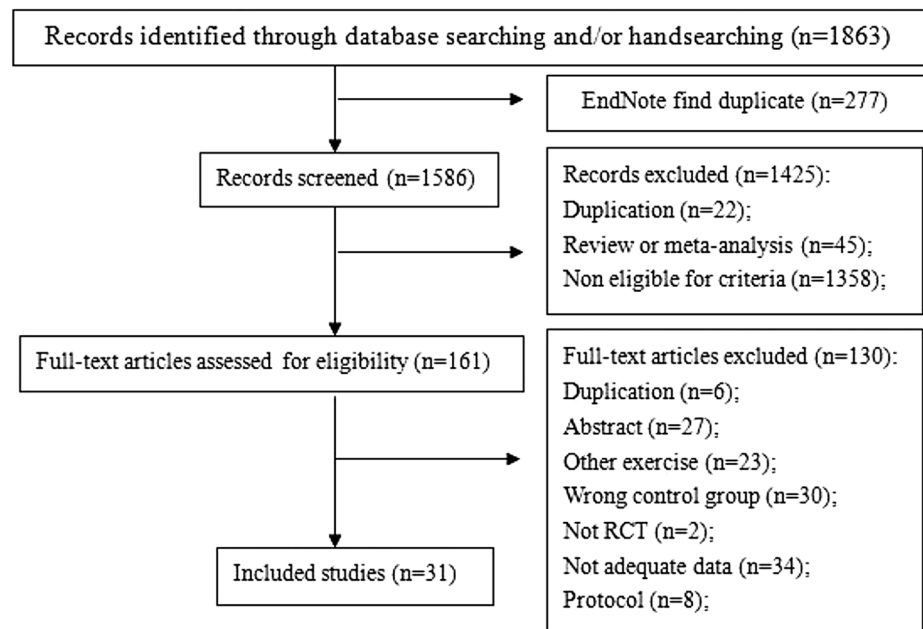
### Characteristics of included studies

The main characteristics of included studies are shown in Tables 1 and 2; 22 studies were single-center studies, five were multicenter studies, the other four studies did not provide this information. The total number of patients included was 1305, ranging from 11 to 227 patients in each study. Mean age of study participants ranged from 37 to 72.5 years. Most of the participants in CKD 5d stage included were treated with hemodialysis. The mostly used aerobic exercise program was moderate intensity (15/31), 3 times/week frequency (22/31), 30 min duration (9/31) with 3 months follow-up (12/31).

### Quality of included studies

In general, only six studies reported the method of randomization (Headley 2014, Koufaki 2002, Matsufuji 2015,

Fig. 1 Flow diagram



Mustata 2011, Tang 2017, Wu 2014), 4 of 45 studies used adequate allocation concealment (Craenenbroeck 2014, Matsufuji 2014, Mustata 2011, Toussaint 2008), 1 study had blinded participants (Parsons 2004). The risk of bias assessments of the included studies is summarized in Fig. 2.

## Meta-analysis

### Exercise capacity

**Aerobic capacity** Aerobic capacity was measured using  $VO_2$  peak in 17 studies (464 patients). Meta-analysis showed that aerobic exercise training could significantly improve aerobic capacity ( $VO_2$  peak) in CKD patients (Table 3; MD 2.08,  $P < 0.0001$ ;  $I^2 = 25\%$ ). Between the two subgroups, the length of intervention  $< 6$  months and  $\geq 6$  months, the difference in post–pre change in  $VO_2$  peak were 2.60 ( $P = 0.0002$ ) and 1.54 ( $P = 0.03$ ), respectively. When studies were divided based on intensity of exercise training, the same results were shown on this outcome.  $VO_2$  peak was significantly better in patients treated with dialysis compared with non-dialysis (MD 3.07,  $P < 0.0001$  vs MD 0.77,  $P = 0.31$ ).

### Exercise duration and muscular endurance

Exercise duration was analyzed in six trials (177 participants). Results showed that aerobic exercise could remarkably improve exercise duration in CKD patients (Table 3; MD 155.57,  $P < 0.0001$ ;  $I^2 = 23\%$ ). Subgroup analysis based on the length of exercise and the treatment of dialysis also reached similar result ( $< 6$  months, MD 146.17,  $P = 0.003$  vs  $\geq 6$  months, MD 165.61,  $P = 0.001$ ) and (dialysis, MD

235.19,  $P < 0.0001$  vs non-dialysis, MD 114.88,  $P = 0.009$ ). Muscular endurance was evaluated using the Sit-to-Stand-to-Sit-60 (STS60) score in five studies (445 patients). Meta-analysis indicated that aerobic exercise could not improve muscular endurance. Subgroup analysis showed no difference when studies were divided based on intensity of exercise training or the length of intervention (Table 3).

