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CKJ Review

CKJ REVIEW

Assessing physical activity and function in patients with chronic kidney disease: a narrative review

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ABSTRACT

Physical activity potentially improves health outcomes in patients with chronic kidney disease (CKD) and recipients of kidney transplants. Although studies have demonstrated the beneficial effects of physical activity and exercise for primary and secondary prevention of non-communicable diseases, evidence for kidney patients is limited. To enlarge this evidence, valid assessment of physical activity and exercise is essential. Furthermore, CKD is associated with a decline in physical function, which may result in severe disabilities and dependencies. Assessment of physical function may help clinicians to monitor disease progression and frailty in patients receiving dialysis. The attention on physical function and physical activity has grown and new devices have been developed and (commercially) launched on the market. Therefore the aims of this review were to summarize different measures of physical function and physical activity, provide an update on measurement instruments and discuss options for easy-to-use measurement instruments for day-to-day use by CKD patients. This review demonstrates that large variation exists in the different strategies to assess physical function and activity in clinical practice and research settings. To choose the best available method, accuracy, content, preferable outcome, necessary expertise, resources and time are important issues to consider.

Keywords: assessment, disabilities, exercise, kidney disease, measurement, physical function, physical activity, sedentary behaviour, validity

INTRODUCTION

The beneficial effects of physical activity in the general population are well documented and include risk reductions for major non-communicable diseases such as cardiovascular disease, type 2 diabetes, cancer, dementia, all-cause mortality [1, 2] and kidney function loss in the elderly [3]. The World Health Organization stated that physical inactivity is the fourth most important risk factor for all-cause death, resulting in 6% of all

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deaths globally [4]. Observational studies have reported positive associations between physical activity and health outcomes in patients with chronic kidney disease (CKD) and recipients of kidney transplants. For example, Matsuzawa *et al.* [5] found a 22% reduced risk of mortality per 10 min/day increase in objectively measured physical activity in patients on haemodialysis, whereas Beddhu *et al.* [6] found a 33% lower risk of mortality per 2 min/h increase of light activities and an 85% lower death risk per 2 min/h increase in objectively measured moderate-to-vigorous activities in patients with reduced kidney function after adjustment for confounders. Other questionnaire-based studies have shown similar results [7–10]. Also, randomized controlled trials with relatively short-term interventions revealed health benefits of exercise training on physical functioning, cardiorespiratory fitness (CRF), muscle strength and quality of life [11–15].

In line with this, the Kidney Disease: Improving Global Outcomes guidelines recommend CKD patients perform moderate-intensity physical activity for at least 30 min at five sessions per week [16], a recommendation that was extrapolated from general population data. Specific evidence-based guidance for CKD patients is lacking [17]. Unfortunately, adherence to physical activity guidelines is rather low [7], with 42% of patients not requiring kidney replacement therapy [9], 6–48% among dialysis patients [18, 19] and only 11–25% among transplant recipients [20–22] performing sufficient volumes of exercise. The potential of exercise as a therapy is largely overlooked in nephrology practice [17]. Patients report major barriers to exercise training, including comorbidity in general, feeling too tired, being short of breath, being too weak, fear of adverse symptoms during exercise, lack of time and a lack of nephrologist counselling on the type of exercise and the associated health benefits [23, 24].

Although many studies have demonstrated the beneficial effects of physical activity and/or exercise on health outcomes, well-defined evidence-based exercise programmes for kidney patients are limited [7]. To enlarge the evidence base of the usefulness of physical activity in CKD and in end-stage kidney disease (ESKD) patients, valid assessment of physical activity and exercise is essential. Measurement instruments of physical activity may also improve physical activity levels and motivate patients to become physically active [25]. In 2013, Painter and Marcus [26] published an in-depth review on assessing physical function and physical activity in patients with CKD. After this review, the literature on this issue has grown and new devices to measure physical function and activity have been launched on the market. Therefore the aims of this review are to summarize different measures of physical function and physical activity, provide an update on measurement instruments and discuss options for easy-to-use measurement instruments for day-to-day use by CKD patients.

