

Assessing Physical Function and Physical Activity in Patients with CKD

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Summary

Patients with CKD are characterized by low levels of physical functioning, which, along with low physical activity, predict poor outcomes in those treated with dialysis. The hallmark of clinical care in geriatric practice and geriatric research is the orientation to and assessment of physical function and functional limitations. Although there is increasing interest in physical function and physical activity in patients with CKD, the nephrology field has not focused on this aspect of care. This paper provides an in-depth review of the measurement of physical function and physical activity. It focuses on physiologic impairments and physical performance limitations (impaired mobility and functional limitations). The review is based on established frameworks of physical impairment and functional limitations that have guided research in physical function in the aging population. Definitions and measures for physiologic impairments, physical performance limitations, self-reported function, and physical activity are presented. On the basis of the information presented, recommendations for incorporating routine assessment of physical function and encouragement for physical activity in clinical care are provided.

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Introduction

Patients with CKD have reduced levels of physical functioning, which, along with low physical activity, predict poor outcomes in patients treated with dialysis (1–6). The hallmark of clinical care in geriatric practice and geriatric research is the orientation to and assessment of physical function and functional limitations in order to better assess well-being and quality of life and to plan for care needs, including individually appropriate interventions to prevent deterioration in functioning (7).

Historically, nephrology practice has not included formal assessment or tracking of physical function, nor is there a routine effort to provide interventions for preventing physical function deterioration. The 2005 publication “K/DOQI Clinical Practice Guidelines: Cardiovascular Disease in Dialysis Patients” includes a recommendation for physical activity (8) (Figure 1). Despite this, nephrology practice related to physical activity has not changed (9) from a 2001 survey reporting that only 28.5% of nephrologists routinely prescribe exercise for their patients and only 4.3% of nephrologists provide patients with written material about exercise (10).

The purpose of this paper is to review the measurement of physical function and physical activity. The goal is to move nephrology research and practice beyond the routine focus on dialysis dosage and other laboratory measures to the study and practice of preventing pervasive functional decline, which severely limits patients’ ability to carry on life activities. The first step in this process is to effectively evaluate physical functioning.

Clarification of Terms

Terms and concepts related to physical functioning are often confused (11–13). This is illustrated within the disablement community, wherein two conceptual models prevail (14). The Nagi model (11,15,16) presents a dynamic pathway that moves from pathology to impairments leading to functional limitations and ultimately to disability. This has been the primary model guiding research in physical function in aging in the United States. The International Classification of Functioning, Disability, and Health framework (ICF) (17) of the World Health Organization is based on a framework that describes the cause of decrements in functioning and disability associated not only with underlying health conditions but also personal and environmental factors. The National Health and Aging Trends Study (NHATS) has developed a model that serves as a guide for research and as a bridge between the other two models (11) (Figure 2).

Despite continued discussion among gerontology researchers regarding the various frameworks, it is important for both CKD researchers and clinicians interested in physical functioning to understand the frameworks that have guided the extensive work in aging populations. Regardless of the particular model used, it is clear that a disease such as renal failure results in changes in body function and structure that impair mobility and performance of basic tasks (Figure 2). These performance limitations reduce the physical ability to perform activities of daily living (ADLs), instrumental ADLs (IADLs), and discretionary activities, thereby negatively affecting an individual’s

- 14.2 All dialysis patients should be counseled and regularly encouraged by nephrology and dialysis staff to increase their level of physical activity. (B)
- 14.2.a Unique challenges to exercise in dialysis patients need to be identified in order to refer patients appropriately (e.g., to physical therapy or cardiac rehabilitation) and to enable the patients to follow regimens successfully. Such challenges include orthopedic/musculoskeletal limitations, cardiovascular concerns, and motivational issues. (C)
- 14.3 Measurement of physical functioning:
- 14.3.a Evaluation of physical functioning and re-evaluation of the physical activity program should be done at least every 6 months. (C)
- 14.3.b Physical functioning can be measured using physical performance testing or questionnaires (e.g., SF-36). (C)
- 14.3.c Potential barriers to participation in physical activity should be assessed in every patient. (C)
- 14.4 Physical activity recommendations:
- 14.4.a Many dialysis patients are severely deconditioned and therefore may need a referral for physical therapy to increase strength and endurance to the point where they are able to adopt the recommended levels of physical activity.
- 14.4.a.i Patients who qualify for cardiac rehabilitation should be referred to a specialist. (C)
- 14.4.a.ii The goal for activity should be for cardiovascular exercise at a moderate intensity for 30 minutes most, if not all, days per week. Patients who are not currently physically active should start at very low levels and durations, and gradually progress to this recommended level. (C)
- 14.4.b Follow-up:
- 14.4.b.i Physical functioning assessment and encouragement for participation in physical activity should be part of the routine patient care plan. Regular review should include assessment of changes in activity and physical functioning. (C)

Figure 1. | Kidney Disease Outcomes Quality Initiative practice guidelines for physical activity. Letters indicate strength or recommendation. Recommendation strength for this guideline is at B or C because the strength of evidence is mostly derived from evidence in other populations, not CKD. SF-36, Short Form-36. Reprinted from reference 8, with permission.