### Walking capacity

Walking capacity was determined by 6-min walk test (m) in eight studies with 496 participants. Results suggested no difference between aerobic exercise group and control group in CKD patients. There was no significant difference in subgroup analysis based on intensity of exercise training or the length of intervention. Patients untreated with hemodialysis had a greater effect on walking capacity during aerobic training, but there were only two small-scale RCTs include non-dialysis CKD patients (two trials, 113 patients, MD 0.58,  $P = 0.003$ ).

### Resting blood pressure and heart rate

There was no significant difference in either resting SBP or DBP in aerobic exercise training group (Table 3, 12 studies, 514 participants). Subgroup analysis on SBP and DBP did not report significant difference. It was also found that aerobic exercise could not significantly affect the resting heart rate when compared with control (Table 3). However, increased maximum heart rate (max HR) could be observed in aerobic exercise training group. Nevertheless, the difference was just marginal (Table 3, MD 5.69,

**Table 1** Characteristics of included studies of dialysis patients

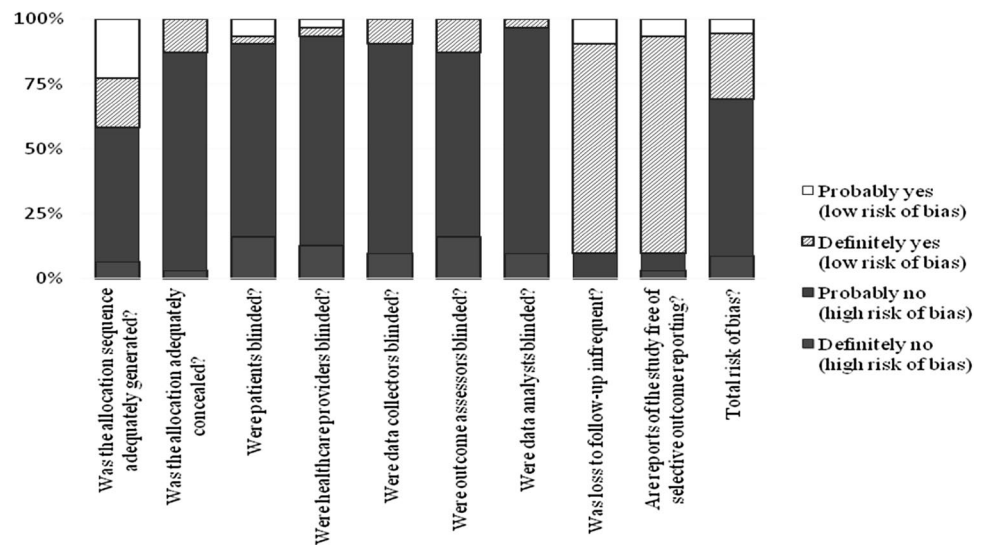
Study	Year	Center	Country	Dialysis	Number		Age (year)		Dialysis (m)		Exercise program				
					Ex	Ctrl	Ex	Ctrl	Ex	Ctrl	S	I	Fre	D	Fo
Frey	1999	1	USA	HD	5	6	40±11	53±13	66±93.6	NS	N	H	3	45	3
Groussar	2015	2	France	HD	8	10	66.5±4.6	68.4±3.7	36.6±8.2	41.2±8.1	Y	M	3	30	3
Hristea	2015	2	France	HD	7	9	68.5±14	70.8±15.2	9.16±4.00	8.18±3.95	N	M	3	30	6
Koufaki	2002	1	UK	PD/HD	18	15	57.8±14.3	51±18.9	41.4±45.2	53.4±52.5	Y	M	3	40	3
Kouidi	1997	1	Greece	HD	20	11	49.6±12.1	52.8±10.2	70.8±58.8	74.4±64.8	Y	M	3	90	6
Manfredini	2016	13	Italy	PD/HD	104	123	63±13	64±14	NS	NS	Y	L	3	20	6
Matsufuji	2015	1	Japan	HD	6	11	68 (61–78)	69 (64–79)	132 (72–300)	180 (108–228)	Y	NS	3	15	3
Pomidori	2016	2	Italy	PD/HD	22	20	63±15	69±10	84±96	60±72	N	M	3	20	6
Reboredo	2011	1	Brazil	HD	12	12	50.7±10.7	42.2±13	39.6±40.8	57.6±52.8	Y	H	3	43	3
Simo	2014	1	Spain	HD	16	24	67.9±15.9	68.7±16.6	58.8±70.1	69±78.9	Y	L	2	60	6
Wihund	2010	1	USA	HD	7	8	60.8±3.2	59.0±4.9	63.3±8.7	44.6±12.2	N	M	3	45	4
Wu	2014	1	China	HD	32	33	45 (37–48)	44 (41–50)	55.5±37.3	39.8±29.7	N	H	3	20	3
Goldberg	1983	1	USA	HD	14	11	38±15	37±12	22.2±17.1	40.1±29.7	Y	H	3	60	12
Carmack	1995	3	USA	HD	10	11	44 (20–72)	NS	NS	NS	N	NS	3	30	2.5
Parsons	2004	1	Canada	HD	6	7	60±17	49±25	25±25	49±26	Y	L	3	15	3
Zhao	2016	1	China	HD	63	63	52.9	54.1	24.9	24.7	N	NS	6	60+	4.5
Matsumoto	2007	1	Japan	HD	17	32	60.8±9.5	57.2±8.3	148.8±81.6	152.4±90	Y	M	3	20	3
Deligiannis	1999	NS	Greece	HD	30	30	48±12	48±11	75.6±36	74.4±43.2	Y	M	3~4	90	6
Deligiannis-Li	1999	NS	Greece	HD	10	12	51.4±12.5	50.2±7.9	62±37	79±86	N	L	≥5	30	6
Konstantinidou	2002	1	Greece	HD	10	12	51.4±12.5	50.2±7.9	62±37	79±86	N	M	5	30	6
Toussaint	2008	1	Australia	HD	9	10	67 (60–83)	70 (28–77)	35±31	72±56	N	NS	3	30	3
Tsuyuki	2003	NS	Japan	HD	17	12	40.1±11.9	39.7±10.7	25.2±30	32.4±31.2	Y	L	2~3	30	5