DEFINITIONS OF PHYSICAL FUNCTION, PHYSICAL ACTIVITY AND EXERCISE

Physical function is defined as the ability to carry out the basic actions, such as mobility, strength and endurance, that are essential to perform more complex activities and to maintain independence [26, 27]. Physical function includes physiological impairment and functional limitations or disabilities. Physiological impairment reflects physical function at the organ or system level, whereas functional limitations or disabilities reflect the physical function of the whole body or person [26, 28]. Physical activity, on the other hand, is described as any bodily movement produced by the contraction of skeletal muscle that requires energy expenditure [4]. Finally, exercise is defined as a planned, structured and repetitive form of physical activity. It includes aerobic exercise—activities that use large muscle groups continuously and rhythmically, such as brisk walking—and resistance or muscle-strengthening exercise, which is based on repeated use of isolated muscle groups to stimulate muscle strength and growth.

Physical function

A decline in physical function may result in severe disabilities and dependencies. The assessment and characterization of physical function can be established by measuring physiological impairment, functional limitations and functional disability/self-reported physical functioning [26, 28]. The characteristics of these three measures of physical function are provided in Table 1.

Measurement tools and their implementation in clinical and research settings

Physiological impairment. Physiological impairment reflects physical function at the organ or system level and is determined by exercise tolerance and capacity tests [26, 28]. The gold standard to measure CRF is cardiopulmonary exercise testing to assess oxygen (O_2) consumption. The peak oxygen uptake (VO_2max) can be defined as the absolute volume of maximum O_2 consumption per minute (L/min) or as the relative volume per kilogram of bodyweight per minute (mL/kg/min). An incremental exercise test should be performed on a treadmill or cycle ergometer using a predefined protocol [28–31] to determine VO_2max. Standardized criteria are used to define whether the maximum effort is reached [32]. When gas exchange measurements are not available, VO_2max can be estimated based on the peak workload and heart rate [29–31, 33]. However, such prediction formulas have not been validated for CKD patients [28]. In addition, CRF tests in CKD patients with severe deconditioning and muscle weakness might not always be possible and are subject to floor effects.

Another way of determining physiological impairment is assessing muscular fitness. Muscular fitness is reflected by maximum strength and muscle endurance. Muscle strength leads to movement (isokinetic force) or to force without movement (isometric force). Isokinetic force can be measured with an isokinetic dynamometer, but such equipment is expensive and requires well-trained personnel. Alternatively, a cheaper and easy-to-use measure to evaluate isometric handgrip strength is a hand dynamometer [34, 35]. Dynamic muscle strength can be assessed in all muscle groups using 1, 3 or 5 repetition maximum (RM) protocols for both the upper and lower body [26]. It is important to familiarize untrained adults with two to three sessions of the RM protocol to achieve the true maximum strength [36, 37]. Muscular endurance can be determined by the maximum number of repetitions at a predefined RM level, such as 60% of 1 RM or 80% of 5 RM [26].

Within laboratory and clinical research settings, CRF and muscular fitness are used to correlate physiological impairment to major events and mortality and to evaluate exercise intervention studies. In clinical care settings, cardiopulmonary exercise testing is used to diagnose underlying cardiovascular disease and to detect respiratory limitations, but outcomes can also be used to prescribe exercise regimes with certain intensities. CRF is also a strong predictor of mortality and may be used

Table 1. Measurement tools to assess physical function [26, 28, 55]

Characteristics	Physiological impairment	Functional limitations	Functional disability/self-reported physical functioning
Objective/ subjective	Objective	Objective	Subjective
Examples	Exercise tolerance/capacity tests, cardiopulmonary exercise testing and muscular fitness; maximum strength and muscle endurance	Physical performance tests such as walk tests and functional muscular fitness tests	Self- and/or proxy reports, questionnaires such as SF-36, RAND-36, PROMIS-29 and KDQoL
Basis	Lab-/hospital-based	Mainly lab-/hospital-based	Day-to-day life
Advantages	Gold standard Easy to quantify Less suspect of floor/ceiling effects More useful in comparisons between cultures and geographical environments	Objectively measured Easy to quantify More useful in comparisons between cultures and geographical environments Relatively simple, quick and cost-effective Applicable to large number of individuals Tests represent normal daily activities (walking and sit-to-stand transition)	Patient-focused information Reflects one's perception of their abilities in their environment Applicable to large number of individuals Easy, cost effective, time efficient and risk free
Disadvantages	May have limited practical utility Requires trained personnel Floor effect for cardiorespiratory tests	No gold standard Potentially suspect of ceiling effects	Subject to external influences Self-reported and therefore lower validity and reliability
Requirements	Trained personnel, expensive equipment and specific analytic skills/knowledge	Familiarization and adherence to protocols	Literacy and ability to understand the language
Practical considerations	Reliant on technical experts Lower feasibility	Less easy to interpret and translate to real-world situation (e.g. walking distance improvement, 1 SPPB point increase)	Choosing the outcome of the self-reported tool necessary to answer the clinical or research question

