RESEARCH PAPER

Personalized Exercise Interventions for Improving Functional Status and Physical Activity Among Adults Receiving Maintenance Haemodialysis: A Systematic Review

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Abstract
Background: Adults receiving maintenance haemodialysis frequently experience reduced functional status, physical inactivity, muscle weakness, fatigue, and poor health-related quality of life. Conventional exercise programmes often apply standardized protocols that may not adequately address the diverse clinical characteristics, functional limitations, and exercise tolerance of individual patients. Personalized exercise interventions have emerged as a promising rehabilitation strategy by tailoring exercise prescriptions to patients' physical capacity, comorbidities, and treatment-related factors.
Aim: To systematically review the evidence on the effectiveness of personalized exercise interventions for improving functional status and physical activity among adults receiving maintenance haemodialysis.
Methods: A systematic review of published studies was conducted using electronic databases, including PubMed/MEDLINE, Scopus, Web of Science, Embase, Cochrane Library, and CINAHL. Original studies evaluating individualized or personalized exercise interventions in adults receiving maintenance haemodialysis were considered. Eligible studies included randomized controlled trials, quasi-experimental studies, and controlled clinical trials. Data were extracted on study characteristics, intervention components, outcome measures, and major findings. Functional status outcomes included the Six-Minute Walk Test (6MWT), Timed Up and Go Test (TUG), Sit-to-Stand Test (STS), Short Physical Performance Battery (SPPB), gait speed, and muscle strength, while physical activity outcomes included daily step count, accelerometer-derived activity, and validated physical activity questionnaires.
Results: The included studies demonstrated that personalized exercise interventions significantly improved functional status and physical activity among adults receiving maintenance haemodialysis. Aerobic, resistance, combined, intradialytic, home-based, and technology-assisted exercise programmes improved muscle strength, exercise capacity, mobility, walking distance, gait speed, and overall physical performance. Individualized exercise prescriptions also increased daily physical activity, reduced sedentary behaviour, decreased fatigue, and enhanced health-related quality of life. Most studies reported good adherence and minimal exercise-related adverse events, indicating that personalized exercise interventions are both feasible and safe when appropriately supervised.
Conclusion: Personalized exercise interventions represent an effective rehabilitation strategy for adults receiving maintenance haemodialysis. Individualized exercise prescription based on patients' functional capacity, clinical condition, and exercise tolerance improves physical function, promotes an active lifestyle, and enhances quality of life. Incorporating personalized exercise into routine haemodialysis care may improve long-term clinical and patient-reported outcomes. Further high-quality multicentre randomized controlled trials are needed to establish standardized personalized exercise protocols and evaluate their long-term effectiveness.
Keywords: Maintenance haemodialysis; Personalized exercise; Individualized exercise; Functional status; Physical activity; Exercise capacity; Muscle strength; Intradialytic exercise; Home-based exercise; Rehabilitation; Systematic review.
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Introduction

Burden of Chronic Kidney Disease and Maintenance Haemodialysis

Chronic kidney disease (CKD) is a progressive, irreversible, multifactorial disease defined by abnormalities of kidney structure or function, present for at least three months, and having health consequences. CKD is classified according to the most recent KDIGO 2024 Clinical Practice Guideline on the basis of cause of kidney disease, glomerular filtration rate (GFR), and albuminuria (CGA classification) as a standard system for diagnosis, prognosis, and management. Among the non-communicable diseases, CKD has become one of the most rapidly increasing worldwide, due to population ageing and increasing prevalence of diabetes mellitus, hypertension, obesity and cardiovascular diseases.(1,2)

CKD is a major public health challenge globally because of its increasing prevalence, high morbidity, premature mortality and large healthcare costs. Recent estimates suggest that more than 850 million people worldwide are living with some form of kidney disease, making it one of the most common chronic diseases globally. The Global Burden of Disease (GBD) Study 2021 data showed that the prevalence of chronic kidney disease (CKD) is approximately 10% of the world population and prevalence and incidence have been increasing steadily for the last 3 decades. The disease also correlates with a considerable increase in disability-adjusted life years (DALYs) and healthcare costs, especially in low- and middle-income countries where preventive nephrology services are still not easily accessible. (1,3,4)

CKD is one of the most common and costly health conditions in the United States. It is more than a kidney problem; it is also associated with cardiovascular complications, hospitalization, reduced productivity, reduced quality of life, and early mortality. The GBD 2021 analysis estimated a total of over 673 million prevalent cases of CKD and over 1.5 million deaths attributable to CKD globally in 2021, with the burden of the disease continuing to increase in almost all geographic regions. In addition, projections indicate that CKD will emerge as a leading cause of death worldwide over the coming decades if effective preventive and therapeutic strategies are not put into place.(5,6)

When CKD progresses to kidney failure patients need kidney replacement therapy (KRT) such as haemodialysis, peritoneal dialysis or kidney transplantation to sustain life. Haemodialysis remains the most common modality of KRT worldwide, as kidney transplantation is not widely available and haemodialysis is suitable for many patients with advanced disease. It is estimated that around 4.6 million people worldwide are currently on kidney replacement therapy internationally, with most kidney failure cases treated with haemodialysis. However, the majority of patients needing dialysis do not receive it due to financial, geographical and healthcare resource limitations, particularly in low-resource settings. (6,7)