Ex exercise, Ctrl control, PD peritoneal dialysis, HD hemodialysis, S supervised, I intensity, Fre frequency (times/week), D duration (min), Fo follow-up (month), NS not specified, M moderate, H high, L low

**Table 2** Characteristics of included studies of non-dialysis CKD patients

Study	Year	Center	Country	CKD stages	Number		Age (year)		Exercise program				
					Ex	Ctrl	Ex	Ctrl	S	I	Fre	D	Fo
Eidemak	1997	1	Denmark	3–5	15	15	45 (22–70)	44 (28–65)	N	M	NS	NS	18–20
Tang	2017	1	China	1–3	42	42	46.26 ± 15.6	43.9 ± 12.44	N	H	3	40	3
Mustata	2011	NS	Canada	3–4	10	10	72.5	64	Y	H	3	60	12
Takashi	2015	1	Brazil	3–4	14	15	55.9 ± 7.7	55.9 ± 7.7	Y	M	3	50	3
Craenenbroeck	2015	1	Greece	3–4	19	21	51.5 ± 11.8	54.7 ± 14.1	Y	M	7	40	3
Headley	2012	1	USA	2–4	10	11	57.5 ± 11.5	52.5 ± 10.6	Y	M	3	45	12
Headley	2014	1	USA	3	25	21	58.0 ± 8.0	57.1 ± 9.0	N	M	3	55	4
Kosmadakis	2012	1	UK	4–5	18	14	61.5	56	N	M	5	30	6
Leehey	2009	1	USA	2–4	7	4	66 (55–81)		Y	H	3	30	6

Ex exercise, Ctrl control, S supervised, I intensity, Fre frequency (times/week), D duration (min), Fo follow-up (month), NS not specified, M moderate, H high, L low

**Fig. 2** Quality assessment of included studies

$P=0.07$ ). The length of exercise and the treatment of dialysis during aerobic training did not show obvious effect on resting and max heart rate in CKD patients (Table 3).

### Lab indexes

No significant changes were observed in serum triglycerides, total cholesterol, LDL-C, albumin, pre-albumin levels between aerobic exercise group and control group (Table 3). However, significantly increased HDL-C level was found in aerobic exercise group when compared with control group (Table 3, MD 3.54,  $P=0.03$ ). Serum creatinine level had not a significantly change between exercise and control groups. Subgroup analysis suggested the change of blood lipid was not significant in patients treated and untreated with dialysis (Table 3).