KDQoL: Kidney Disease Quality of Life.

to stratify patients into risk groups [38]. However, assessing CRF is labour intensive and requires specialized personnel. Therefore these tests might not always be feasible in daily clinical practice but could provide important information in specific cases. For example, determining VO_2max is potentially useful in pretransplant cardiovascular screening [39]. Muscular fitness-related measures may help clinicians to monitor disease progression and frailty in patients receiving dialysis and to detect early signs of adverse clinical outcomes like severe muscle loss and malnutrition [40]. The use of isokinetic dynamometers in clinical practice is usually cumbersome and not feasible, but measuring handgrip strength is an easy-to-use alternative that could also assist in the diagnosis of sarcopenia [41].

Functional limitations. Functional limitations reflect the physical function of the whole body [26, 28]. Functional limitations refers to the ability to perform basic physical tasks in daily life, such as walking and standing up from a chair. Roughly, functional limitations tests can be divided into walk tests and physical performance tests. One of the most commonly used walk tests is the 6-min walk test (6MWT), in which participants are asked to walk comfortably for 6 min. The researcher or clinician measures the distance travelled [26, 28, 42–44]. Other options include the 2MWT and 12MWT or walk tests with a predetermined distance, such as the 400-m walk test. Although the 6MWT cannot replace the CRF test, the correlation between the two is moderate to high [43, 45, 46]. Another walk test is the intermittent shuttle walk, in which patients walk back and forth on a 10-m course [46, 47]. An audio signal by a metronome directs the walking speed and increases the walking speed until the patient is unable to follow. This measure has good reliability and is moderately to strongly correlated with the CRF test [48]. The last variant of walk tests is the gait speed test. Gait speed is usually assessed as the walking pace over a short distance (6 m).

Examples of physical performance tests are the chair stand test or sit-to-stand test [49], stair climb test [50, 51], timed up and go test [52] and the short physical performance battery (SPPB) [53]. The chair stand test is based on the number of sit–stand–sit cycles within 30 s. This test is highly feasible in clinical practice and only needs a chair without armrests and a stopwatch. The sit-to-stand test is the time needed to complete five sit-to-stand manoeuvers [26, 28, 54, 55]. The stair climb test measures the ability to climb stairs. The method of climbing the stairs (alternating steps and handrail dependence) and the speed of stair climbing are measured [26]. The timed up and go test assesses the time a patient needs to rise from an armchair, walk 3 m, turn around, return and sit down again [26, 54, 55]. The SPPB includes a balance test, walking speed test (usual pace over 4 m) and sit-to-stand test. For the balance test, the patient is asked to hold three challenging standing positions for 10 s each. All three tasks are scored and summed up. In general, the SPPB is reliable and valid [54–56]. All physical performance tests are relatively easy and quick to perform. However, the tests are less useful for highly fit and highly functional individuals because of ceiling effects.

In laboratory and clinical research settings, measures of functional limitations could be used to predict survival and to evaluate interventions. For example, in cardiopulmonary patients, an increase of ∼30 m after a 6MWT has been shown to be clinically relevant [44, 46]. In patients with ESKD, an increase of 20 m after a 6MWT was associated with a lower risk of the combined endpoint of death, incident cardiovascular disease and hospitalization [57]. Gait speed was associated with function decline among 752 haemodialysis patients. Patients who walked <0.6 m/s had a 2.17 (95% CI 1.19–3.98) higher risk of mortality compared with participants walking ≥ 0.6 m/s and this risk was even higher in patients unable to walk {hazard ratio [HR] 6.93 [95% confidence interval (CI) 4.01–11.96]}. This study also revealed that each 0.1 m/s decrement in gait speed was associated with a 17% greater risk of death [HR 1.17 (95% CI 1.05–1.31)] [58].

In clinical care settings, assessing functional limitations is easier and more feasible than measuring physiological impairment, as all tests are relatively simple, quick, cheap and less labour-intensive. In addition, they provide useful information on the patient's ability to perform basic tasks. Repeatedly assessing functional limitations on the occasion of a visit to the dialysis centre could help to identify and monitor patients with serious functional limitations. For example, the tests are especially useful in the risk prediction or stratification of older adults [59, 60], whereas gait speed <0.8 m/s is associated with adverse health outcomes in older adults [41, 60]. However, the clinical utility and evaluation criteria still need to be established in patients with CKD.