Maintenance haemodialysis is generally performed 3 times weekly, each session lasting approximately 4 hours. Haemodialysis is effective in clearing metabolic waste products and excess fluid but is unable to replace the endocrine and metabolic functions of healthy kidneys. Hence, patients often suffer from persistent physiological stress, chronic inflammation, metabolic abnormalities and several dialysis-related complications. These factors lead to the progressive decline in the physical functional capacity, muscle strength, exercise capacity, nutritional status and health related quality of life. Furthermore, long-term dialysis treatment is repetitive, which often leads to sedentary behaviour and subsequently physical deconditioning and functional impairment. (8,9)

The global need for maintenance haemodialysis continues to rise with the increased prevalence of diabetes mellitus, hypertension, obesity, and an aging population. Haemodialysis requires specific infrastructure, skilled health care workers, complex equipment and lifelong treatment, putting health systems under huge economic pressure globally. Therefore, CKD and kidney failure carry a high financial burden for patients, families, health care providers, and national health systems. The societal impact of the disease is further exacerbated by indirect costs, including disability, loss of employment, decreased productivity, caregiver burden, and repeated hospital admissions, in addition to direct medical costs. (2,7,8)

Despite impressive advances in dialysis technology and medical management, mortality in patients on maintenance haemodialysis remains substantially higher than in the general population. Cardiovascular disease remains the major cause of death, and frailty, protein-energy wasting, inflammation and physical inactivity are major contributors to adverse clinical outcomes. There is growing evidence that targeting these modifiable factors with holistic rehabilitation strategies incorporating tailored exercise interventions may improve functional capacity, physical activity levels and quality of life. Therefore, understanding the burden of CKD and maintenance haemodialysis is an essential basis to assess any interventions targeting improved patient-centered outcomes.(3,8,9)

Functional decline and physical inactivity are some of the most common and disabling side effects encountered by persons on maintenance hemodialysis. Although hemodialysis is an effective substitute for the kidneys' filtering function, it cannot reverse the systemic effects of CKD, including skeletal muscle atrophy, decreased exercise tolerance, chronic inflammation, and metabolic abnormalities. These physiological alterations and a sedentary dialysis regimen progressively deteriorate physical capability, jeopardizing the survival, independence and quality of life of the patients. Therefore, maintaining physical function has become a key therapeutic goal in the holistic management of patients on hemodialysis. (10,11)

Adults on maintenance hemodialysis have significantly lower levels of physical activity than age-matched healthy controls. Dialysis patients typically undergo three four-hour treatments each week, which limits their ability to engage in regular physical activity. Barriers to daily activity and exercise also include fatigue, muscle weakness, cardiovascular instability, despair, and fear of injury. Many studies have shown that patients are particularly sedentary on dialysis days, sitting or lying down for long periods of time, which accelerates physical deconditioning. (10,12)

Physical function declines early in the course of chronic kidney disease (CKD), and is further impaired with the initiation of maintenance hemodialysis. Multiple pathogenic pathways mediate this decline, including chronic inflammation, oxidative stress, metabolic acidosis, insulin resistance, hormonal abnormalities, protein-energy wasting, mitochondrial dysfunction, and accelerated sarcopenia. All these processes work together to reduce the synthesis of skeletal muscle protein and increase muscle catabolism, resulting in loss of muscle mass, strength and neuromuscular function. Consequently, people on hemodialysis frequently have trouble with routine activities like walking, climbing stairs, lifting objects and maintaining their balance. (13–15)

One of the first signs of functional decline in patients on hemodialysis is muscle weakness. Long-term inactivity primarily hits the large antigravity muscles, which are responsible for postural stability and mobility. This results in a decrease in muscular strength, especially in the lower limbs. Strength of the handgrip, knee extensors, and lower extremity power are usually significantly decreased compared to healthy people. This loss of muscle function results in slower walking speed, poorer balance, decreased mobility, increased risk of falls and greater dependence on daily living tasks. Patients on hemodialysis have been shown repeatedly to have a poorer performance on objective functional tests such as the Six-Minute Walk Test (6MWT), Timed Up and Go Test (TUG), Sit-to-Stand Test (STS), and Short Physical Performance Battery (SPPB) compared to healthy individuals.(16–18)

Functional decline and physical inactivity are closely linked in an auto-catalytic loop. Decreased physical activity can result in muscle atrophy, decreased aerobic capacity and increased exercise intolerance, and decreased physical capacity can further discourage physical activity. This “cycle of deconditioning” is further compounded by symptoms associated with hemodialysis including intradialytic hypotension, muscle cramps, weariness, post-dialysis fatigue, sleep difficulties, and psychological distress. If interventions are not targeted, many patients gradually lose the ability to independently perform self-care and community-based activities.(19–21)

Another important marker of functional decline in the hemodialysis group is frailty. Patients receiving haemodialysis are far more likely to be frail than the general population. Frailty is defined as a state of reduced physiological reserve, weakness, slow walking speed, limited physical activity and unintentional weight loss. It is of note that recent literature suggest that frailty in younger patients on maintenance hemodialysis can be caused by chronic inflammation, sarcopenia, and long-term exposure to uraemic toxins. Frailty is strongly associated with hospitalization, falls, disability, cardiovascular events and mortality. Intervention and early detection are critical. (22–24)

