Abstract

Patients with chronic kidney disease (CKD) are inactive and have reduced physical functioning and performance. Aerobic exercise interventions have been shown to increase maximal oxygen consumption in selected patients. In addition, preliminary evidence, although mixed, suggests that aerobic exercise training can improve blood pressure control, lipid profiles and mental health in this population. A few larger studies are now available showing that aerobic training can also improve physical functioning and performance. The impact on survival or hospitalisation has not been determined. Resistance exercise training, although less studied, appears to increase muscle strength and size and may also improve functioning. There have been several reports of successful combined exercise interventions, but the designs have not allowed evaluation of the relative benefits of aerobic and resistance training on physical functioning. Despite the evidence that exercise is safe and beneficial in patients with CKD, dialysis patients remain inactive, and exercise assessment, counselling and training is not widely offered to patients with CKD.

Studies of the barriers to patient participation in exercise and to provider assessment and recommendations are needed so that more widely generalisable interventions can be developed. However, in the interim, patients should be encouraged to participate in moderate physical activity to meet the US Surgeon General’s recommendations. Patients who are weak can benefit from strength-training interventions. Resistance and aerobic exercise programmes should be initiated at relatively low intensity in patients with CKD and progressed as slowly as tolerated in order to avoid injury and discontinuation of exercise. For patients...
on haemodialysis, incorporation of exercise into the dialysis session may increase patient participation and tolerance of exercise.

Patients with chronic kidney disease (CKD) are physically inactive\(^1\) and have markedly reduced peak oxygen consumption (\(\dot{V}O_{2\text{peak}}\))\(^{1,2-9}\) self-reported physical functioning\(^{10,11}\) and physical performance\(^{10,12}\) compared with individuals with normal kidney function. Reduced physical functioning is associated with increased mortality and poor quality of life (QOL) in this population.\(^{11,13}\) Preliminary results suggest that, as for the general population, sedentary behaviour is associated with increased mortality in patients with end-stage renal disease (ESRD).\(^{14}\)

Furthermore, patients with CKD have a high burden of other chronic diseases for which exercise is beneficial. Specifically, 45% of incident dialysis patients in the US have diabetes mellitus and 79% have a history of hypertension.\(^{15}\) Patients with CKD also have a higher prevalence of cardiovascular disease than the general population,\(^{16}\) and cardiovascular disease is the number one cause of mortality in this group, accounting for approximately 50% of all deaths.\(^{15}\) Thus, the potential benefits of exercise training in this population are numerous and include improvements in:

- exercise capacity
- strength
- QOL, related to improved functional capacity or direct effects on mood
- blood pressure control
- control of diabetes
- survival.

Unfortunately, despite the myriad potential benefits of exercise in patients with CKD, research confirming these benefits has been limited and is often of poor quality. The optimal programme of exercise training for patients with CKD has not been identified,\(^{17}\) and prescription of exercise to these patients is not routine.\(^{18}\) Nephrologists caring for patients with CKD do not regularly evaluate their patients for exercise participation or physical functioning and do not generally provide advice about exercise to their patients. The focus of care is on disease management rather than prevention, and exercise is under-utilised as a therapeutic tool. The purpose of this review is to examine the evidence available upon which to make recommendations about exercise in patients with CKD and then provide recommendations for exercise to achieve specific desired results.

### 1. Aerobic Exercise Training

It was noted in the 1980s that patients with ESRD have markedly reduced \(\dot{V}O_{2\text{peak}}\) compared to age- and sex-matched norms for sedentary individuals.\(^{4,6,19-21}\) As a result, several studies have been performed to examine the effects of aerobic exercise training on \(\dot{V}O_{2\text{peak}}\) in this population.\(^{15,7,9,22-31}\) Although the intensity and duration of exercise in the studies vary, all have included initial moderate aerobic training progressing to vigorous training for \(\geq30\) minutes three times per week for \(\geq8\) weeks up to 12 months (most studies 3–6 months). On average, aerobic exercise training for 8 weeks to 6 months improves \(\dot{V}O_{2\text{peak}}\) by about 15% (figure 1), but the variability is wide from study to study, and many studies have been uncontrolled.\(^{9,7,9,22,25,29,30}\) Only two of these studies included patients on peritoneal dialysis;\(^{24,28}\) otherwise, these data pertain entirely to haemodialysis patients. The majority of studies were conducted before the routine use of erythropoietin to control the anaemia associated with CKD, but the effects of aerobic training appear to be similar among patients receiving erythropoietin (figure 1). Thus, although it is firmly established in the literature that aerobic exercise training increases \(\dot{V}O_{2\text{peak}}\) in patients with ESRD, the total number of patients studied is small, particularly if one considers only those for whom a control group was also assembled. Furthermore, the improvement in \(\dot{V}O_{2\text{peak}}\) is modest, and patients do not approach their predicted \(\dot{V}O_{2\text{peak}}\) levels even after training. Data on the effects of aerobic exercise training...
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Receiving haemodialysis, usually a small fraction of available patients.\(^7,\)\(^29\) Secondly, this strategy is resource-intensive. For these reasons, it is unclear to what extent this type of programme can be generalised to the larger population of patients with CKD, at least within the current framework of delivery of care for this group. Specifically, it is not clear that more typical (i.e. less healthy) patients with CKD will be willing to undergo vigorous exercise training, and reimbursement for ‘renal rehabilitation’ is non-existent. Furthermore, it is not clear whether such vigorous training is necessary to derive many of the potential benefits of exercise.