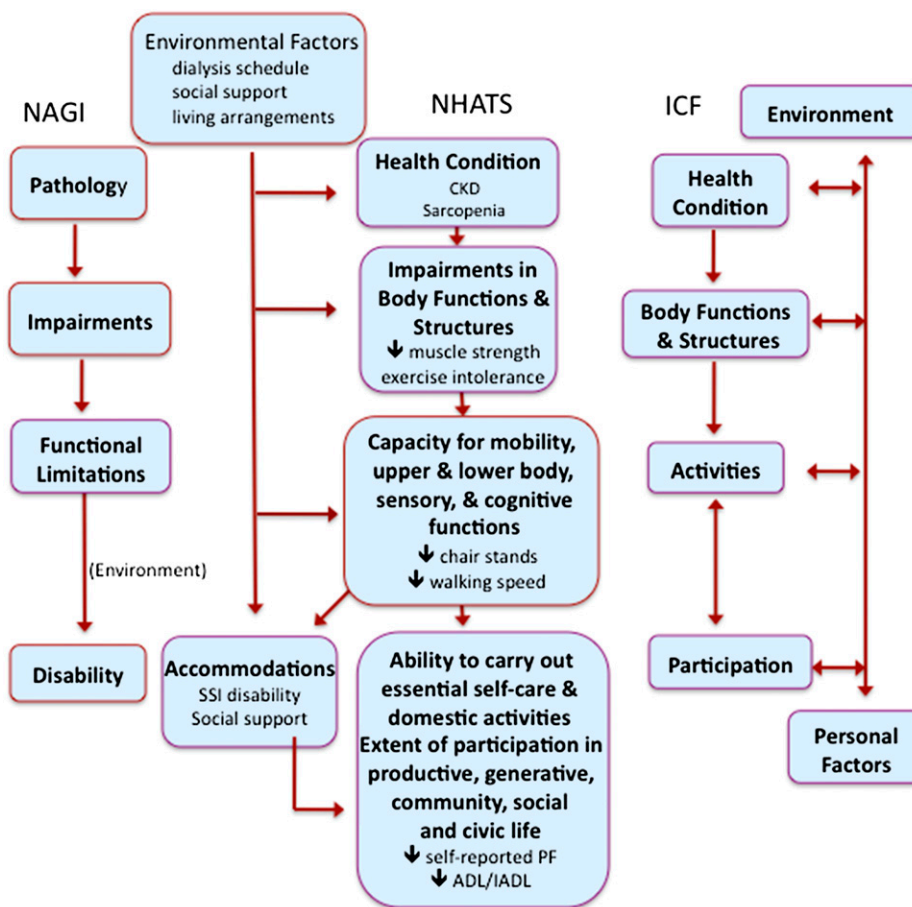


Figure 2. | The Nagi, National Health and Aging Trends Study (NHATS), and International Classification of Functioning, Disability, and Health models for measurement of physical function and disablement. Examples of each concept as it relates to CKD are presented as part of the NHATS model. Reprinted from reference 11, with permission. ADL, activity of daily living; IADL, instrumental activity of daily living; ICF, International Classification of Functioning, Disability, and Health; SSI, Social Security income.

quality of life. All models recognize personal and environmental factors that affect an individual's ability to perform life activities. This review focuses on physiologic impairments and physical performance limitation (impaired mobility and functional limitations) and how they are measured.

Value of Measuring Physical Function

It is clear that physical performance limitations in older adults predict disability, health care utilization, nursing home admission, and mortality, regardless of the specific tests or test batteries used (18–21). Gait speed alone is highly predictive of adverse outcomes in older individuals (19,21–23). Studenski *et al.* (21) analyzed the relationship of gait speed to survival in nine cohort studies, each with >400 older adults (age >65 years) for whom gait speed data at baseline were available and who were monitored for survival for at least 5 years (range, 6–12 years). In that study of 24,485 individuals, the overall adjusted hazard ratio for survival per 0.1 m/sec faster gait speed was 0.88 (95% confidence interval, 0.87–0.90; $P<0.01$). In patients with CKD treated with dialysis, lower self-reported physical function (1,2,6,24) and lower levels of peak oxygen uptake (4) predict poor outcomes of hospitalization and mortality.

Assessment of physical function is valuable in clinical practice to (1) identify patients who may benefit from preventive interventions (2) identify patients at high risk of early death who may be targeted for more extensive evaluation (cardiopulmonary, neurologic, and musculoskeletal systems) for potential modifiable risks to health and survival; (3) better characterize patients as likely to be in poor health and function; (4) monitor over time to identify a decline in function that may indicate a new health problem; (5) stratify risks for surgery, chemotherapy, or other complex clinical interventions and (6) monitor the effectiveness of clinical and behavioral (*i.e.*, physical activity) interventions (25,26).

Because physical function is independently associated with outcomes, assessment in research studies is important to characterize the population at baseline, to assess changes over the trial, and to determine the effects of the intervention on physical functioning. Neglecting to account for the effects of an intervention on physical function could result in incomplete interpretation of the trial results. For example, although the primary clinical outcome of an interventional trial may be positive, the treatment may result in symptoms or adverse effects that reduce physical activity. The resulting decline in physical function, an unintended and negative result of the trial, would be missed if physical function was not measured; in addition, the interpretation of the results would be incomplete and misleading. Of note, there could be a subsequent negative effect on physical activity, quality of life, and overall well-being.