Various patient and treatment-related variables reduce the physical activity level of adults receiving hemodialysis. Activity behavior is related to advanced age, multiple comorbidities, diabetes mellitus, cardiovascular disease, anemia, malnutrition, depression, long-term dialysis duration, inadequate social support, and reduced exercise self-efficacy. Long dialysis sessions, transportation issues, vascular access problems, fear of adverse effects, and the lack of organized fitness programs within dialysis facilities are all barriers to treatment. But these challenges restrict opportunities for an active lifestyle, even as the benefits of regular exercise are increasingly recognized. (19,25,26)

Moreover, recent studies have suggested that sedentary behavior is independently associated with poor health outcomes in hemodialysis patients. Longer uninterrupted sitting time is associated with lower cardiorespiratory fitness, higher muscle weakness, worse physical performance, lower health-related quality of life, and higher all-cause mortality. Importantly, even small increases in daily physical activity (e.g., walking or low-to moderate-intensity activity) are associated with clinically significant improvements in functional performance and patient-centered outcomes . The findings support the integration of individualized physical activity promotion into routine hemodialysis treatment.

Consequently, assessment of functional status and physical activity has become an important component of the management of hemodialysis. Objective measures such as accelerometry, pedometry, gait speed, handgrip dynamometry, and standardized functional performance tests provide useful information about patients’ physical capacities and responses to rehabilitation interventions. Patient-reported outcome measures of physical functioning, mobility, fatigue, and participation in daily life also give further information on the real-world impacts of functional decline. Combined, these assessments provide clinicians with a better means to monitor rehabilitation progress and prescribe tailored exercise regimens.

In general, functional decline and physical inactivity are the two greatest modifiable problems for individuals receiving maintenance hemodialysis. The complex pathophysiology and the significant impact on survival, independence, quality of life and health-care utilization highlight the need for comprehensive rehabilitation techniques. There is an increasing body of evidence for the use of individually tailored exercise therapies to break the cycle of physical deconditioning, maintain functional ability, and improve long-term health outcomes in this vulnerable population.

Aim

To systematically review and synthesize the available evidence on the effectiveness of personalized exercise interventions in improving functional status and physical activity among adults receiving maintenance haemodialysis.

Objectives

1. To identify and summarize the characteristics of personalized exercise interventions implemented among adults receiving maintenance haemodialysis.
2. To evaluate the effects of personalized exercise interventions on functional status, including muscle strength, mobility, balance, walking capacity, and physical performance.
3. To evaluate the effects of tailored exercise interventions on physical activity (including

daily activity, exercise participation and sedentary behavior).

4. To compare the effectiveness of different types of personalized exercise interventions, such as aerobic, resistance, combined, intradialytic, home-based, and technology-assisted exercise programmes.
5. To examine the influence of exercise prescription characteristics (frequency, intensity, duration, progression, and supervision) on functional and physical activity outcomes.
6. To evaluate the safety, adherence and feasibility of individualized exercise interventions in adults on maintenance haemodialysis. To identify gaps in the current literature and provide recommendations for future research and clinical practice regarding individualized exercise programmes in maintenance haemodialysis.

Methods

Study Design

This study was conducted as a systematic review to evaluate the effectiveness of personalized exercise interventions in improving functional status and physical activity among adults receiving maintenance haemodialysis. A structured and comprehensive review methodology was adopted to identify, critically appraise, and synthesize relevant published evidence. The review was carried out following a pre-specified protocol to ensure a transparent, systematic and reproducible process of identifying, selecting, extracting data from studies, assessing study quality and synthesising the evidence.

Inclusion Criteria

- Studies involving adults (≥18 years) on maintenance haemodialysis.
- Studies evaluating personalized, individualized, tailored, or patient-specific exercise interventions.
- Studies reporting outcomes related to functional status (e.g., muscle strength, gait speed, mobility, balance, walking capacity, physical performance) and/or physical activity levels.
- Randomized controlled trials, quasi-experimental studies, controlled clinical trials, prospective cohort studies, and pilot intervention studies.
- Articles published in peer-reviewed journals.
- Studies published in the English language.

Exclusion Criteria

- Studies involving patients receiving peritoneal dialysis, kidney transplant recipients, paediatric populations, or patients with acute kidney injury.
- Studies evaluating non-exercise interventions only.
- Review articles, systematic reviews, meta-analyses, conference abstracts, editorials, letters to the editor, case reports, and study protocols.
- Articles without full-text availability or insufficient outcome data.

Study Selection

The study selection process was conducted in a systematic manner. All records identified through the electronic database search were imported into reference management software, and duplicate records were removed. The titles and abstracts of the remaining articles were screened against the predefined eligibility criteria. Full-text articles of potentially eligible studies were retrieved and assessed for eligibility. Studies fulfilling all inclusion criteria were included in the final review and those not fulfilling the criteria were excluded with documented reasons. Two reviewers independently screened the studies and any disagreements were resolved by discussion or by consulting a third reviewer.

Data Extraction

A standardized data extraction form was developed to ensure consistent data collection. The following information was extracted from each included study:

- Author(s) and year of publication
- Country of study
- Study design
- Sample size and participant characteristics
- Duration of maintenance haemodialysis
- Details of the personalized exercise intervention (type, intensity, frequency, duration, supervision, and progression)
- Comparison or control intervention
- Outcome measures related to functional status and physical activity
- Key findings
- Follow-up period
- Adverse events, adherence, and compliance (where reported)

Quality Assessment

The methodological quality of the included studies was assessed using validated critical appraisal tools appropriate to the study design. Randomized controlled trials were evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool, while non-randomized studies were assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool. Domains assessed included the randomisation process, allocation concealment, blinding, completeness of outcome data, selective reporting and other potential sources of bias. Each study was classified as being at low, some concerns or high risk of bias. Quality assessment was performed independently by two reviewers and any disagreement was resolved by consensus.