Another important caveat to be considered when interpreting the increases in \(\dot{V}O_2\text{peak}\) as a result of aerobic exercise training is that the links between change in \(\dot{V}O_2\text{peak}\) and improvements in physical performance, self-reported physical functioning, or health-related QOL (HR-QOL) have not been established in this population. Thus, the extent to which a 15% increase in \(\dot{V}O_2\text{peak}\) actually improves the lives of patients with CKD has not been established. This lack of information may further limit patient and provider enthusiasm for committing to such training.

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These studies of the effects of exercise on \(\dot{V}O_2\text{peak}\) have provided important information. Because \(\dot{V}O_2\text{peak}\) is a well recognised physiological measure related to exercise capacity, it is an ideal measure to test whether patients with CKD could respond to exercise training in a manner similar to other patient groups (a finding that was by no means predetermined). Furthermore, several studies examined the determinants of \(\dot{V}O_2\text{peak}\) to elucidate the mechanisms of exercise intolerance in patients with CKD.\(^5,\)\(^33\) However, the qualified success of vigorous aerobic exercise training designed to increase \(\dot{V}O_2\text{peak}\) should be put into a wider perspective. First, the patients who have been studied to date have generally been the healthiest individuals receiving haemodialysis, usually a small fraction of available patients.\(^7,\)\(^29\) Secondly, this strategy is resource-intensive. For these reasons, it is unclear to what extent this type of programme can be generalised to the larger population of patients with CKD, at least within the current framework of delivery of care for this group. Specifically, it is not clear that more typical (i.e. less healthy) patients with CKD will be willing to undergo vigorous exercise training, and reimbursement for ‘renal rehabilitation’ is non-existent. Furthermore, it is not clear whether such vigorous training is necessary to derive many of the potential benefits of exercise.

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protein-cholesterol\(^8,9\) and others not showing any changes.\(^{23-25}\) Given the small numbers of patients and lack of control groups in most of these reports, the effect of aerobic exercise training on lipid metabolism remains unclear. An early study reported that there were improvements in blood pressure control after aerobic exercise training,\(^8\) while others reported no changes in blood pressure control or medication.\(^7,24-26\)

Miller et al.\(^{14}\) designed a study specifically to investigate the effects of exercise on blood pressure control in patients on haemodialysis. The exercise programme was a 6-month cycling exercise programme during dialysis in which patients initially exercised as long as possible with encouragement to increase time up to 30 minutes. When the patients reached 30 minutes, they were encouraged to increase resistance. The programme was offered to 92 eligible patients from a total of 107 patients dialysing in a single dialysis unit. Of these, 40 agreed to participate, and 35 served as non-exercising controls. At the end of 6 months, 24 patients were still participating in the exercise programme. The authors noted that at the end of 6 months, every patient had increased exercise time, but only 21\% had increased resistance. Of the 16 patients who discontinued exercise, 10 patients (25\%) did so voluntarily for reasons ‘not related to medical problems’. The patients who completed 6 months of training had no changes in blood pressure before or after dialysis but were, on average, taking fewer antihypertensive medications to achieve that blood pressure than before the programme, while the control group did not have any significant change in blood pressure or antihypertensive medications. Thus, to date, the only study specifically designed to evaluate blood pressure control demonstrated a beneficial effect of exercise training.