Considerations for Choosing Measures

The type of test used depends on the goal of the assessment, the characteristics of the population, and operational considerations (*i.e.*, patient burden, inclusiveness, and costs) (25,26). Given that many tests (*e.g.*, gait

speed) have ceiling effects in healthier and more physically fit populations, assessment of physical function as a primary research endpoint may require a more precise measure and one that measures a wide range of levels of function (*i.e.*, intermittent shuttle walk test). The population of interest will also determine the assessment used; age, comorbid conditions, ambulatory status, cognitive function, fitness levels, and activity levels should also be considered. Operational considerations include staff expertise, time available for testing, location (clinic versus laboratory), and the timing of testing in relation to dialysis treatment (to account for factors such as fatigue, balance, weakness, or fluid status). Patient burden, precision of the measure, and cost must be balanced. Measurement of physical function in the clinical setting will be determined by the ability to incorporate the measure effectively and efficiently within the routine clinic operations (26).

Measurement of Physical Functioning

There is a spectrum of measurement possibilities (25–27) (Figure 3). *Physiologic impairment* (at the level of individual organ function or integrated body system function) will often result in physical performance limitations. Physiologic impairments typically require measurement in a laboratory setting, along with specialized equipment and trained technicians. Measurement of *physical performance limitation* (at the level of specific activities) is typically determined using physical performance testing, which can be done in the field. Measurement of disability or activity participation (restrictions at the level of a person within the associated social and cultural environment) is typically determined using self-report.

The following is an example of the spectrum of measures for cardiorespiratory fitness (which is a primary component of physical fitness and is reduced in CKD [*i.e.*, a physiologic impairment]). Exercise testing with measurement of oxygen uptake is considered to be the “gold standard” measure of the integrated functioning of the pulmonary, cardiac, circulatory, and muscle metabolic systems in transporting and using oxygen to generate muscle contractions. Physical performance measures, such as the incremental shuttle walk, the 6-minute walk (6MW), or 400-meter walk, measure physical performance limitations that are related to, but are only *indicators* of, cardiorespiratory fitness. They may be most appropriate for use and most valid in individuals with compromised fitness levels. Self-report would be used to assess daily activity limitations that may be related to cardiorespiratory fitness, such as difficulty walking across a room (measured disability or activity participation). Each type of measure becomes less specific as a measure of cardiorespiratory fitness. This does not mean that physical performance measures are less valuable or informative, but these field tests are indicators, not direct measures, of the basic fitness components. The performance measures may actually provide more useful information specific to tasks of daily living than the direct “gold standard” measures.

Measurement of Physiologic Impairment (Laboratory Based)

Cardiorespiratory fitness is the most commonly tested outcome reported in exercise studies in CKD using exercise

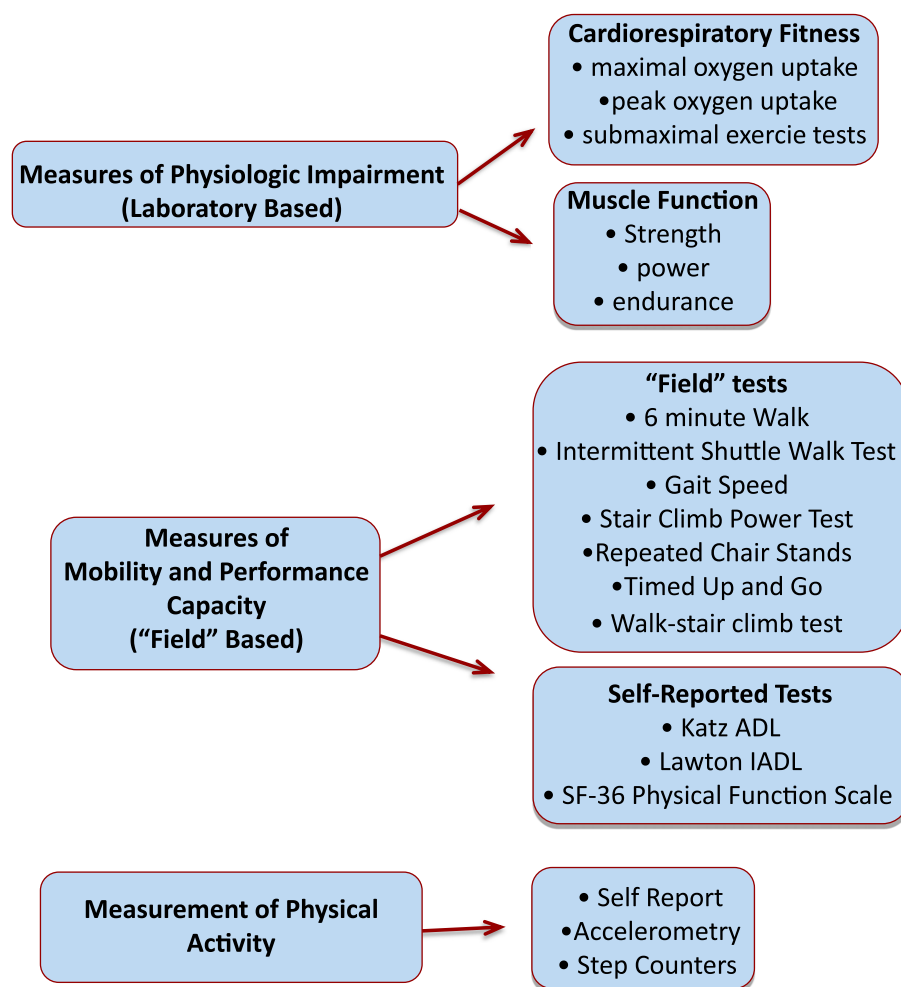


Figure 3. | The spectrum of measurement of physical function and physical activity. 6MW, 6-minute walk; ADL, activity of daily living; IADL, instrumental activity of daily living; ISWT, intermittent shuttle walk; SF-36, Short Form-36; SPPB, Short Physical Performance Battery; TUG, Timed Up and Go.