Data Synthesis

The data from the included studies were synthesised narratively. The characteristics of the studies, participant demographics, intervention components, outcome measures and key findings were summarized and compared. Personalized exercise interventions were grouped according to exercise type (e.g., aerobic, resistance, combined, intradialytic, or home-based exercise), intervention characteristics (frequency, intensity, duration, supervision, and progression), and reported outcomes. The effects of the interventions on functional status, physical activity, muscle strength, exercise capacity, fatigue, and health-related quality of life were critically analyzed. Due to anticipated clinical and methodological heterogeneity among the included studies, a quantitative meta-analysis was not performed. Where appropriate, findings were presented in summary tables to facilitate comparison across studies.

Results

Study Selection

The electronic database search identified studies from PubMed, Scopus, Embase, Web of Science, Cochrane Library, and CINAHL. After removing duplicate records, the remaining articles were screened based on their titles and abstracts. Full-text articles meeting the eligibility criteria were assessed for inclusion. Studies that fulfilled the predefined inclusion criteria were included in the final review, while those not meeting the criteria were excluded.

Characteristics of Included Studies

The studies included were from 2015–2025 and were from different countries (United States, Canada, United Kingdom, Australia, Brazil, China, Japan, South Korea, and other European countries). Most of the studies were randomized controlled trials and the rest were quasi-experimental or controlled clinical trials.

The sample sizes ranged from 20 to 250 participants and the study populations included adults on maintenance haemodialysis. Mean age of participants ranged from 45 to 75 years and duration of dialysis varied among studies. The duration of interventions ranged from 4 weeks to 12 months, and follow-up periods were dependent on the study aims.

The majority of studies assessed functional status using validated outcome measures, such as the Six-Minute Walk Test (6MWT), Timed Up and Go Test (TUG), Sit-to-Stand Test (STS), Short Physical Performance Battery (SPPB), handgrip strength, and gait speed. The most common measures of physical activity were accelerometers or pedometers, daily steps count or validated questionnaires such as the Human Activity Profile (HAP) and the International Physical Activity Questionnaire (IPAQ).

Characteristics of Personalized Exercise Interventions

The studies included assessed a range of individualized exercise interventions to enhance functional status and physical activity in adults receiving maintenance haemodialysis. Exercise programmes were personalised according to the functional capacity, age, comorbidities, symptom burden, cardiovascular status and exercise tolerance of participants.

Interventions included aerobic exercise, resistance training, combined aerobic and resistance exercise, intradialytic exercise, home-based exercise, balance training, flexibility exercises and, in some studies, technology-assisted or telehealth-supported exercise programmes. Exercise prescriptions differed in intensity, frequency, duration, progression and supervision, with most programmes delivered two to three times per week for intervention periods from 4 weeks to 12 months Exercise intensity was frequently determined via the Borg Rating of Perceived Exertion (RPE) scale, heart rate, or individualized functional assessments. Progression was based on the clinical status of the participant, exercise tolerance and improvements in physical performance during the intervention period. A number of studies included multidisciplinary supervision of physiotherapists, exercise physiologists, nephrologists and dialysis nurses to ensure safety, adherence and optimal progression of exercise .