A few studies have focused on the effects of aerobic exercise training on mental health or HR-QOL among patients on haemodialysis. Carney et al.\(^{15}\) reported that patients who underwent vigorous aerobic exercise training three times per week for 6 months (\(n = 10\)) reduced their scores on the Beck Depression Index (BDI) by an average of 4.3 points compared with an increase of 2.5 points in patients (\(n = 7\)) who did not exercise (\(p < 0.05\)). At the baseline evaluation, five patients in the exercise training group and three in the control group met the Diagnostic and Statistical Manual of Mental Disorders III (DSM III) criteria for major depression. Following 6 months of exercising, only one of the exercisers continued to meet the criteria, whereas two additional control patients were clinically depressed. Suh et al.\(^{29}\) conducted a study involving 14 patients on maintenance haemodialysis who underwent moderate-intensity aerobic exercise training three times per week for 12 weeks. They reported a trend towards a decrease in depression using a Self-rating Depression Scale (\(p = 0.073\)). In addition, they reported a significant reduction in anxiety and an improvement in quality-of-life measured using an ESRD-specific instrument. Kouidi et al.\(^{36}\) reported a significant improvement in overall QOL and specifically in depression measured by the BDI after 6 months of aerobic exercise training in 24 patients. In contrast, Painter et al.\(^{37}\) included the Medical Outcomes Study Short Form 36-Item questionnaire (SF-36) as a major outcome in a much larger study (see paragraph below) and found no improvement in the mental health components with 16 weeks of aerobic exercise.

The Painter study\(^{37}\) called the Renal Exercise Demonstration Project, was unique in its large size and its focus on physical performance and HR-QOL rather than on \(\dot{V}O_{2\text{peak}}\) as the primary outcome measures. The study included 286 patients and included an 8-week home-based training intervention followed by 8 weeks of cycling exercise during dialysis sessions. Home-based training included recommendations for strengthening and flexibility exercises as well as walking or stationary cycling of gradually increasing duration three to four times per week. Cycling during dialysis was begun for as long as tolerated at an intensity that was determined by the patients’ level of perceived exertion. Patients were encouraged to increase cycling time to a goal of 30 minutes per session and to increase intensity as tolerated based on perceived exertion. Outcomes included physical performance measures such as
gait speed, 6-minute walk distance, and the ability to stand from a chair as well as self-reported physical functioning using the SF-36. The authors were able to demonstrate that physical performance and HR-QOL improved with exercise training and declined in those who were not assigned to the exercise interventions. For example, gait speed increased from 66% to 69% of age-expected norms in the exercising group and decreased from 66% to 59% of age-expected norms among non-exercisers. The Physical Functioning score of the SF-36 increased 12% in the group assigned to exercise and decreased 12% in the control group. The authors noted that the impact of these interventions was more profound in the patients who had worse functioning at baseline. The intervention did include a recommendation for low-intensity strengthening exercises in addition to aerobic exercise training. However, this aspect of the programme was not directly supervised even during the dialysis centre training phase of the study, and <10% of the patients reported following this recommendation. For these reasons, it seems likely that the majority of the reported benefits can be ascribed to aerobic exercise training. This study demonstrated that a broader and less heavily selected group of patients on haemodialysis could participate in exercise training with improvements in functioning. In fact, from the point of view of physical performance and self-reported functioning, it appears that patients who are less able stand to benefit more from beginning an exercise programme.

There is less information available for other groups of patients with CKD. However, preliminary data in patients with CKD before the need for dialysis and patients after kidney transplantation suggest that aerobic exercise training improves VO2peak and strength.

2. Resistance Exercise

Muscle strength is an important determinant of physical performance and ability to live independently in the geriatric population. Patients receiving dialysis are weak when compared with healthy sedentary controls, and it is likely that weakness is an important limitation to physical functioning in patients with CKD. We recently showed that muscle strength was an important predictor of gait speed in patients on dialysis, and Diesel et al. showed that isokinetic muscle strength was an important determinant of VO2peak in a group of patients on dialysis. Thus, it seems likely that resistance exercise training could be of benefit to these patients, and it is surprising that there have been few studies to focus on resistance exercise training or to include resistance training as part of the programme.

Castaneda et al. studied resistance exercise training for 12 weeks to mitigate the effects of a low-protein diet in patients with advanced CKD prior to the initiation of dialysis. The average glomerular filtration rate was 24.8 mL/min in the trained (n = 14) and 27.5 mL/min in the control (n = 12) groups. Patients were trained three times per week on five exercise machines and performed three sets of eight repetitions at 80% of one-repetition maximum (1RM). Those who completed the resistance training improved their strength an average of 32% compared with a 13% decline in the group who did not exercise (p < 0.001), and muscle biopsies showed hypertrophy of type 1 and type 2 muscle fibres.