tolerance testing, by either an incremental treadmill or a cycle ergometer protocol. The typical measure in these tests is maximal oxygen uptake for cardiorespiratory fitness. Specific endpoints indicate that maximal levels are achieved in normal healthy individuals (28); however, patients with renal disease typically do not achieve these conditions. Thus, the tests that are reported in patients who do not meet the criteria for maximal exercise are called symptom-limited tests, and the measure obtained is referred to as “peak” oxygen uptake. These peak-exercise tests may provide valuable information on the upper level of integrated system functioning but may be limited in providing information on ability to perform ADLs. Other physiologic variables can be derived from respiratory gas analysis during exercise testing, such as oxygen uptake efficiency slope, oxygen uptake kinetics, ventilatory equivalents of oxygen, and carbon dioxide (25,26). Measures of various physiologic phenomena may or may not be relevant to the evaluation of physical function. Submaximal exercise testing may also be used to evaluate some physiologic responses (*i.e.*, oxygen uptake at the ventilatory threshold) and may be less influenced by

discomfort, exercise intolerance, and motivation (25,26). Heart rate and BP are often reported as exercise testing measures, but these responses are highly dependent on medications, fluid status, and the timing of the testing in relation to the dialysis treatment (29,30). Prediction of maximal work or oxygen uptake from submaximal heart rate responses depends on normal heart rate responses to exercise, which cannot be assumed because of abnormal chronotropic response to exercise (31,32). This may also affect interpretation of exercise responses using heart rate recovery. Specific considerations for cardiorespiratory testing protocols are found in Supplemental Material 1.

Muscle strength and endurance are key components of physical fitness, and muscle dysfunction can take many forms, including impairments in strength, endurance, and power. Muscle strength is the ability to generate maximal force, whereas muscle endurance is the ability to generate submaximal force, either repeated or sustained, over a given period. Muscle power is the ability to generate force quickly. All are important indicators of muscle function and can affect physical functioning in the CKD population. It should be noted that muscle function is influenced by

muscle contraction type (*i.e.*, isometric, concentric or eccentric), speed of contraction, and test joint angle. All of these variables should be considered when assessment methods are chosen (33). Although muscle strength is most commonly assessed in clinical and research settings, muscle power may provide a more accurate picture of the patient's functional status because power consistently explains more of the variance in functional limitation than strength in older adults with mild to moderate functional limitations (34–36). Muscle endurance, although intuitively important, has not shown consistent relationships with physical function (37,38). It is beyond the scope of this paper to describe specifics for testing of all of these however, brief descriptions and resources are found in Supplemental Material1.

Measurement of Mobility and Physical Performance (Field Based)

Researchers in gerontology have developed standardized tests that assess physical performance limitations, such as specific movements (*i.e.*, walking or getting up from a chair) or tasks encountered in daily life. These measures have many advantages, including ease of use in the field, reproducibility, time efficiency, cost-effectiveness, and low patient burden. Many of these measures are widely used in cohort studies that provide large databases for comparison. These tests are highly predictive of disability, nursing home admission, and healthcare utilization in older individuals (18,19,21,39). However, the plethora of these types of measures, each developed to address a specific question or situation, makes selection of a specific test difficult. A guide to some tests that includes procedures, scoring, and other details can be found at <http://web.missouri.edu/~proste/tool/>. Unfortunately, there is no set algorithm for making a decision on the test choice.

Investigators choose specific performance tests on the basis of their area of interest, the research question, and often general preference. The variability in testing leads to difficulty in comparing results between studies and confusion in interpretation. Although many tests have been validated in the general rehabilitation and gerontology research literature, there are few data on reliability, reproducibility, prognostic utility, and what constitutes meaningful change for these tests in patients with CKD. However, many of the cohorts in whom the tests were validated were older and included patients with multiple comorbid conditions, including reduced renal function (40). It may therefore be safe to assume they can be appropriately used in the CKD population. However, reproducibility may be different in dialysis patients, depending on the timing relative to the treatment.

Walking Tests. Various walking tests have been reported. They are most commonly used in the cardiopulmonary domains, including 2-, 6-, and 12-minute walk tests that determine the distance traveled in the time allotted (41). Of these, the six-minute walk (6MW) test is most commonly used. Patients choose their own intensity of walking and are allowed to stop and rest during the test. Maximal exercise capacity is not achieved and the test does not measure cardiorespiratory fitness (or peak oxygen uptake) but may indicate integrated responses of systems involved

during exercise (41). It is not a replacement for cardiorespiratory exercise testing and cannot be used to determine the mechanisms of exercise intolerance. The correlation between the 6MW test and peak oxygen uptake in patients with cardiac or pulmonary disease ranges from 0.51 to 0.90 (42); however, the correlation is much lower in community-dwelling elders with mild to moderate mobility limitations (43). A change in walking distance between 53 and 71 meters has been suggested as clinically meaningful in cardiopulmonary populations (41). Although not widely used as an outcome measure in exercise training studies in patients with CKD, improvements in the 6MW test of >53 meters have been reported (44–49). We have found high variability on the 6MW test in dialysis patients (*i.e.*, 346 ± 127 meters at baseline) (48), possibly because (1) patients are unaware of how to pace themselves, (2) there is a wide spectrum of functioning in patients with CKD, and (3) although testing was done immediately before a mid-week dialysis session, physiologic status (*i.e.*, fluid, electrolytes, symptoms) vary significantly.