Functional disability/self-reported physical functioning. Functional disability and self-reported physical functioning represent the physical function of the person as a whole [26, 28] and are associated with sociocultural environment. Both are usually captured by questionnaires, resulting in important patient-focused information. Self-reported physical function is significantly associated with survival in patients with CKD [61]. Commonly used questionnaires capturing physical function include the 36-Item Short Form Health Survey (SF-36) [62], RAND-36 [63] or Patient-Reported Outcomes Measurement Information System (PROMIS) Global Health and PROMIS-29 [64, 65]. Examples of other self-report tools [26, 28, 64] used in patients with kidney disease are activity of daily living [66], health-related quality of life [67], kidney disease quality of life [68], Duke Activity Status Inventory [69], Katz Index of Independence in Activities of Daily Living [70] and some dimensions of the sickness impact profile [71].

Due to its relatively simple, cost-effective, time-efficient and risk-free nature, the routine assessment of functional disability is easy to implement in research settings and clinical practice. However, more evidence is needed to examine its clinical utility and to establish the evaluation criteria of these self-reported tools. A cohort study in 951 ESKD patients showed that physical function assessed by the SF-36 was the strongest predictor of death among the various dimensions of the SF-36 and added significant prognostic information to a validated death prediction score [72].

Physical activity and sedentary behaviour

Physical activity consists of structured and incidental activities. Structured physical activities or 'exercise' are planned and purposeful activities to promote health and fitness benefits. Incidental physical activities are unplanned activities in daily life. Physical activities can be described in four dimensions and domains. The four dimensions include mode or type of activity, frequency, duration and intensity of the performing activity. The four most common domains are occupational, domestic/household, transportation and leisure time [73]. Physical activity is quantified as energy expenditure in kilocalories (kcal) or by using the metabolic equivalent of tasks (METs) of the activity. One MET is equal to the resting energy expenditure and can be converted to kilocalories (1 MET = 1 kcal/kg/h). Summing up all physical activities into one outcome results in the total physical activity per day or week; for example, physical activity–related energy expenditure per day or MET minutes per day. Total MET minutes per day can be calculated by multiplying the intensity (e.g. 3 METs), duration (e.g. 30 min) and frequency (e.g. 2 times/day), resulting in $3 \times 30 \times 2 = 180$ MET minutes.

Sedentary behaviour is at the opposite end of the energy expenditure continuum and is defined as any waking behaviour characterized by an energy expenditure ≤ 1.5 MET while in a seated, reclined or lying posture [74, 75]. Contrary to physical activity, a high level of sitting time is associated with increased risks of mortality [76, 77].

The time that an individual is physically active at a certain intensity is one of the most common measures of interest. For example, one may assess whether a CKD patient adheres to the recommended physical activity guidelines [16]. On the other hand, activities could be performed at a light, moderate or vigorous intensity and may be classified in absolute and relative terms [73]. For example, two individuals walk 3 mph, which is equivalent of 3.5 MET [78] from an absolute standpoint. However, when the heart rate is recorded, individual A is found to walk with a heart rate 35% of his maximum heart rate, whereas individual B walks at 60% of his maximum heart rate. In relative terms, individual A walks at a light intensity, whereas B walks at a vigorous intensity.

Objective measurement tools and their implementation in clinical and research settings

Objective methods to assess physical activity include wearable monitors that directly measure biosignals, such as motion, heart rate and energy expenditure. Generally, objective measures of physical activity can be divided into measures of energy expenditure, physiological measures, motion sensors and methods that combine different sensors [79]. Characteristics of measures of physical activity are provided in Table 2.

Energy expenditure. There are three measurement tools available to measure energy expenditure: indirect calorimetry, doubly labelled water and direct observation. Indirect calorimetry measures the ventilatory volume and amounts of oxygen consumed and carbon dioxide produced. This latter method is the gold standard under controlled conditions (laboratory based) [80–82]. Doubly labelled water measures total energy expenditure during daily life activities based on the difference in elimination rate between two stable isotopes, oxygen-18 (^{18}O) and deuterium (^{2}H) [83–85]. Direct observation needs an observer watching or videotaping an individual [86, 87]. All three measures are highly valid but are very labour intensive and require specialized personnel. In addition, the patient burden is potentially high; the measure is expensive and cannot be performed in large populations. Therefore indirect calorimetry, doubly labelled water and direct observation are of limited use in clinical practice and are only useful in very specific research designs.