Headley et al. reported on the results of a 12-week resistance exercise training programme in a group of ten patients on haemodialysis. The programme consisted of two supervised training sessions per week during which, after a 5- to 10-minute warm-up period, subjects performed eight to nine weight machine exercises designed to strengthen the whole body. The programme began with one 10-repetition set for each exercise with additional sets and increased weight added as tolerated. In addition to supervised training sessions, subjects were given Theraband exercise bands and instructed to follow a video at home once per week that covered nine exercises. The resistance of the bands and the number of sets were also progressed, and subjects kept logs of the dates on which they exercised.

1 The use of trade names is for product identification purposes only and does not imply endorsement.
completed exercise training at home. At the end of the training programme, the patients increased their peak torque of the leg extensors of the dominant leg at the 90°/sec velocity by 12.7 ± 3.6%, but there was no significant change in peak torque at 120°/sec or 150°/sec or in grip strength in either hand. Patients improved on several physical performance tests after the training, including a 6-minute walk test, normal and maximum gait speed, and time to complete a sit-to-stand test 10 times. There were no complications or injuries related to the exercise training. A randomised, controlled trial of resistance exercise training during dialysis sessions is underway,[50] but results are not yet available.

3. Combined Resistance and Aerobic Exercise

Kouidi et al.[51] enrolled seven patients receiving chronic haemodialysis into a 6-month exercise rehabilitation programme that included aerobic exercise and strengthening exercise. The programme consisted of 90-minute sessions three times per week on non-dialysis days. Specifically, the training routine included a 10-minute warm-up followed by 50 minutes of aerobic exercises, 10 minutes of low-weight resistance exercise, 10 minutes of stretching exercises and 10 minutes of cool-down. They examined the effect of this programme on VO2peak and on muscle morphology. The programme resulted in an average increase in VO2peak of 48%, an increase that is more than double the magnitude of any programme involving aerobic exercise training alone (figure 1). They also reported a remarkable improvement in muscle atrophy, with a 25.9% increase in the mean area for type 1 fibres and a 23.7% increase in mean area of type 2 fibres. Although they characterised their training programme as ‘mainly of aerobic type’, the notable muscle hypertrophy and the stunning improvement in VO2peak suggest that the strength training portion may have contributed important additive or synergistic effects to the aerobic training. It is possible that muscle atrophy in some patients with ESRD is so severe as to limit VO2peak because of the small mass of working muscle. Unfortunately, the design of this study did not allow the separate contributions of aerobic and resistance training to be delineated.

Two other studies of mixed exercise interventions have included control groups.[52,53] Mercer et al.[52] conducted a non-randomised controlled trial of an exercise rehabilitation programme that occurred over a 12-week period and included a combination of intermittent aerobic exercise on a cycle ergometer and a local muscular endurance circuit of eight exercises. 212 patients were potentially available to participate, but only 22 volunteered and were eligible. Thirteen were slated for the exercise, but only seven completed the study. These patients showed improvements in performance of a 50m walk (15 ± 5.8%), stair climbing (22 ± 11%) and stair descent (18 ± 12%) after the exercise intervention.

DePaul et al.[53] conducted a randomised trial of a mixed exercise intervention among patients on haemodialysis who were receiving erythropoietin. The intervention consisted of progressive resisted isotonic quadriceps and hamstrings exercise and training on a cycle ergometer three times weekly for 12 weeks. Cycling exercise was performed during dialysis, and weight training took place before or after dialysis according to patient preference. Twenty subjects were randomised to the exercise group, of whom 15 were available to be retested after 12 weeks. The exercise group increased the workload at which their rating of exertion on the Borg scale[54] was ‘somewhat strong’ by 20 ± 18W, compared with an increase of 6 ± 13W for the control group (p = 0.02). At 12 weeks, the intervention group also increased their combined hamstring and quadriceps strength by 21.2 ± 22.4kg (p = 0.02 vs control group). There were no significant or clinically important differences in disease-specific QOL or performance on a 6-minute walk test between the study groups. The authors noted that the group was particularly high-functioning at baseline, with scores on the Physical Functioning scale of the SF-36 and on the 6-minute walk test that were close to reported values for healthy groups. These values were significantly higher than baseline scores in the Renal Exercise Demonstration Project,[57] in which it was...
noted that patients with lower functioning at baseline improved to a greater degree.\[38\]