Intermittent Shuttle Walk. A graded walking test that has well defined end points (50,51), the intermittent shuttle walk test uses an audio signal from a voice recorder to direct the walking pace of the patient back and forth on a 10-meter course. Walking speed increases every minute from 0.5 m/sec until the patient is unable to reach the turnaround point within the required time. It has good reproducibility and is more highly correlated with peak oxygen uptake than is the 6MW test (41). The structure of the test allows for assessment of total walking distance as well as peak gait speed. The pacing and the objective endpoint addresses the motivation issue associated with the 6MW test, and the incremental nature, allows for testing of a wide range of functioning. The intermittent shuttle walk test has been used in dialysis patients by Wilund *et al.* (52), who reported a 15% increase in the distance walked after 4 months of intradialytic cycle ergometry training.

Gait Speed. Gait speed is one of the most widely used physical performance tests leading researchers to advocate that the measurement become a vital sign for older individuals (21,53). Figure 4 shows gait speed requirements for various activities and average gait speeds for dialysis patients. Gait speed is typically measured as the patient's usual pace over short distances (8 feet to 6 meters). A usual gait speed of <0.6 m/sec is associated with poor outcomes in older individuals. Some investigators have used "fast" gait speed (instruction is to walk as fast as comfortably possible) (54,55), but this does not change the association with survival (21). There is probably a ceiling effect on the gait speed test in younger or more fit individuals, which has resulted in the development of a 400-meter walk test for use in healthier and more fit individuals (56).

Chair Stands. Moving from a seated to standing position requires lower-extremity strength and has been used as an indicator of lower-extremity function (26,39,57), specifically muscle power (58,59). Patients are asked to rise unassisted from a standard height chair. Test protocols involve variations, including (1) the time it takes to stand up and sit down 5 times (STS5) or 10 times (STS10) and (2) the number of cycles completed in 30 seconds or 60

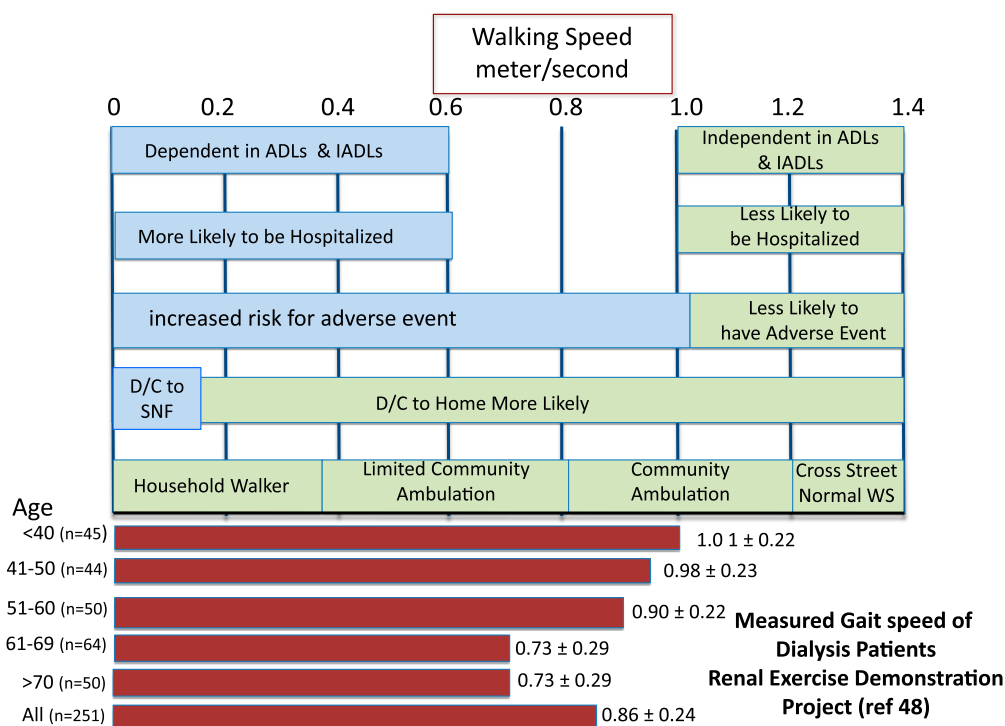


Figure 4. | Gait speed placed into perspective of requirements for various activities and outcomes, with indication of normal gait speed of 251 hemodialysis patients in the Renal Exercise Demonstration Project. Gait speeds presented as mean \pm SD. ADL, activity of daily living; D/C, discharge; IADL, instrumental activity of daily living; SNL, skilled nursing facility; WS, walking speed. Reprinted from reference 53, with permission.

seconds (an indicator of muscle endurance or fatigability) (26). The coefficient of variation in a small sample of dialysis patients was reported to be 15% for the STS5 and 12.8% for the STS 60 seconds (60). A significant number of dialysis patients are unable to rise from a chair unassisted. Brodin *et al.* (61) reported that for every 1 mL/min per 1.73 m² decrease in GFR, the odds of being unable to complete one rise unassisted were 1.5 times higher, and in those with diabetes the odds were much higher. The STS5 has been shown to be an important predictor of falls in elderly individuals without CKD (62).