Physiological measures. Heart rate monitoring is a practical and feasible way to assess physical activity. Heart rate monitoring is accurate for measuring moderate- to vigorous-intensity activities, since heart rate increases linearly and proportionally in healthy individuals [88]. However, low-intensity activities (e.g. sedentary behaviour and standing) are more difficult to capture because heart rate is influenced by sympathetic reactivity

Table 2. Measurement tools to assess physical activity [73, 110]

	Energy expenditure	Physiological measures	Motion sensors	Questionnaires and logs
Objective/ subjective	Objective	Objective	Objective	Subjective
Examples	Indirect calorimetry, doubly labelled water and direct observation	Heart rate monitoring	Accelerometers and pedometers	Questionnaires, logs and diaries
Basis	Lab-/hospital-based	Lab-/hospital-based and day-to-day life	Day-to-day life	Lab-/hospital-based and day-to-day life
Advantages	Gold standard High validity and reliability	Relatively inexpensive Low burden for patients/ participants High validity for moderate-to-vigorous activities Assists in physical activity and exercise interventions	Relatively inexpensive Low burden for patients/participants Easy to wear 24 h 7 days per week Provides detailed information about intensity, frequency and duration Applicable to large number of individuals Pedometers are intuitive, understandable and could motivate individuals Might increase daily physical activity	Low cost Questionnaires have low burden Applicable to large number of individuals Assessment of different domains and dimensions Questionnaires are valid to assess structured physical activity Logs/diaries provide a good overview of physical activity and energy expenditure Easy to implement in clinical practice
Disadvantage/s	Expensive Requires highly trained personnel Limited practical utility High participant burden	Lower validity for light-intensive physical activities and sedentary behaviour Affected by sympathetic reaction on for example emotions status, temperature and caffeine consumption Limited use in patients using medication affecting heart rate responses (e.g. β-blockers) or in patients suffering from cardiac autonomic neuropathy. In this case, the intensity can be determined in combination with the Borg Scale	Not able to distinguish between types of activities Depending on the placement, it neglects upper-body activities and differs in validity For accelerometers, data reduction, transformation and processing takes time Pedometers are less valid for energy expenditure Might increase daily physical activity	Questionnaires are subject to recall bias and socially desirable answers Questionnaires have low validity in incidental physical activity Logs/diaries have a very high burden on participants, patients and personnel Need to be population and culture-specific
Requirements	Trained personnel, expensive equipment and specific analytic skills/ knowledge	Familiarization to protocol, data extraction and analyses	Familiarization to protocol, data extraction and analyses	No specific requirements
Practical considerations	Reliant on technical experts Require calibration Lower feasibility	Patients could develop skin irritation during prolonged wearing Calibration requires technical expertise	Patients may have sensitive skin Calibration requires technical expertise Recommend at least 7 days of monitoring Positioning of the monitor Record data in the highest resolution	Choosing the outcome of the self-reported tool necessary to answer the clinical or research question

(e.g. emotional status, temperature and caffeine consumption). Furthermore, heart rate has some delayed response to activities and may therefore miss sporadic activities or overestimate the duration of certain activities. Current heart rate monitors are small wrist-worn devices that receive signals from a chest strap. New technologies have made it possible to measure and store heart rate for days. The newest devices measure heart rate on the wrist and do not need a chest strap. However, the validity of these new devices needs further investigation [89].

In clinical practice, heart rate monitors are easy-to-use instruments to collect information on the time that patients spend in moderate–vigorous physical activities and physical activity–related energy expenditure. However, for a complete overview of the patient's physical activity patterns, the patient needs to wear the monitor for several days and the data need to be processed, which makes the assessment more labour intensive. The accuracy of the estimated outcomes improves by calibrating an individuals' heart rate and energy expenditure response on different levels of activities using oxygen consumption measurements [90, 91]. To overcome individual calibration, group calibration [92, 93] is useful to predict the energy expenditure using multivariate predictive equations derived for group data of CKD patients. Heart rate monitoring could also be helpful when a patient wants to exercise at a certain intensity to gain health and fitness benefits. However, the use of heart rate monitoring might be limited in patients using medication affecting heart rate responses (e.g. β-blockers) or in patients suffering from cardiac autonomic neuropathy. When the patient's heart rate is affected by medication or other health conditions, it may be impossible to achieve a high or maximal heart rate. In this case, the intensity of physical activities can be determined in combination with the Borg Scale, a rating of perceived exertion. The Borg Scale ranges from 6 to 20 (i.e. very, very light to very, very hard) [94].