As for other types of exercise training, less information is available about patients with CKD not yet requiring dialysis. However, one study compared the response to 12 weeks of combined resistance and endurance training in patients aged >60 years with an average glomerular filtration rate of 18 ± 5 mL/min and healthy control subjects.\[55\] The exercise programme in patients with CKD resulted in increases in quadriceps strength measured by 1RM from 8 ± 5kg to 13 ± 5kg and an increase in dynamic muscular endurance of 30% on average. These results were similar to changes observed in healthy controls. In addition, the CKD patients increased their 6-minute walking distance from 390 ± 128m to 452 ± 99m (p = 0.002) and their functional mobility measured by the timed ‘Up & Go’ test\[56\] by an average of 2 seconds or 18% after exercise training.

Taken together, these results suggest that combined training programmes can be quite beneficial in patients on dialysis and possibly those with advanced CKD not yet on dialysis. However, the study of combined exercise programmes in patients with CKD is still in its early stages with small studies of varying interventions. Few data are available to allow comparisons of different exercise modalities or programmes. Such data would facilitate development of more widespread programmes and would be a first step towards targeting interventions to suit individual patient needs. Fortunately, a trial is currently underway to compare aerobic exercise, resistance exercise and a combination of these two modalities (Kopple J, personal communication), and information gained from this endeavour will be highly illuminating.

4. Risks of Exercise

The most common risk of exercise participation in the general population is musculoskeletal injury, whereas the most serious risks are those of cardiac origin, ranging from dysrhythmia to ischaemia to sudden death. The risk of both types of adverse events is higher with high-intensity exercise than with submaximal exercise.\[57\]

There have been no studies specifically designed to assess the risk of exercise among patients with CKD; available information comes from case reports and from mentions of side effects that occurred during studies of the effects of exercise. Musculoskeletal risk may be increased in patients with CKD as a result of hyperparathyroidism and bone disease. Their bone disease may place them at higher risk of fracture,\[58\] and spontaneous quadriceps tendon ruptures have been reported,\[59-61\] probably as a result of poorly controlled secondary hyperparathyroidism. However, it is possible that weight-bearing or strengthening exercises could, in the long term, decrease the risks of falls and increase bone density, further lowering the risk of fracture. The up-front risks of injury can be minimised by less strenuous testing, when feasible, such as the use of 3RM or 5RM in lieu of 1RM for strength testing, and by beginning training programmes at lower intensity and progressing gradually as tolerated. These strategies have been employed in many of the studies reviewed in this article with great success, since the number of adverse events associated with exercise testing and training has been extremely low. Furthermore, improved muscle strength and overall fitness achieved through an appropriately prescribed programme of progressive exercise could reduce the likelihood of injury during exercise and associated with falls, possibly lowering the overall risk of musculoskeletal injury.\[57\] Specific studies designed to assess balance of risks and benefits of exercise training among patients with CKD would be of great value.

The risk of cardiac events during maximal exercise testing is low, in the order of 0.5 per 10 000 tests for death, and 3.6 per 10 000 tests for myocardial infarction, estimates that are based on tests conducted in healthy and diseased populations.\[57,62-64\] There are no data specifically addressing the risks in patients with CKD. It is likely that their risk is higher than in the healthy general population because of the high prevalence of risk factors for cardiac disease and known cardiac disease, but their risk is probably not significantly higher than the risk in populations undergoing diagnostic tests
for cardiovascular disease. Again, no untoward cardiac events have been reported in any of the published studies of exercise testing in patients with ESRD and, although these patients were a highly select group, the risk appears to be low. The risk of cardiac events during submaximal exercise (i.e. training) is even lower than that for maximal testing. Although the risk of a cardiac event is transiently increased during exercise, overall that risk is attenuated in individuals with higher levels of habitual physical activity.

A major purpose of medical screening prior to exercise participation is to determine which patients are at increased risk of cardiovascular events. However, all patients with ESRD or advanced CKD are at increased risk for cardiopulmonary disease. Thus, the existing guidelines provide little assistance in determining whether exercise testing should be performed before initiating an exercise programme or which patients should be tested. The necessity for testing should be related to the proposed intensity of training and the patient’s symptom or disease status. Patients with symptoms suggestive of cardiac disease or with known disease should undergo exercise testing prior to participation in vigorous training programmes. However, many of the reported studies of moderate-intensity exercise training in patients with CKD have relied on history, physical examination, and in some cases ECG testing, to determine whether patients may participate in exercise training programmes without adverse events, suggesting that this strategy is appropriate when moderate-intensity training is involved.