Stair Climb Test. Climbing stairs is an important basic movement that can be easily assessed as a part of a physical performance evaluation. The test can be used to assess whether the individual is able to climb stairs, the method in which they climb stairs (*i.e.*, alternating steps, hand-rail dependence), and the speed of stair climbing. The stair climb power test, which can discern between older and younger men and older men with mobility limitations (63), is a clinically relevant measure that is significantly associated with mobility (35). The outcome measure for the power test is lower-extremity power (force \times velocity), determined from a test in which the patient climbs one flight of stairs as fast as safely possible. Stair climb time and vertical height of the stairs are used to calculate velocity, and body mass and acceleration due to gravity (9.81 m/sec [2]) are used to calculate force.

Combined Tests. Combining single tests into test batteries has been suggested as a way to more accurately assess overall physical performance. Some of these focus on

balance, strength, and power of the lower extremities, whereas others incorporate upper-extremity tasks and simple tests of dexterity for upper-extremity function.

Short Physical Performance Battery. The Short Physical Performance Battery (SPPB) is a well validated test battery that measures overall lower-extremity function (39) (<http://www.grc.nia.nih.gov/branches/ledb/sppb/>). It is reliable and valid for predicting disability, institutionalization, hospital admission, and mortality in older individuals. There are extensive data available for comparison in older individuals because the test has been used in several large cohort studies, including the Established Population for Epidemiologic Studies in the Elderly (EPESE) cohort (18). The SPPB consists of three different tests of lower-extremity function: 4-meter gait speed, chair stand (STS5), and standing in three different positions for assessment of balance. Scores from these three performance measures are assigned a score ranging from 0 to 4, with 4 indicating the highest level of performance and 0 the inability to complete the task. A summary score ranging from 0 (worst performers) to 12 (best performers) is calculated. Older kidney transplant candidates demonstrated SPPB scores that were significantly lower than those of patients of the same age with chronic obstructive pulmonary disease, heart failure, and high cardiovascular risk (64). The baseline distribution of SPPB scores for hemodialysis patients enrolled in the Frequent Hemodialysis Study (65) (average age, 50.6 years) was lower than that for the 70-year-old cohort of the EPESE study (18).

Timed Up and Go Test. The Time Up and Go (TUG) test is commonly used and measures the time in seconds for a

patient to rise from a standard armchair, walk 3 meters, turn around, and return and sit down again. Reliability is well documented, and the TUG is highly correlated with other tests of mobility. The TUG is able to discriminate various conditions, including residential status and falls. Normative reference values have been determined through meta-analysis (66).

Walk-Stair Climb Test. Mercer *et al.* (67) developed a test for use with dialysis patients that combines tasks to assess gait speed as well as dynamic strength using stair climb. Split times for each of the four distinct parts (walk 50 meters, ascend and descend 22 steps, and walk 50 meters to return to the start point) and the total time are recorded. The overall test score has a significant correlation with peak oxygen uptake and is highly reproducible, with a coefficient of variation of 8.2%.

Other Tests. Many other tests and test batteries can be used to assess physical performance limitations, including the Musculoskeletal Impairment Index (68), Functional Fitness Test (69), Physical Performance Test-7 item (70), and Modified Physical Performance Test-9 item (71). Procedures and scoring for many of these tests and others can be found at <http://web.missouri.edu/~proste/tool/>. Segura-Ortí and Martínez-Olmos (72) have reported test-retest reliability and minimal detectable change scores for chair stands and the 6MW test in hemodialysis patients. Further measurement characteristics, a discussion of clinically meaningful change, and cut-points for some tests are found in Supplemental Material 2.

Measures of Self-Reported Functioning

The ultimate concern in declining physical function is the effect of performance limitations on the ability to participate in life activities. Depending on the framework, this may be referred to as “disability” (16) or “restricted activity participation” (11) (Figure 2). This aspect of function is typically assessed using self-report questionnaires, such as the Katz Independence in Daily Living questionnaire (73), Instrumental Activities of Daily Living (74), the Sickness Impact Profile (75), the Short Form-36 physical function scale (76), or the Duke Activity Status Inventory (77). Most of these assessments determine the level of perceived difficulty or limitations the patient experiences with various activities; some are disease specific, whereas others assess more general health concerns. As with the physical performance measures, there is a vast array of questionnaires to assess activity participation, a listing of which is beyond the scope of this paper.

An excellent resource for clinicians and researchers for patient-reported outcome measures that includes activity participation assessments is the Patient Reported Outcomes Measurement Information System (PROMIS) (78). PROMIS (<http://www.nihpromis.org>) is funded by the National Institutes of Health to provide clinicians and investigators “a system of highly reliable, precise measures of patient-reported health status for physical, mental, and social well-being. The measurement tools provided by PROMIS serve as primary or secondary endpoints in clinical studies of treatment effectiveness and measure concepts that include physical function limitations, pain, fatigue, depression, anxiety, and social function. PROMIS has constructed item banks (a collection of questions

measuring the same thing) that can be administered in short forms or adaptively through computerized testing. A test bank of questions can be developed to assess self-reported limitations in activity participation.”

Measurement of Physical Activity

Physical activity is a complex, multidimensional behavior influenced by characteristics of the individual and the environment that occurs in all domains of life (home, work, and transport) (79). The measurement of physical activity is fraught with challenges (80,81), many of which were addressed in the proceedings of a conference sponsored by the National Cancer Institute and the American College of Sports Medicine in 2011 (<http://journals.humankinetics.com/jpah-supplements-special-issues/jpah-volume-9-supplement-january>). A comprehensive discussion of physical activity assessment methods is beyond the scope of this paper however, we briefly discuss some basic concepts related to physical activity measurement.