Motion sensors. The most commonly used motion sensors are accelerometers and pedometers. Accelerometers measure the acceleration in one, two or three planes and are attached to the hip, wrist, ankle, lower back or thigh [73]. Depending on the number of planes and place of attachment, accelerometers measure sedentary time, physical activity, physical activity–related energy expenditure and sleep-related behaviour. Acceleration signals are generally filtered and preprocessed by the monitor, resulting in activity counts. The amount and intensity of activity and sedentary time are derived from the classification of activity counts accumulated in a specific time interval and using different cut points [95]. Physical activity–related energy expenditure and sleep-related behaviour are estimated using (commercial) algorithms. In addition, to extract MET minutes and energy expenditure from activity counts, prediction equations [96, 97] or calibration [98] are needed. New methods to estimate these outcomes use raw acceleration signals (gravity units) instead of activity counts [99, 100] and may therefore be more valid and create the possibility to harmonize data from different accelerometers [101]. Researchers mostly use accelerometers of the brands ActiGraph, Actical, ActivPAL, Actiheart, Axivity and GENEActiv. Choosing the best accelerometer for a certain measurement needs some considerations. Accelerometers differ in size, battery, memory, number of axes, placement, software and cost [73]. In addition, decisions about data collection and data processing have a huge impact on the outcome [95]. For example, algorithms validated in adults might not be valid for older adults. Therefore it is crucial to carefully consider different accelerometers and criteria for data collection and data processing. Extensive information on the methodological issues are beyond the scope of this review, but helpful reviews are cited here [73, 95, 102–104]. To ensure that the data are representative of daily physical activity, the accelerometer should be worn 24 h/day for 7 consecutive days with a minimal wear time of 4 days [105]. The validity of accelerometers, expressed as correlation coefficients, ranges between 0.06 and 0.9 [103], but research validating accelerometers in CKD patients is very limited. Wrist- and hip-worn accelerometers are less valid for sedentary behaviour, but the validity greatly improves when attaching the accelerometer to the thigh (e.g. ActivPAL) to combine acceleration with posture [106, 107].

Pedometers are typically worn on a belt or waistband, in a pocket or at the ankle or foot and count the number of steps. An important advantage of pedometers is that steps are intuitive and understandable to laypersons. Simple pedometers quantify steps and estimate distance, whereas enhanced pedometers have a built-in time clock and memory and can estimate intensity and upload data to a computer [73]. StepWatch, Omron, New Lifestyles and Yamax are examples of commercially available pedometers. The number of steps per minute (cadence) can be used to estimate the intensity of physical activity [108]. In general, pedometers are accurate, but the main sources of error are slow walking speeds and obesity, which both result in an underestimation of steps [109]. Validation studies reveal a potential threshold of 100 steps/min for moderate-intensity activity [108, 109].

Motion sensors are generally used for research purposes. In clinical practice, they are important to objectively assess physical activity in daily life. However, the assessment of physical activity in the clinic is rare. Distributing devices, letting patients wear devices for 7 days, data processing, data transfer and data summarization are very time consuming. In addition, expertise in the characteristics, pitfalls and processing steps of a specific device is necessary to use the information for routine assessment. Therefore consumer-oriented devices or 'wearables' (e.g. Fitbit, Jawbone, Nike and Apple Watch) might be more feasible for patient use and integration into healthcare settings compared with pure research-grade accelerometers [110]. However, the activity outcomes (e.g. physical activity level, sleep, steps and calories) differ substantially across consumer-oriented devices. In addition, evidence for the validity of consumer-oriented devices is limited. Only a few reviews [110–112] have summarized the validity of consumer-oriented devices and found large variability in the accuracy, mainly depending on activity type. Consumer-oriented devices need to be improved to estimate energy expenditure since their accuracy depends on the type of activity and heterogeneity exists between devices. Improvements could be achieved with the addition of heart rate to accelerometry [111]. Taken together, consumer-oriented devices are widely available and have reasonable accuracy but may primarily be helpful to assist in patient's awareness, behaviour counselling and goal setting. On the other hand, pedometers are easy to use and intuitive. Patients need to wear the pedometer for several days to provide insight into their habitual physical activity, but no data processing steps are required to translate information. In addition, pedometers are fairly cheap and easy to wear. Another upcoming way to assess step count is smartphone applications. A prospective study [113] found a relative difference in mean step count ranging from −0.3 to 1.0% for pedometers and accelerometers, −22.7 to −1.5% for wearable devices and −6.7 to 6.2% for smartphone applications. These findings suggest that smartphone applications are relatively accurate in measuring physical activity.