### Health-related quality of life

Seven of the 31 included trials reported a validated HRQoL measure with 36-item Short Form [7, 9, 13, 19, 21, 30, 31]. Meta-analysis showed that aerobic exercise could remarkably relieve pain ( $P=0.007$ ,  $I^2=49\%$ ) and improve quality of life on physical role, general health with significant heterogeneity (Table 3). Physical function, social function, and mental health were increased in aerobic exercise training group, however, the difference was just marginal (Table 3;  $P=0.09$ , 0.08 and 0.08, respectively). Other items were not pooled for insufficient studies.

### Assessment of publication bias

An assessment of publication bias was conducted for the  $VO_2$  peak and HRQoL of physical role that contained

**Table 3** The effects of aerobic exercises training in CKD patients

Outcome	Trials	Number		Meta-analysis of changes (post–pre)			
		Exercise	Ctrl	Est (95% CI)	Z	P	I <sup>2</sup> (%)
VO <sub>2</sub> peak (mL/kg/min)	17	235	229	2.08 [1.1, 3.05]	4.19	<0.0001	25
<6 months	9	129	124	2.60 [1.23, 3.97]	3.73	0.0002	0
≥6 months	8	106	105	1.54 [0.15, 2.92]	2.18	0.03	47
Exercise duration (s)	6	88	89	155.57 [85.83, 225.3]	4.37	<0.0001	23
<6 months	2	31	33	146.17 [49.19, 243.16]	2.95	0.003	44
≥6 months	4	57	56	165.61 [65.29, 265.94]	3.24	0.001	35
STS60 (s)	5	208	237	0.01 [−0.51, 0.50]	0.02	0.98	82
<6 months	3	88	90	−0.06 [−0.80, 0.68]	0.15	0.88	82
≥6 months	2	120	147	0.10 [−0.59, 0.79]	0.28	0.78	76
6-min walk test (m)	8	236	260	0.04 [−0.52, 0.59]	0.13	0.9	86
<6 months	5	103	108	0.11 [−0.54, 0.76]	0.33	0.74	77
≥6 months	3	133	152	−0.06 [−0.89, 0.78]	0.13	0.9	83
DBP (mmHg)	12	251	263	−1.11 [−3.41, 1.20]	0.94	0.35	0
<6 months	6	9	87	−2.40 [−5.71, 0.91]	1.42	0.16	36
≥6 months	6	160	176	0.11 [−3.11, 3.33]	0.07	0.95	0
SBP (mmHg)	12	251	263	−2.91 [−6.68, 0.87]	1.51	0.13	40
<6 months	6	91	87	−4.66 [−15.07, 5.75]	0.88	0.38	66
≥6 months	6	160	176	−0.15 [−5.17, 4.87]	0.06	0.95	0
HR max (bpm)	7	115	108	5.69 [−0.36, 11.75]	1.84	0.07	0
HR resting (bpm)	8	203	213	−1.75 [−4.21, 0.71]	1.39	0.16	6
<6 months	5	172	186	−2.00 [−4.62, 0.63]	1.49	0.14	26
≥6 months	3	31	27	−0.01 [−6.97, 6.95]	0	1	0
Triglycerides (mg/dl)	8	192	212	−10.92 [−28.60, 6.76]	1.21	0.23	0
Cholesterol (mg/dL)	10	218	241	4.25 [−3.02, 11.53]	1.15	0.25	0
LDL-C (mg/dL)	5	60	70	7.18 [−10.99, 25.36]	0.77	0.44	70
HDL-C (mg/dL)	6	74	81	3.54 [0.43, 6.65]	2.23	0.03	0
Albumin (g/dL)	11	223	266	−0.05 [−0.17, 0.07]	0.77	0.44	81
Pre-albumin (mg/dL)	3	28	39	0.89 [−3.42, 5.19]	0.4	0.69	0
Creatinine (mg/dL)							
Dialysis	6	187	209	−0.36 [−0.88, 0.15]	1.38	0.17	0
Non-dialysis	3	39	33	0.01 [−0.23, 0.25]	0.12	0.90	0
HRQoL (SF-36)							
Physical function	6	247	275	8.36 [−1.24, 17.95]	1.71	0.09	76
Physical role	7	266	296	14.65 [1.47, 27.84]	2.18	0.03	78
Social function	6	207	240	8.24 [−1.09, 17.58]	1.73	0.08	85
Pain	6	249	264	5.94 [1.65, 10.23]	2.71	0.007	49
General health	7	266	296	8.90 [2.48, 15.32]	2.72	0.007	71
Mental health	6	256	286	7.30 [−0.94, 15.54]	1.74	0.08	84