Physical activity is defined as any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level. Physical activity can be categorized by mode, intensity, and purpose (context), among others (82,83). Note that physical activity participation as described here differs from the “activity participation” of the NHATS model (above) in that the activity participation is the ability for participation in ADL/IADL. Exercise (or exercise training) is a subcategory of physical activity that is “planned, structured, repetitive and purposive in the sense that the improvement or maintenance of one or more components of physical fitness is the objective” (82,84). Given these definitions, it is obvious that a measure of physical performance, although it may be highly correlated with physical activity, is not an appropriate surrogate measure for physical activity.

Physical activity is typically measured using self-report instruments, but motion sensors (accelerometry) and step counters can also be used for specific purposes. A wide variety of accelerometers are available, which use different measurement and output measures ranging from vector magnitude to counts (which may be derived from amplitude or frequency). Not all units are calibrated using the same methods, and there is significant intra-unit variability (even within units from the same manufacturer) (85). Thus, the correlations between accelerometer output and exercise intensity is device dependent. Although some investigators have reported cut-points for various intensity categories using accelerometers (86), this may be specific to a given type of accelerometer thus, cut-points in counts should be used carefully. Neither accelerometers nor step counters can assess activities in which the mode of activity is something other than walking or jogging. The quality of data derived from these devices depends on such factors as placement and adherence (87). Calibration of the devices and analysis of the data also must be standardized and consistent. These devices may be more effectively used in combination with self-report (88). As technology advances, monitoring of physical activity using devices will undoubtedly improve (89).

Self-report is widely used for physical activity assessment despite many shortcomings, including recall bias,

misinterpretation of questions, and quantification of energy expenditure. Choice of an instrument requires careful consideration because physical activity is a complex behavior and can be presented and thus evaluated in many different ways (81). Physical activity can be characterized by contextual domains (leisure, work, recreation, sports/exercise, housework, commuting) or by the mode or type of physical activity (walking, riding), frequency (how often performed), intensity (light, moderate, or vigorous), or duration (time spent performing activity) (82).

The type of physical activity can be assessed by open-ended questions and categorized according to contextual domain or intensity (activities listed individually or grouped according to levels such as light, moderate, and vigorous). Activities can be presented according to intensity: absolute intensity, defined using MET values or caloric cost or relative intensity, which is determined by the fitness level of the individual (82). Self-report measures also differ in the time frame assessed (*i.e.*, during the past week, usual during the past year, or during the lifetime).

The summary scores can be chosen according to level of detail for the specificity of the physical activity participation: The summary score may be a dichotomous variable (*i.e.*, active versus nonactive, meeting guidelines or not), an ordinal continuous variable (low active, medium active, high active), or a continuous score (MET-minutes per day or week, kcal per day or week). Some instruments have summary scores that may not be translatable into useful amounts of physical activity (*i.e.*, adjusted activity score on the Human Activity Profile). Subscores may also be of interest, such as upper- versus lower-body activities, leisure versus occupational activities, and structured versus nonstructured exercise participation (81,90).

Given the multidimensionality of physical activity behavior, the choice of an instrument depends on many factors. In their excellent report, Sternfeld and Goldman-Rosas present a systematic approach to selection of a physical activity measure (90) that includes the following considerations: (1) the primary aim of the study (or program); (2) the study design (which will dictate the time frame of physical activity assessment); (3) the study hypothesis (is physical activity an independent or dependent variable or covariate?), which will determine the level of detail needed in the summary score; (4) the construct of interest (*i.e.*, is the interest in participation in moderate to vigorous activity or in activities below that intensity?); (5) the domains of interest (leisure time activity versus activity in housework or care-giving); (6) the parameters of physical activity interest (*i.e.*, total energy expenditure versus participation in activity at a recommended level or not); (7) specificity of activity participation (level of categorization of activities); (8) whether a summary score or subscale scores are of interest; (9) the target population (*i.e.*, if the population is elderly or not working, then most physical activity may be achieved during leisure time activities [and, thus, an instrument that includes assessment of occupational activity may not be appropriate], or, in a population of patients who are known to have significant functional limitations, a recall that asks only the time spent in moderate to vigorous activities may yield minimal information); and (10) logistic considerations (*i.e.*, costs, participant and staff burden, analysis complexity).

A compendium of questionnaires was published in 1997 (91) and is now accessible in expanded form on the interactive Physical Activity Resource Center for Public Health website (www.parcph.org). Borowski and Bowles (92) provide an excellent set of resources for locating and selecting self-reported measures of physical activity. Another critical resource is the 2008 "Physical Activity Guidelines Advisory Committee Report" to the Department of Health and Human Services (82), which is an update of "Physical Activity and Health: A Report of the Surgeon General" published in 1996 (83).

Frailty and Physical Functioning

Frailty is a concept that has recently emerged in the literature of CKD (40,93,94). Because many factors contribute to frailty, a specific definition remains elusive. The most commonly used definition of frailty is "a geriatric syndrome of decreased reserve and resistance to stressors, resulting from cumulative declines across multiple physiologic systems, causing vulnerability to adverse health outcomes including falls, hospitalization, institutionalization and mortality" (95–97). Research is ongoing to develop comprehensive measures for research and clinical use (97), but most measures of frailty include the measurement of physical functioning (mobility and performance capacity and physical activity). The most widely used screening criteria for physical frailty was developed from the phenotype described by Fried *et al.* (95) using data from the Cardiovascular Health Study. This measure of frailty has been used to document the prevalence of frailty in older individuals with and without reduced renal function (40).