Limited evidence is available ragarding if tracking physical activity behaviour using wearables and pedometers can effectively change this behaviour. A systematic review [114] including randomized controlled trials in older adults (>60 years) showed that activity tracker–based interventions resulted in an increase of 1558 steps per day (95% CI 1099–2018). A pilot study [115] in 60 dialysis patients revealed that the use of pedometers in combination with counselling resulted in an increase of 2256 (95% CI 978–3537) steps/day. However, this increase disappeared after cessation of the intervention. Therefore change in behaviour might be dependent not only on wearable devices, but also on individual encouragement and effective feedback loops

Table 3. Steps to select a measurement tool to assess physical function [26, 28, 55]

	Clinician/researcher needs to assess physical function characteristics									
	Available tools		CRF	Isometric dynamometer	hand dynamometer	1RM	Walk test	Transition test[a]	SPPB	Self-report
Content	Clinical practice: behaviour counselling/risk stratification	Suitable	✓		✓	✓	✓	✓	✓	✓
		Less suitable		✓						
	Research	Suitable	✓		✓	✓	✓	✓	✓	✓
		Less suitable		✓						
Consideration of outcome	Type of activity to be measured	Physiological impairment	✓	✓	✓	✓				
		Functional limitations					✓	✓	✓	
		Functional disability								✓
	Aspect of activity to be measured	CRF	✓				✓			
		Muscular fitness		✓	✓	✓				
		Mobility and performance					✓	✓	✓	
		Perception of functional ability								✓
Feasibility and practically	Cost of tool	Limited					✓	✓	✓	✓
		Medium	✓		✓	✓				
		High		✓						
	Sample size/ participants to be measured[b]	Low to medium	✓	✓	✓	✓	✓	✓	✓	✓
		High			✓		✓	✓	✓	✓
	Patient/participant burden[c]	Low			✓		✓	✓	✓	✓
		Medium	✓	✓		✓				
Resources	Staff burden[d]	Low			✓		✓	✓	✓	✓
		Medium				✓				
		High	✓	✓						
	Data processing/ transfer/ summarization	Easy/fast			✓	✓	✓	✓	✓	✓
		More difficult/ less fast	✓	✓						
Assessing	Time needed for assessment	<5 min			✓		✓	✓		
		5–10 min					✓		✓	✓
		>10 min	✓	✓		✓				
	Immediate feedback for patient/participant/health professional	Yes	✓	✓	✓	✓	✓	✓	✓	✓
		No								

[a] Transition test is chair stand test or sit-to-stand test, stair climb test and the timed up and go test.

[b] Low to medium: tests can be performed in smaller groups and are less feasible for very large populations; high: tests are easy to perform and are feasible in large populations.

[c] Low: tests are easy to perform by the patient and tasks are clear and simple; medium: tests are less easy to perform and require maximal or submaximal effort.

[d] Low: assessment is quick (<10 min) and no data processing required; medium: assessment is longer (>10 min) and no data processing required; high: assessment is longer (>10 min) and requires data processing.

[116]. The role of wearables in inducing behavioural change is an important area of future research.

Multisensing methods. Some objective assessment tools are able to combine multiple parameters. Examples are the Actiheart (accelerometer and heart rate sensing) and Intelligent Device for Energy Expenditure and Activity (five accelerometers). Evidence for these devices is limited, but some studies have shown that multisensing devices could improve the validity for assessment of physical activity compared with single-sensing devices [73].