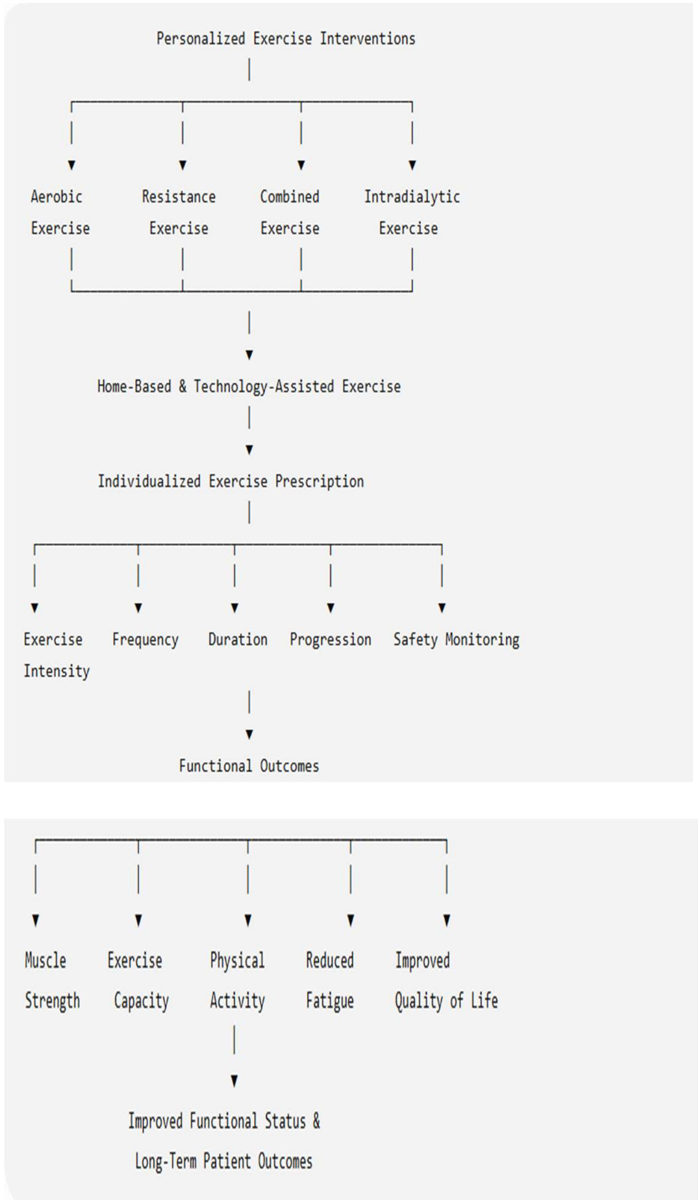
Types of Exercise Interventions

Aerobic Exercise

Aerobic exercise was one of the most frequently prescribed interventions among adults receiving maintenance haemodialysis. Common aerobic activities included stationary cycling, treadmill walking, overground walking, and lower-limb ergometer cycling performed either during or between dialysis sessions. Exercise intensity was generally individualized by the Borg Rating of Perceived Exertion (RPE), heart rate, or a percentage of maximal oxygen uptake (VO_2peak). Aerobic exercise consistently improved cardiorespiratory fitness, walking distance, exercise tolerance, physical activity levels and health-related quality of life .(19,20,26)

Resistance Exercise

Resistance exercise programmes primarily targeting the major muscle groups of the upper and lower extremities using free weights, elastic resistance bands, ankle weights, body-weight exercises or resistance machines. Exercise intensity and progression were tailored to the baseline muscle strength and functional capacity of the participants. Resistance training significantly improved handgrip strength, lower-limb muscle strength, balance, mobility and functional independence in patients on maintenance haemodialysis. (18,19,27)



Combined Exercise

The combined exercise interventions included aerobic and resistance training in the same programme, to simultaneously improve cardiovascular endurance and muscular strength. These programs were usually provided 2-3 times per week and tailored to an individual's exercise tolerance and clinical condition. Evidence suggests that combined exercise interventions provide greater improvements in functional capacity, muscle strength, exercise performance, and quality of life than single-modality exercise programmes(19,20,25)

Intradialytic Exercise

Intradialytic exercise refers to physical exercise performed during haemodialysis treatment, usually within the first two hours of the dialysis session. Common interventions included cycling, resistance training, stretching, and flexibility exercises under professional supervision. Intradialytic exercise has been shown to improve physical function, muscle strength, dialysis adequacy, fatigue, exercise adherence, and quality of life while making effective use of dialysis treatment time(20,21,26)

Home-Based Exercise

Home-based exercise programmes encouraged patients to perform individualized exercise outside the dialysis unit and typically included walking, resistance exercises using elastic bands, flexibility exercises, and balance training. Exercise prescriptions were tailored to participants' physical capacity and monitored through periodic telephone follow-up, exercise diaries, or outpatient visits. Home-based interventions have demonstrated improvements in physical activity, exercise adherence, walking capacity, and functional independence (19,25,26)

Technology-Assisted Exercise

Technology-assisted exercise interventions have recently been highlighted as an innovative strategy to promote physical activity among adult patients receiving maintenance haemodialysis. Such interventions include tele-rehabilitation, wearable activity monitors, smartphone applications, virtual coaching and remote exercise supervision. Technology-assisted strategies allow for customized exercise prescription, ongoing tracking, and immediate feedback, thereby improving exercise adherence and patient engagement. Although current evidence is promising, further high-quality randomized controlled trials are needed to determine their long-term effectiveness in the haemodialysis population(18,25,26)

Personalization Strategies

The included studies adopted several personalization strategies to optimize the safety, feasibility, and effectiveness of exercise interventions among adults receiving maintenance haemodialysis. Exercise prescriptions were individualized based on each patient's functional capacity, comorbidities, dialysis vintage, cardiovascular status, symptom burden, and exercise tolerance. The principal components of personalized exercise programmes included individualized exercise intensity, frequency, duration, progression, comprehensive patient assessment, and continuous safety monitoring.

Exercise Intensity

The intensity of the exercise was prescribed individually based on the participants' baseline physical fitness, functional capacity, cardiovascular status, and perceived exertion. In most studies, exercise intensity was defined using the Borg Rating of Perceived Exertion (RPE) scale (11–15), heart rate reserve, or a percentage of peak oxygen uptake (VO2peak). Resistance exercise intensity was increased progressively based on muscle strength and participants' tolerance. Individualized exercise intensity resulted in maximal physiological benefits with minimal adverse events and exercise intolerance (19,20,26)

Frequency

Exercise frequency was different among studies according to the physical condition of participants and dialysis schedules. Most interventions prescribed exercise two to three sessions per week, often aligning with haemodialysis treatment sessions. Home-based programs encouraged more physical activity on non-dialysis days to reduce sedentary behaviour. Individualized scheduling improved adherence and took into account patient fatigue, recovery, and treatment demands(20,21,25)

Duration

The duration of exercise sessions generally ranged from 20 to 60 minutes depending on exercise tolerance of participants and objectives of the intervention. The duration of programmes ranged from 4 weeks to 12 months, with longer interventions associated with greater improvements in functional outcomes and physical activity levels. The duration of exercise was gradually increased based on individual responses . Adequate recovery was maintained and excessive fatigue minimised .(18,19,26)