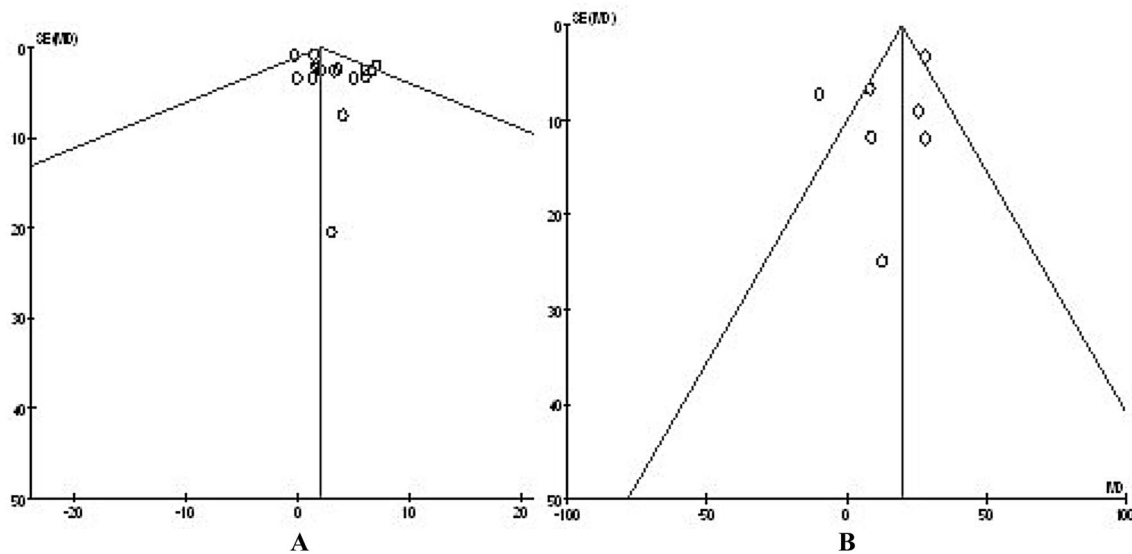
*Bpm* beats per minute, *CI* confidence interval, *DBP* diastolic blood pressure, *Est* estimate, *HR* heart rate, *HDL-C* high-density lipoprotein cholesterol, *HRQoL* health-related quality of life, *LDL-C* low-density lipoprotein cholesterol, *N* number of participants, *STS60* Sit-to-Stand-to-Sit-60 test, *SBP* systolic blood pressure, *SF-36* 36-item Short Form, *VO<sub>2</sub>peak* peak oxygen consumption

enough study data (Fig. 3). Funnel plots were visually assessed as reasonably symmetrical, indicating little publication or small study bias.

## Discussion

Chronic kidney disease (CKD) is a worldwide public health problem. The physical fitness in adults with CKD is progressively reduced and the main causes are renal anemia and





**Fig. 3** Funnel plot:  $VO_2$  peak (a), HRQoL of physical role (b)

skeletal muscle disorder. Frailty is associated with the risk of adverse prognosis and the quality of life [2]. Aerobic exercise training is the most widely used program, however, the great difference in experimental design and outcome indicators make its effect in CKD patients is unclear at present. Our research updates and evaluates the effects of aerobic exercise training in adults with CKD.

Regular exercise improves cardiorespiratory function, strength and physical function, and health-related quality of life in CKD patients [38].  $VO_2$  peak is one of the most commonly studied parameters in cardiorespiratory function. When compared to control group, we found that aerobic exercise improved  $VO_2$  peak and exercise duration, while there were no significant differences in walking capacity and muscular endurance. The intensity of aerobic exercise program and the length of intervention did not alter results. These findings are in accordance with the previous Cochrane review [2]; Aerobic exercise training will improve  $VO_2$  peak (2.08 mL/kg/min) and physical fitness with clinically significant [39].  $VO_2$  peak was significantly greater in patients treated with dialysis than non-dialysis (MD 3.07,  $P < 0.0001$  vs MD 0.77,  $P = 0.31$ ), but the RCTs including patients untreated with dialysis were small-scale and not statistically significant (six trials, 167 patients,  $P = 0.31$ ). Due to the relatively short intervention period, a beneficial effect in walking capacity and muscular endurance were not expected. Hence, our study supports the application of aerobic exercise in adult CKD patients, especially those undertaking hemodialysis. The recommend aerobic exercise program should be moderate intensity of training lasting 30–60 min per time, 3 times/week and last for 3–6 months.