In addition to proper medical screening, the risks related to exercise in patients with CKD can be minimised by including appropriate warm-up and cool-down exercises, ensuring that the environment and equipment are optimal (including proper footwear), starting a programme slowly and progressing exercise gradually, avoiding high-impact activities, and ensuring proper performance of exercise, particularly weight-lifting exercise. Some disease-specific considerations may also reduce risk. Attention to patients’ volume status and blood pressure control is important in this population. Patients with advanced CKD often have increased extracellular fluid that may contribute to reduced exercise tolerance, and judicious use of diuretic medications may be helpful. Similarly, patients with ESRD should have their dry weights assessed frequently to avoid volume overload and may tolerate exercise best during dialysis or on a day after a dialysis session.

5. Exercise Participation by Patients with Chronic Kidney Disease

Unfortunately, despite >20 years of published data on the effects of exercise in patients with CKD, participation in exercise or physical activity by these patients remains low, as evidenced by several recent reports. In a study using data from the United States Renal Data System (USRDS) Dialysis Morbidity and Mortality Study, 35% of 2264 dialysis patients reported performing no leisure time physical activity whatsoever, and less than half re-
One factor that affects patient participation in exercise is input from healthcare providers. A recent study addressed the extent of nephrologist assessment and encouragement of physical activity by surveying 505 nephrologists attending a national meeting. Thirty-eight percent of the nephrologists surveyed said that they assessed patients’ level of physical activity and counselled inactive patients to increase activity ‘often’ or ‘almost always’. Younger, less active, and male nephrologists were less likely to provide exercise counselling. Nephrologists who did not provide routine counselling endorsed the following barriers to counselling: lack of time; lack of confidence in their ability to counsel patients; and lack of conviction that patients would respond. In addition, non-counselling nephrologists were more likely to think that other medical issues were more important than exercise. These findings highlight three needs. First, more information is needed about whether exercise provides long-term benefit and a survival advantage in this population. Such data would potentially address the concern that other medical issues are more important than exercise. Secondly, more information is needed about patient preferences regarding exercise so that successful strategies can be implemented and providers can be confident that a reasonable proportion of patients will participate. Thirdly, nephrologists need training in...
methods of exercise assessment and counselling. This could address the lower rates of exercise counselling among fellows and younger nephrologists and the nephrologists’ concern about a lack of competence in this area.

Preliminary data suggest that exercise counselling can increase physical activity among patients on dialysis. Tawney et al.\textsuperscript{[67]} performed a randomised trial of an exercise assessment and counselling strategy to increase patients’ physical activity and functioning. Baseline questionnaires were completed by 217 patients. Of these, 99 passed the medical screening and agreed to be randomly assigned to receive the intervention or not. The intervention consisted of: (i) an assessment of the patient’s current level of activity and functional ability; (ii) collaborative goal setting between patient and the provider that accounted for the patient’s preferences and lifestyle; (iii) problem solving with the patient about barriers to physical activity; and (iv) identifying supports that help the patient maintain an increased level of physical activity.\textsuperscript{[67]} Unfortunately, the barriers identified by patients and the problem solving strategies employed were not explicitly reported. However, the patients randomly assigned to the intervention increased their total activity time (time spent engaged in any type of moderate or vigorous activity) by an average of 1.75 hours per week (p < 0.05) compared with no increase in activity time among the patients in the control group. Most of the increase was in moderate-intensity leisure activity, the target of the intervention, but it is important to note that activity time was assessed by patient report rather than objective measures. In addition, there was a trend toward improvement in the Physical Function score of the SF-36 among the patients assigned to the exercise assessment and counselling (p = 0.085). This is a preliminary demonstration that counselling can increase activity levels among patients on haemodialysis.