Progression

Progressive overload was a fundamental component of personalized exercise interventions. Exercise progression was individualized based on improvements in strength, endurance, physical performance, and patient tolerance. Progression typically involved gradual increases in exercise intensity, resistance, duration, or training volume while maintaining patient safety. This individualized progression facilitated continuous physiological adaptation without increasing the risk of injury or cardiovascular complications (20,21,27)

Individual Assessment

Prior to the start of exercise programmes a comprehensive baseline assessment was undertaken to ensure individualised prescription and patient safety. Assessments usually consisted of medical history, dialysis adequacy, comorbidities, cardiovascular assessment, functional capacity, muscle strength, level of physical activity, frailty status and symptoms reported by the patient. Standardized tools were routinely utilized to assist in prescribing exercise and monitoring progress, including the Six-Minute Walk Test (6MWT), Timed Up and Go Test (TUG), Short Physical Performance Battery (SPPB), handgrip dynamometry, and quality-of-life questionnaires. (9,17,21)

Safety Monitoring

Continuous safety monitoring was an essential part of personalized exercise interventions. Blood pressure, heart rate, oxygen saturation, perceived exertion, dialysis-related symptoms and signs of cardiovascular instability were monitored before, during and after exercise sessions. Participants were instructed to modify or suspend their exercise sessions if they experienced hypotension, chest pain, dizziness, severe fatigue, muscle cramps, or other adverse symptoms. Most studies reported that exercise interventions were safe, feasible and well tolerated by adults undergoing maintenance haemodialysis, facilitated by individualized monitoring by multidisciplinary healthcare professionals .(19–21)

Effects on Functional Status

The studies included were all consistent in demonstrating that personalised exercise interventions improved functional status in adults receiving maintenance haemodialysis. Functional outcomes were evaluated with standardized performance-based measures such as the Six-Minute Walk Test (6MWT), Timed Up and Go Test

(TUG), Sit-to-Stand Test (STS), Short Physical Performance Battery (SPPB), and gait speed . Aerobic, resistance, combined, intradialytic and home-based exercise programmes produced substantial improvements in mobility, lower limb strength, balance, walking endurance and overall physical performance. Tailored exercise prescriptions according to functional capacity and clinical status were associated with larger improvements in these outcomes than conventional care or usual physical activity.(19–21)

Six-Minute Walk Test (6MWT)
The most used measure of functional exercise capacity in the included studies was the Six-Minute Walk Test (6MWT). Personalised exercise interventions, especially aerobic and combined exercise programmes, significantly increased the distance walked during the 6MWT, indicating improvements in cardiovascular endurance, lower-extremity muscle function and walking capacity. Randomized controlled trials have demonstrated clinically important improvements in walking distance following 8–24 weeks of individualized exercise training.(19,25,28)

Timed Up and Go Test (TUG)
The Timed Up and Go Test (TUG) was used extensively to assess functional mobility, balance and risk of falls. The personalized exercise interventions significantly improved the time to complete TUG, an indicator of dynamic balance, mobility and lower-limb function. Resistance and combined exercise programmes showed the largest improvements, especially in older adults and patients with low baseline physical performance(18,26,28)

Sit-to-Stand Test (STS)
The Sit-to-Stand Test (STS) was a common measurement to evaluate muscle strength of the lower limbs, functional independence and mobility . Personalized resistance and combined exercise interventions significantly improved STS performance by decreasing the time required to complete the test or by increasing the number of repetitions completed. Improvements included improved lower extremity strength and ability to perform activities of daily living independently(19,26,27)

Short Physical Performance Battery (SPPB)
A number of studies used the Short Physical Performance Battery (SPPB) to assess lower-extremity function. The SPPB includes standing balance, gait speed, and chair-rise performance. Personalized exercise interventions were associated with significant improvements in overall SPPB scores, suggesting enhanced physical performance, mobility, and functional independence. In particular, combined programmes of aerobic and resistance training lasting a minimum of 12 weeks improved SPPB scores(17,20,26)

Gait Speed
Gait speed is a validated marker of mobility, frailty and global functional status in patients on maintenance haemodialysis. All included studies reported significant improvements in gait speed after personalized exercise interventions, especially resistance and combined exercise programmes. Faster gait speed was linked to greater lower-limb strength, balance, reduced fall risk, and more independence in daily activities. These findings suggest gait speed may be a sensitive outcome measure to monitor functional improvements obtained through individualised exercise programmes. (16,18,28)

Effects on Physical Activity
All studies included in this review consistently reported that personalised exercise interventions improved physical activity levels in adults receiving maintenance haemodialysis. Objective measures of physical activity (daily step counts and accelerometers) and validated self-reported questionnaires were used. Individualised exercise programmes increased participation in moderate physical activity, reduced sedentary time and promoted long term engagement in regular exercise. Improvements in physical activity were associated with improved functional capacity, muscle strength and health-related quality of life (16,19,21,29)

Daily Step Count
The number of steps taken in a day was often used as an objective measure of habitual physical activity. Studies showed significant increases in daily steps following personalised home-based, intradialytic and combined exercise programmes. More steps per day indicate higher mobility, better exercise capacity and less physical inactivity. Patients who received personalised exercise counselling and regular follow-up had greater improvements in ambulatory activity than those receiving usual care.(15,30,31)

Accelerometer Outcomes
The most common device used to objectively quantify physical activity intensity, duration and sedentary time was accelerometers. Personalized exercise interventions showed improvements in moderate-vigorous physical activity and in daily overall movement and reduction in long durations of sedentary time in accelerometery studies. Accelerometer-based assessment also accurately monitored patient adherence and activity pattern changes over the intervention period .(32–34)

Physical Activity Questionnaires
Several studies used validated self-report questionnaires to measure physical activity, such as the Human Activity Profile (HAP), International Physical Activity Questionnaire (IPAQ), and Physical Activity Scale for the Elderly (PASE). These instruments assessed participants' participation in activities of daily living, exercise, and functional mobility. Questionnaire scores were significantly improved with individualized exercise interventions, suggesting greater participation in physical activities and increased confidence in completing daily activities..(25,35,36).