Cardiovascular disease is a major cause of mortality in CKD patients. Blood pressure and heart rate play important roles in the progression of CVD. In both normotensive and hypertensive subjects, it is reported that aerobic training could reduce blood pressure at rest, especially in hypertensive subjects [40]. However, in line with the latest review in CKD stages 3–4 [41], our result did not indicate difference in diastolic or systolic blood pressure after aerobic training in adults CKD patients. The possible explanation might be a generally well controlled BP at baseline and the use of antihypertensive drugs. It is well known that regular exercise training lowers resting HR in healthy people. Nevertheless, our meta-analysis and the previous Cochrane review [2] showed that aerobic training could decrease the rest HR in CKD patients (1.75 bpm), but the difference could not reach the statistical significance ( $P = 0.16$ ). Relatively small sample size which may mask the effect of aerobic training. The association between aerobic exercise and max HR remains a heated debate. Studies in healthy people reported that aerobic training could affect the max HR by the following mechanism: plasma volume expansion, enhanced baroreflex function, alteration of the electrophysiology of the sinoatrial node and decreased  $\beta$ -adrenergic receptor number. As a result, max HR may be reduced during aerobic exercise [42, 43]. However, both this meta-analysis and the Cochrane review [2] could only find a marginal increase of max HR after aerobic training in CKD patients (5.69 bpm,  $P = 0.07$ ). Absence of adequate procedural details of measuring max HR or the short duration of exercise may be the reason of this negative finding. Subgroup analysis also had non-significant effects on blood pressure, resting HR and max HR. More research focusing on blood pressure,

resting HR and max HR in CKD patients are needed before conclusions can be drawn.

Dyslipidemia is a common comorbidity in patients with CKD, and is a major risk factor for CVD. Low HDL levels were shown to be a significant risk factor for coronary heart disease [44]. In the current study, we found that aerobic training could increase the serum HDL-C concentrations obviously ( $P=0.03$ ), while not affecting the triglycerides, total cholesterol, LDL-C levels in adult CKD patients. The comparison based on patients treated and untreated with dialysis did not alter results. The result is, however, based on a relatively small sample size and further research is needed. It was reported that aerobic training might play a role in the maintenance of kidney function and improve estimated glomerular filtration rate (eGFR) in patients with CKD [41]. However, our meta-analysis showed that aerobic exercise training could not decrease the serum creatinine level in non-dialysis patients CKD patients (CKD 2–5 stage). Further high quality and multicenter research is needed to clarify this effect.

Health-related quality of life (HRQoL) was apparently decreased in CKD patients [45]. Our study suggested that aerobic training could improve the HRQoL of CKD patients in physical role, general health and pain management significantly when compared with control. Therefore, it is plausible that aerobic exercise have beneficial effect on emotional and behavioral aspects including increased social interaction, decreased anxiety and improved attitude toward self.

This study had several limitations. First, most included trials were short term (3–6 months); second, intention-to-treat (ITT) analysis was not used in most studies, and there were deficiencies in the reporting of methodological and results information, such as method of randomization, blindly, dropout rate, adverse events, and compliance. These might have inflated the apparent results; third, some outcomes had been measured with different methods, which complicates the pooling of results. Finally, the effects of aerobic exercise training between males and females or in CKD patients without hypertension and/or diabetes remained unknown for insufficient original data from RCTs. Further studies with large-scale, multicenter, longer exercise interventions and more sensitive indicators would provide more scientific information on the effects of aerobic exercise in adults with CKD.

## Conclusion

Aerobic exercise training will benefit adults with CKD and help them in their maximal oxygen consumption, exercise duration, HDL-C and health quality of life. Although differences in muscular endurance, blood pressure, HR, blood lipid, kidney function did not reach statistical significance between aerobic exercise and usual care group, it is

speculated that exercise training in CKD patients may still have potential benefits. Future long-term studies focusing on multidisciplinary programs, such as Tai Chi, Yoga, dancing, and patient-relevant outcomes are warranted.

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