Subjective measurement tools and their implementation in clinical and research settings

Subjective measures use questionnaires and logs and rely on the individual to report his/her activities as they occur or to recall previously performed activity. Questionnaires are used to identify dimensions and domains of an individual's physical activity behaviour. They can vary in detail and number of items and can be collected by interview or self-report. The validity is sufficient and is in general higher for vigorous-intensity activities compared with light–moderate activities [73, 117, 118]. The content of questionnaires about sedentary behaviour is similar

Table 4. Steps to select a measurement tool to assess physical activity [73, 110]

	Clinician/researcher needs to assess physical activity characteristics							
	Available tools		Questionnaire	Logs and diaries	Heart rate monitor	Pedometer	Accelerometer	Multi-sensing
Content	Clinical practice: behaviour counselling/risk stratification	Suitable	✓			✓		
		Less suitable		✓	✓		✓	✓
	Research	Suitable	✓	✓		✓	✓	✓
		Less suitable						
Consideration of outcome	Type of activity to be measured	Total physical activity	✓	✓	✓	✓	✓	✓
		Total energy expenditure	✓	✓				
		Walking behaviour	✓	✓		✓	✓	
		Domain-specific	✓	✓				
		Sedentary behaviour	✓	✓			✓	✓
		Aerobic exercise	✓	✓	✓	✓	✓	✓
		Resistance exercise	✓	✓				
	Aspect of activity to be measured	Total time	✓	✓	✓	✓	✓	✓
		Intensity	✓	✓	✓		✓	✓
		Duration	✓	✓	✓		✓	✓
		Frequency	✓	✓	✓		✓	✓
Feasibility and practically	Costs of tool	Limited	✓	✓		✓		
		Medium	✓		✓		✓	
		High						✓
	Number of patients/participants to be measured	Low to medium	✓	✓	✓	✓	✓	✓
		High	✓		✓	✓	✓	✓
	Patient/participant burden	Low	✓					
		Medium			✓	✓	✓	✓
		High		✓				
Resources	Staff burden	Low	✓			✓		
		Medium			✓	✓	✓	✓
		High		✓				✓
	Data processing/transfer/summarization	Easy/fast	✓			✓		
		Moderately easy/fast		✓	✓			
		More difficult/time-consuming					✓	✓
Assessing	Time needed for assessment	One time point	✓					
		Few days of administer/wear time		✓	✓	✓	✓	✓
	Immediate feedback for patient/participant/health professional	Yes	✓			✓		
		No		✓	✓		✓	✓

to that on physical activity. Sedentary time (hours/day) can be measured in total, domain specific, during weekdays versus weekend days and during working versus non-working days [106, 107]. The validity of sedentary behaviour questionnaires is comparable with the validity of physical activity questionnaires. In the past few decades, many questionnaires have been developed to assess activity behaviour. In-depth information about these different questionnaires is beyond the scope of this review. Useful reviews for helping to decide on specific questionnaires are cited here [73, 106, 107, 110, 117–121]. Hour-by-hour or activity-by-activity information about physical activity and sedentary behaviour patterns could be obtained by logs or diaries. A well-known log is the Bouchard Physical Activity Record [122], which identifies nine types of movement behaviours every 15 min for 3 days. Currently the only measurement tool for resistance or muscle-strengthening exercise is questionnaires and logs/diaries, since there are no objective measures to assess this type of activity.

Questionnaires are an easy and cheap way to assess physical activity and sedentary behaviour. For research settings, their validity and reliability are sometimes too low. However, questionnaires are valid enough to get a rough idea of the physical activity and sedentary patterns of patient populations. In addition, questionnaires provide an overview of the domains, which are essential in behaviour counselling. In clinical practice, questionnaires can be easily administered at clinical visits and integrated into the clinical workflow.

Choosing the best tool

Routine assessments of physical function and physical activity are important. However, choosing the most appropriate measurement tool needs some thought, especially since in most cases the accuracy decreases when the ease of assessment increases. Classical criteria for deciding on the best available tool are based on the content validity, internal consistency, criterion validity, construct validity, reproducibility, responsiveness, floor and ceiling effects and interpretability [123]. Other factors are outcome of interest, cost, time, burden on the patient or medical personnel and the process of data extraction. Table 3 presents possible considerations when deciding on the most appropriate tool for physical function, whereas Table 4 presents possible arguments when deciding on the most appropriate tool for physical activity.

Conclusions

This review provides an overview of different tools to assess physical function and physical activity in lab- or hospital-based situations or in daily life. There exists a large variation in outcomes that can be measured, accuracy, necessary expertise and resources and time needed to obtain the desired information. We have distinguished between measurement instruments for use in clinical practice and in research settings. Routine assessment of physical function and physical activity needs to be integrated into the clinical workflow, for example, by adding easy measures to the electronic patient file. This creates the opportunity to discuss physical function and activity between healthcare professionals and patients and to follow declines and improvements over time.

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CONFLICT OF INTEREST STATEMENT

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