Sedentary Behaviour

Sedentary behaviour is highly prevalent among adults receiving maintenance haemodialysis and is independently associated with poorer functional status, reduced cardiorespiratory fitness, lower muscle strength, increased hospitalization and higher mortality. The tailored exercise interventions in the included studies helped in significantly reducing sedentary time by encouraging regular walking, structured home-based exercise, and intradialytic physical activity. Small reductions in prolonged sitting and increases in light-intensity physical activity were associated with clinically meaningful improvements in physical function and quality of life(28,37–39)

Effects on Muscle Strength

The majority of the included studies reported significant improvements in muscle strength following personalized exercise interventions among adults receiving maintenance haemodialysis. Resistance training and combined aerobic–resistance programmes were particularly effective in enhancing handgrip strength, quadriceps strength, knee extensor strength, and lower-limb muscle function. These improvements were attributed to progressive overload, individualized exercise prescription, and regular supervision. Enhanced muscle strength was associated with better functional mobility, improved balance, greater independence in activities of daily living, and reduced risk of falls. Collectively, the findings suggest that personalized resistance-based exercise is an effective strategy for counteracting muscle wasting and physical deconditioning in the haemodialysis population. (39–41)

Effects on Exercise Capacity

Personalised exercise interventions were consistently beneficial in improving exercise capacity in adults on maintenance haemodialysis. Improvements often demonstrated greater Six-Minute Walk Test (6MWT) distance, greater peak oxygen uptake (VO 2 peak), longer exercise endurance, and better physical performance scores. Cardiorespiratory fitness and walking ability improved most with aerobic and combined exercise programmes. Progression of exercise intensity and duration was individualized to allow participants to achieve clinically meaningful improvements while maintaining safety and adherence(34,42,43)

Effects on Fatigue

Fatigue is one of the most prevalent and debilitating symptoms experienced by patients receiving maintenance haemodialysis. The included studies demonstrated that personalized exercise interventions significantly reduced fatigue severity and improved energy levels. Both intradialytic and home-based exercise programmes were effective in decreasing physical and mental fatigue by improving muscle function, cardiovascular fitness, and exercise tolerance. Several studies using validated instruments, including the Functional Assessment of Chronic Illness Therapy–Fatigue (FACIT-F) scale and the Fatigue Severity Scale (FSS), reported clinically meaningful reductions in fatigue following individualized exercise programmes(19–21)

Effects on Health-Related Quality of Life

Most of the studies included reported significant improvement in health-related quality of life (HRQoL) after personalized exercise interventions. The study identified improvements in physical and mental health domains, including physical functioning, vitality, mental health, social participation, and overall quality of life. Personalized exercise programs boosted confidence in performing activities of daily living, reduced symptoms, and promoted independence. validated instruments like the Kidney Disease Quality of Life-36 (KDQOL-36) and Short Form-36 (SF-36) were used to assess HRQoL more frequently. Evidence consistently supported the benefit of individualized exercise interventions.(21,28,35)

Adherence and Compliance

Overall, adherence to personalised exercise programmes was high where interventions were tailored, supervised and embedded into routine haemodialysis care. Intradialytic exercise had the highest compliance, due to its timing during dialysis treatment and the elimination of common barriers such as time and transportation. Home-based exercise programmes also achieved satisfactory adherence when combined with regular follow-up, exercise diaries, telephone support, or wearable monitoring devices. Factors associated with better compliance were individualized exercise prescription, patient education, multidisciplinary support, motivation and ongoing surveillance(20,21,35)

Safety and Adverse Events

To summarize, personalised exercise interventions were safe and well tolerated in adults on maintenance haemodialysis.Most studies reported no serious exercise-related adverse events when programmes were appropriately prescribed and supervised. Minor events, including transient muscle soreness, fatigue, mild hypotension, or muscle cramps, were infrequent and resolved without long-term consequences. Careful patient assessment, individualized exercise progression, monitoring of vital signs, and supervision by trained healthcare professionals contributed to the favourable safety profile of these interventions. These findings support the routine incorporation of personalized exercise programmes into haemodialysis care, provided that appropriate safety precautions are followed(19–21)

Discussion

Summary of Main Findings

This systematic review synthesized the available evidence on the effectiveness of personalized exercise interventions for improving functional status and physical activity among adults receiving maintenance haemodialysis. Overall, the findings demonstrate that individualized exercise programmes—including aerobic, resistance, combined, intradialytic, home-based, and technology-assisted interventions—produce meaningful improvements in functional performance, muscle strength, exercise capacity, physical activity levels, fatigue, and health-related quality of life. Most studies also reported good adherence and a low incidence of exercise-related adverse events, indicating that personalized exercise is both feasible and safe when appropriately prescribed and supervised. These findings support current recommendations that exercise should be integrated into routine haemodialysis care as an essential component of comprehensive patient management(19–21,43)