Frailty as defined by this phenotype requires the presence of three or more of the following clinical characteristics: weakness, weight loss, slow walking speed, exhaustion, and low levels of activity. Each of these clinical characteristics is linked with physical function, underscoring the importance of measuring physical performance in CKD. Operationalization of these constituent components has differed among studies, resulting in rates of frailty prevalence in CKD ranging from 68% (93) to 24% in dialysis patients (98), with the differences arising from the measures used for walking speed and weakness. These discrepancies underscore the importance of appropriate measurement of physical performance constructs (98). For a more in-depth discussion of these issues, the reader is referred to reference 98.

Recommendations for Clinical Practice

Figure 5 presents a schematic for implementing the Kidney Disease Outcomes Quality Initiative guideline for assessment of physical function and recommendations and encouragement for physical activity into practice. In addition to a routine medical history, the patient's ability to perform ADLs and IADLs, along with their self-report of mobility, can be easily assessed using standard lists of activities derived from Katz (73) and Lawton (74). Patients are asked whether they have difficulty performing ADLs, IADLs, and basic mobility tasks (list of activities in Figure 6). If they are unable to do any of them, there is reason for

referral to a specialist (clinical exercise specialist, cardiac rehabilitation, physical therapist) for further evaluation and appropriate intervention. Patients may state they have no difficulty at the current time; however, asking if the task has become more difficult or if they have had to modify their performance will indicate whether the patient is in a preclinical state of disability, also warranting referral to other health care services for preventive interventions. Actual assessment of mobility using a gait speed test (which takes <2 minutes) or the SPPB (which takes <10 minutes) will better indicate mobility (and possible referral) and allow for tracking of changes in mobility that may lead to eventual disability. Indicators of impaired mobility are found in Supplemental Material 2. In addition

to assessment for the need for intervention, mobility and activity limitations can be early indicators of other medical concerns (potential falls, muscle weakness, pain or discomfort, shortness of breath) that should be further evaluated as a part of routine medical care. If there are no activity limitations, the patient should be provided information to safely participate in regular physical activity, with encouragement for participation at every clinical encounter. “Exercise: A Guide for People on Dialysis” is a comprehensive program of flexibility, strengthening, and cardiovascular exercise for dialysis patients and is available for free download from <http://lifeoptions.org/catalog/>. The National Institute on Aging also has educational materials that are available for free download (<http://www.nia.nih>).

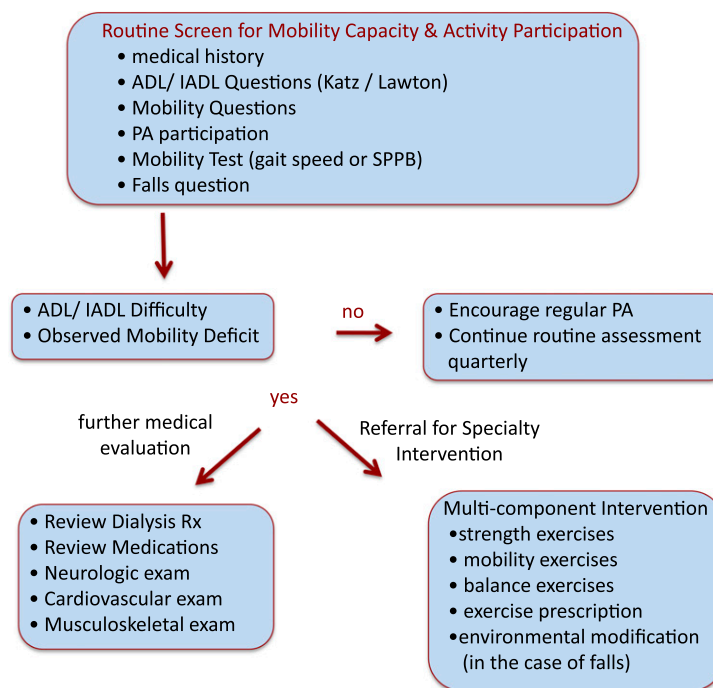


Figure 5. | Algorithm for routine management of mobility limitations in CKD. ADL, activity of daily living; IADL, instrumental activity of daily living; PA, physical activity; SPPB, Short Physical Performance Battery.

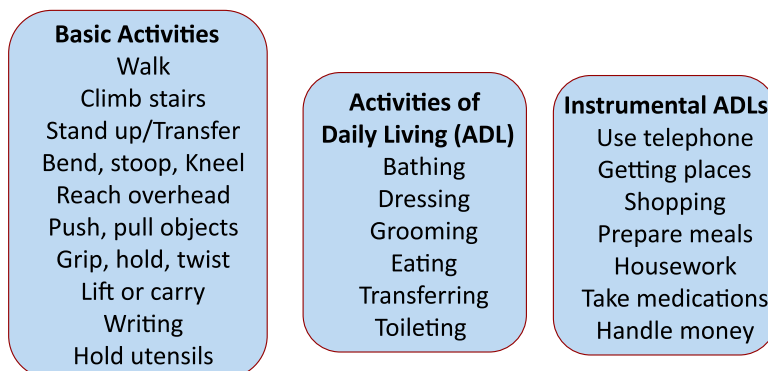


Figure 6. | Specific basic movements, activities of daily living, and instrumental activities of daily living. Data obtained from Katz (73) and from Lawton and Brody (74).

gov/health/publication/exercise-physical-activity-your-everyday-guide-national-institute-aging-1). Both are step-by-step guides, provide explanations and diagrams for specific exercises, and provide examples of progressive cardiovascular exercise programs tailored to low-fit and older individuals.

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