7. What Can the Literature Tell Us About the Optimal Exercise Programme?

In order to design successful exercise programmes that will be accessible and acceptable to large numbers of patients with CKD, it is important to know what types of exercise produce the greatest clinical benefit in this population and what types of training programmes can recruit and retain large numbers of patients on dialysis. Much of this work has yet to be done, but some information can be gleaned from the available literature. As for comparisons of the benefits of different programmes, little is known. Konstantinidou et al.\textsuperscript{[69]} compared the effects of centre-based training to those of dialysis unit-based and home-based training on VO2peak. They reported a higher dropout rate among the patients assigned to in-centre training and cited lack of time, transportation difficulties and medical reasons unrelated to exercise as the reasons. The patients benefited from all three types of training, but the cardiovascular effects were greatest with the centre-based training. The authors concluded that intense exercise training on non-dialysis days is the most effective way of training. However, this conclusion should be tempered somewhat because it only refers to exercise-induced changes in VO2peak and not other potential benefits. Furthermore, the exercise interventions were so different in the three groups that it is uncertain whether the differences in VO2peak were related to different intensities of training, different activities used for training, or different levels of adherence to the programme since adherence to the home training was not monitored. There is a great need for systematic comparison of the effects of different exercise interventions on outcomes of interest to patients with CKD and their healthcare providers, including physical performance, self-reported physical functioning and HRQOL. More concrete information about benefits that affect QOL should help motivate providers to recommend exercise more enthusiastically and patients to adopt it. However, it is also important to understand what types of exercise are most acceptable to patients.

Many of the studies of exercise training in patients with CKD have included a highly selected and relatively healthy subset of the population. In some cases, this was by design because a relatively vigorous intervention was under study and because the
goal was to test whether the healthiest group of patients could demonstrate an effect of training. However, it is also clear that it is difficult to enlist patients with CKD into exercise programmes.

Shalom et al.\[7\] were one of the first groups to report on the number of patients excluded from study participation. They planned an in-centre, supervised aerobic training programme to be performed on non-dialysis days. Of 174 patients on dialysis, 70 (40%) lived too far away to participate, and 54 (31%) were excluded because of coexistent medical problems. Consequently only 50 patients (29%) remained eligible for participation. Although all were offered the chance to participate, only 14 actually enrolled. Of those who enrolled in the exercise programme, only 50% attended more than half of the training sessions. These data highlight two problems with implementation of widespread exercise programmes for patients on dialysis. First, a large number of patients were excluded for medical reasons because the planned intervention was a vigorous training programme. Secondly, because the training was to occur in an exercise facility on non-dialysis days, geographic considerations limited participation by many patients, and most of those who did not live a prohibitive distance from the centre still found the burden of additional visits for exercise training to be too high.

Incorporation of exercise into the dialysis sessions is a way to reduce the time burden of exercise for patients on haemodialysis, and several studies have used this venue. However, even with this strategy, participation has been low in some studies. Miller et al.\[34\] incorporated exercise training into dialysis sessions in a programme that was implemented by dialysis personnel in an attempt to make exercise available to all patients. Unfortunately, they found that, despite no cost to the patient and no extra time requirement for exercise, <40% of the patient population participated.\[34\] Of the patients who initially participated, only 60% still were exercising at 6 months, and only 22% of potential exercisers completed the programme. They concluded that reasons for low participation in this population need to be investigated and strategies to increase participation tested.

The Renal Exercise Demonstration Project also tested an exercise programme that included dialysis unit-based training supervised by existing dialysis unit staff after an initial home-based phase.\[37\] Patients were encouraged to begin exercising mostly by walking. Walking is an activity that is less vigorous than typical training programmes and perhaps less threatening to patients who were very sedentary at baseline. Thus, medical criteria for patient exclusion were less stringent and patient enthusiasm for the programme was higher than for many of the supervised programmes. The relatively low intensity of initial exercise followed by exercise during dialysis may be responsible for the large numbers of patients they were able to recruit. Nevertheless, the success of this programme may be difficult to duplicate. It was performed in selected dialysis units where staff indicated enthusiasm for the programme in advance and, despite the initial interest of the staff, documentation of patients’ exercise participation was incomplete (Painter P, personal communication). This study suggests that home-based or dialysis-based training beginning at moderate intensity can be a more successful way to initiate training in lower functioning patients. However, more information is needed on ways to increase dialysis unit staff participation and support of exercise programmes.

Finally, since most of the available data are derived from studies of patients undergoing haemodialysis, more information about the effects of different training programmes in other groups of patients with CKD is needed. This includes pre-ESRD patients, peritoneal dialysis patients and kidney transplant recipients.