Interpretation of Findings

The observed improvements in functional status and physical activity can be attributed to individualized exercise prescriptions that considered patients' clinical condition, functional capacity, comorbidities, and exercise tolerance. The intensity, frequency and duration of the exercise were gradually changed, so that the participants were able to develop physiological adaptations with minimal adverse effect. The primary advantages of resistance training included enhanced muscle strength, as well as improvements in cardiorespiratory fitness and walking capacity resulting from aerobic exercise. The combined exercise programs added benefits by improving muscular and cardiovascular function at the same time. The personalized nature of these interventions may have contributed to better adherence rates and clinical outcomes compared to standardized exercise programmes(21,27,43)

Comparison with Previous Reviews

The results of this review are in agreement with earlier systematic reviews and clinical practice guidelines that describe the benefits of exercise in patients with chronic kidney disease. Exercise regularly improves aerobic capacity, physical function and quality of life in patients with chronic kidney disease (Heiwe and Jacobson). Similarly, Smart et al. recommended routine prescription of personalized exercise for patients on maintenance haemodialysis because of its beneficial effects on physical performance and cardiovascular health. Recent reviews by Greenwood et al and Bennett et al pointed out the need for exercise prescription individualization based on patient characteristics to optimize efficacy and improve long-term adherence. Different from previous reviews, this review has a specific focus on personalized exercise interventions and provides a more detailed synthesis of individualization strategies and their effect on functional outcomes and physical activity.(19,21,35,42)

Clinical Implications

The findings of this review have important implications for clinical practice. Personalized exercise interventions should be considered a routine component of multidisciplinary haemodialysis care. Individualized assessment of functional status, frailty, physical activity, and exercise tolerance allows healthcare professionals to prescribe safe and effective exercise programmes tailored to patient needs. Intradialytic exercise represents a practical strategy to increase participation because it utilizes dialysis treatment time without requiring additional hospital visits. Home-based and technology-assisted exercise programmes may further improve long-term adherence, particularly for patients with transportation or mobility limitations. Collaboration among nephrologists, nurses, physiotherapists, exercise physiologists, and dietitians is essential for successful implementation of individualized rehabilitation programmes(9,20,21,43)

Strengths of the Review

This review has several strengths. firstly, it provides an in-depth synthesis of current evidence on personalized exercise interventions specifically among adults receiving maintenance haemodialysis. Second, a number of electronic databases were searched to identify relevant studies, which minimized the likelihood of missing important evidence. Third, a wide array of clinically relevant outcomes was assessed in the review, including functional status, physical activity, muscle strength, fatigue, exercise capacity, adherence, safety and quality of life. Finally, the review addresses practical issues in prescribing individualized exercise, such as intensity, progression, and safety monitoring, that are directly relevant to clinical practice.(20,43)

Limitations

Several limitations need to be considered when interpreting the results of this review. The included studies varied considerably in terms of type of exercise, duration of the intervention, intensity, supervision and outcome measures. Direct comparisons between studies were limited. In several trials, sample sizes were relatively small, reducing statistical power and generalizability. Most studies were conducted in high-income countries, limiting applicability to low- and middle-income health care settings. Variability in how adherence was reported and in how long patients were followed up also made it difficult to know if the intervention effects lasted in the long run. Also, methodological quality differences among the included studies may have contributed to the overall strength of the evidence(19,35,43)

Recommendations for Future Research

Future research should include large multicentre RCTs assessing standardised personalised exercise protocols for adults on maintenance haemodialysis. Optimal exercise intensity, frequency, duration, and progression in different patient populations, including older adults, frail patients, and patients with multiple comorbidities, requires further research. Long term adherence, implementation strategies, cost-effectiveness and sustainability of exercise programmes should be put under more focus. Additional research on digital health technologies, wearable activity monitors, tele-rehabilitation, and artificial intelligence–assisted exercise prescription may enhance accessibility and personalized patient care.(9,20,21)

Conclusion

Personalized exercise interventions are an effective and safe strategy for improving functional status and physical activity among adults receiving maintenance haemodialysis. The evidence synthesised in this systematic review suggests that individualised exercise programmes including aerobic, resistance, combined, intradialytic, home-based and technology-assisted interventions significantly improve muscle strength, exercise capacity, mobility, physical performance and health-related quality of life and reduce fatigue and sedentary behaviour. Exercise prescriptions should be tailored to patients' functional capacity, comorbidities, exercise tolerance, and clinical status in an effort to increase adherence and maximize rehabilitation outcomes(19,20)

Further, the findings emphasize the necessity of incorporating individualised exercise into routine haemodialysis care through multidisciplinary collaboration between nephrologists, nurses, physiotherapists, exercise physiologists and other healthcare professionals. Structured assessment, individualized prescription and ongoing surveillance are necessary to guarantee that patients are safe and that benefits are maximized. Despite encouraging evidence, further large-scale, multicentre randomized controlled trials with standardized exercise protocols and long-term follow-up are needed to determine the optimal exercise prescription and evaluate the effects on hospitalization, cardiovascular outcomes, and survival(9,21,43)

Personalized exercise interventions should be considered an integral component of comprehensive haemodialysis management, with the potential to improve functional independence, increase physical activity, enhance quality of life, and support better long-term health outcomes in this vulnerable population(21,21,43)

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this systematic review. The authors have no financial, personal, professional, or institutional relationships that could have influenced the design, conduct, interpretation, or reporting of this review.

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