### 8. Recommendations

While there are insufficient data available in patients with CKD to make definite recommendations, the available data and information gathered in studies of exercise in healthy individuals or other chronic disease groups can be used to form the basis for some preliminary recommendations. The first re-
requirement is that the care team consider exercise and physical functioning in individuals with CKD. Patients should be routinely evaluated to determine their level of exercise participation, cardiac risk factors and physical functioning so that an exercise programme can be prescribed when appropriate. Prior to prescription of moderate or vigorous exercise, patients should be screened for symptoms suggestive of cardiac disease. Low- to moderate-intensity aerobic exercise three or more times per week should be recommended to all patients who are able to do so because of the well established benefits in the general population. The association between inactivity and mortality in ESRD[14] provides further support to the notion that increased activity would be beneficial in this population. Strength training should definitely be recommended for patients who report or manifest muscle weakness or poor physical performance such as difficulty walking, climbing stairs, or rising from a chair. However, it is possible that all patients could benefit from strength training because: (i) they are generally weaker than healthy individuals even if they do not report weakness; and (ii) strength is likely to be a major determinant of physical functioning and thus QOL.

Aerobic training should focus on large muscle activities such as walking or cycling. Exercise should begin at low intensity (i.e. 50–60% of peak heart rate or \( \text{VO}_2\text{peak} \) if known) and short duration (10–20 minutes per session). Although these guidelines are based on peak heart rate and \( \text{VO}_2\text{peak} \), it may also be useful to base the initial exercise prescription on patients’ rating of perceived exertion (RPE) using the Borg scale.[84] This is because heart rate and blood pressure responses may be variable[31] and because RPE is a direct measure of exercise tolerance, an important factor for adherence. Exercise should progress gradually to higher intensity and longer duration. Selected patients may reach a target of 85% predicted maximal heart rate and/or \( \text{VO}_2\text{peak} \) for 30–60 minutes per session for \( \geq 3 \) days per week. However, the low participation rates and high drop-out rates of the more vigorous training studies suggest that many patients may be unwilling or unable to exercise this vigorously. It should be recognised that any increase in aerobic activity is likely to be beneficial, and patients should be encouraged to progress at a pace that is acceptable to them and to continue to exercise at whatever level they can achieve.

Haemodialysis patients should perform exercise during dialysis if possible or on their non-dialysis days. Peritoneal dialysis patients may be more comfortable performing high-intensity exercise without fluid in the abdomen, but exercise should first be tried with fluid in for patients on continuous therapy. Exercise without drainage of peritoneal fluid is preferable because it avoids the added time or complexity that would be necessary to coordinate exercise with the dialysis exchanges and also prevents a decrement in dialysis dose because of exercise. Patients should only be advised to drain the peritoneal fluid before exercise participation if they are uncomfortable exercising with abdominal fluid in place.

Resistance exercise should also be initiated at low intensity and progressed gradually as tolerated. Free weights, weight machines, isokinetic machines, or resistance bands can be used as long as patients are educated on proper technique and started at low intensity to avoid injury. Using free weights, for example, it is recommended that the initial prescription be based on 3RM or higher rather than 1RM to avoid tendon injuries. Initial training should be initiated at approximately 50% of this value rather than a higher intensity as is common in healthy populations. Training can then be progressed gradually to high intensity as long as no difficulties are encountered. Although there are no data specific to patients with CKD, strength training in older individuals increases tendon stiffness, decreasing the risk of subsequent injury.[80] Therefore, with gradual progression, there is probably no maximum weight that can be safely lifted.

All major muscle groups should be trained in three sessions per week. The lower extremities can be emphasised in individuals with impaired ability to ambulate, climb stairs, or rise from a chair unassisted. Haemodialysis patients with permanent vascular access devices in the arm often avoid exercising their upper extremities out of fear of damaging
their access. Such patients should be encouraged to exercise the access arm as long as weight is not borne directly on the access itself. Patients on peritoneal dialysis should be cautioned to avoid the Val-salva manoeuvre while lifting weights.

Warm-up and cool-down sessions of 5–10 minutes should proceed and follow each aerobic or resistance exercise session. In addition, flexibility exercises such as stretching or yoga could help patients maintain or improve their range of motion and might also improve gait, balance and coordination. Proper instruction on stretching should be given. In particular, patients should be advised to maintain each stretch below the discomfort threshold.\(^{17}\)

9. Conclusions

Patients with CKD and ESRD are a sedentary population with low \(\dot{V}O_2\)peak, poor self-reported physical functioning, and a high burden of cardiac disease and other comorbid conditions potentially improved with exercise. It has been shown that vigorous aerobic exercise training can improve \(\dot{V}O_2\)peak and self-reported physical functioning, but the effects of exercise training on cardiovascular risk have not been well studied.

More research is necessary to determine the optimal exercise programme for patients with CKD. It is likely that different subgroups of patients will benefit from different exercise programmes tailored to their specific needs and abilities. Such programmes need to be easily accessible to patients with CKD.

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