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Original Article

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Subjective and objective physical limitations in high-functioning renal dialysis patients

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Abstract

Background. The utility of subjective measures of physical function as discriminative, evaluative and predictive tools in patients with ESRD is accepted, but objective performance tests also provide valuable information on patient status. The aims of this study were to determine what objective physical limitations exist in a select group of dialysis patients, designated as 'high-functioning' on the basis that they had low comorbidity and subjectively perceived themselves to function well, and to examine relationships between the objective and subjective measures.

Methods. Twelve patients (male, 7; female, 5) aged 18–55 years, with scores of $\geq$75 points in the Short Form-36 Physical Function scale (PF) and low comorbidity (Charlson score $\leq$ 2) were recruited for comparison with age and sex-matched sedentary controls. Objective performance measures included vibration perception threshold (VPT), peak quadriceps isokinetic and isometric muscle torque, time to reach peak isometric torque, balance (body sway with eyes open and closed), temporal gait parameters and the sit to stand test (STST).

Results. Dialysis patients demonstrated significant deficits by comparison with controls in subjective PF score ($P < 0.001$), VPT ($P < 0.01$), quadriceps isometric and isokinetic torque ($P < 0.05$, $P < 0.005$), body sway with eyes open ($P < 0.01$) and closed ($P < 0.05$), self selected ($P < 0.005$) and maximum ($P < 0.01$) walk speed, duration of gait cycle ($P < 0.05$) and STST ($P < 0.001$). There was significant agreement between the subjective PF score and VTP ($P < 0.01$), isokinetic torque ($P < 0.05$), body sway with eyes open ($P < 0.05$) and closed ($P < 0.05$), self-selected walk speed ($P < 0.01$) and STST ($P < 0.01$).

Conclusions. Subtle but significant deficits in subjective and objective physical function existed even in this select group of dialysis patients. These findings define in more detail the underlying neuromuscular impairments and support the early implementation of active targeted rehabilitation programmes. The subjective and objective measures used here offer a useful panel of tests for clinical use in high-functioning dialysis patients.

Keywords: dialysis; measurement; objective physical performance; rehabilitation; subjective physical function

Introduction

Physical well-being is a fundamental component of health and quality of life, underpinning the ability to engage in activities of daily living and participate in social, recreational and vocational roles. It has long been recognized that physical function is compromised in patients with end-stage renal disease (ESRD). This can be attributed primarily to the effects of uraemia and the comorbidity associated with chronic renal failure, but inactivity also contributes to physical deconditioning and debilitation [1].

Physical function can either be quantified subjectively through self-reported and observer-scored rating scales or objectively by direct measurement of physical performance. Rating scales have already been found to be significant predictors of morbidity and mortality outcome in ESRD [2] and are accepted as useful instruments for patient assessment. Most subjective scales are concerned with the individuals' perceived functional ability in tasks of daily living i.e. what they feel they can do. Subjective reports are meaningful, since they capture the patient's viewpoint, but some scales are categorical in nature and they may suffer from ceiling and floor effects, which limits responsiveness. Objective performance measurement offers more tangible evidence of physical status,

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quantifying what a person is capable of doing in terms of observed variables such as speed and strength. Objective measures such as these provide continuous level data, affording greater discriminative ability. Furthermore, the identification of specific physical performance deficits in the underlying body systems allows targeted rehabilitation strategies to be devised. Thus both subjective and objective measures of physical function may be of value in ESRD.

The aims of this study were (i) to determine what physical performance deficits exist in a select group of renal dialysis patients, through comparison with an age and sex matched sedentary control group. The dialysis patients selected were free from symptoms of neurological or musculoskeletal disorders and reported good subjective function relative to previous dialysis cohorts and (ii) to explore the relationship between objective measures and subjective ratings of physical function in dialysis patients.

Subjects and methods

Patients attending at the dialysis unit of the Mater Misericordiae Hospital Dublin were admitted to the study provided they were aged 18–55 years; were established on dialysis for at least 3 months; had low to moderate comorbidity, based on Charlson Comorbidity Index scores [3]; had no clinical signs or symptoms of musculoskeletal dysfunction or peripheral neuropathy and had a subjective Physical Function (PF) score of 75 points or more in the Short Form-36 (SF-36) health survey [4]. This latter criterion was determined from the results of a previous study where 75 points delineated the upper quartile of PF scores in dialysis patients under the age of 65 years [5]. On the basis of these inclusion criteria the sample was designated as a being a 'high-functioning' dialysis group. Control subjects were admitted to the study if they had no history of renal impairment, no past history or current symptoms of neuromuscular dysfunction and were neither participating in physical exercise training, nor engaged in heavy manual labour as part of their job. Ethical approval was obtained and all participants gave informed consent before enrollment.

Subjective and objective physical function

Screening procedures prior to recruitment included a review of clinical history and calculation of Charlson Comorbidity Index scores. Patients with high comorbidity (> 2 point score) were excluded. Self-reported physical function was measured by the 10-item PF sub-scale of the SF-36, which describes a hierarchy of performance tasks and thus quantifies subjective physical function.

Objective assessment of physical function entailed evaluation of vibration sensation, muscle strength, speed of contraction and balance as well as the ability to walk and perform the sit to stand manoeuvre. Vibration perception threshold (VPT) testing is reported to be useful in clinical diagnosis of mild or pre-clinical cases of neuropathy [6] and this was measured at the supero-medial border of the dominant first metatarsal using a biothesiometer (Bio Medical Instruments, Newbury, OH). Isometric (static) and isokinetic (dynamic) torque of the dominant quadriceps muscle was measured in a sitting position with a Cybex II isokinetic dynamometer (Cybex, Lumex Inc., NY). Peak torque in Newton metres (Nm) generated under isometric conditions was first measured with the knee positioned at 90° flexion, following which isokinetic peak torque was recorded over 20 repetitions at a constant velocity of 180°/s through a range of 90°, from knee flexion to full extension. Torque measurements were standardised by expressing the force generated as a percentage of body mass (torque/body mass*100). Time taken to reach peak torque was also noted in the isometric test. Static standing balance was assessed by determining the magnitiude of body sway, occurring during a 10 s test period, first with eyes open and then eyes closed. This was quantified by centre of pressure (CoP) displacement and measured using a Bertec forceplate (Bertec Corporation, Columbus, OH) and Pro-Vec software (Pro-Vec 5.0; MIE Medical Research Ltd, Leeds, UK). The change in CoP displacement between test conditions was also calculated. Assessment of walking ability included measurement of self selected and maximum walking speed during the 10 metre walk test [7] as well as kinematic analysis of temporal gait parameters using a Kinemetrix two dimensional optoelectric motion analysis system (Kinemetrix system, version 2D/1; MIE Medical Research Ltd). The time taken to complete five repetitions of the sit to stand test (STST) was the final measure of physical performance [8].

Reliability

All measurements were taken by one observer in order to eliminate inter-rater error. Efforts were made to ensure good intra-rater consistency through standardization of the questionnaire administration and test protocol, calibration of equipment and test–retest reliability procedures for those objective performance measures which were open to observer variation. Intraclass correlation values for VPT testing, self selected walk speed, maximum walk speed and the STST were 0.99, 0.99, 0.98 and 0.98, respectively. Subject variation was minimized by including standard familiarisation procedures and scripted instructions in the test protocol. This allowed subjects to acquaint themselves with each of the physical test procedures prior to conducting the test proper and ensured consistency in the verbal encouragement provided.

Statistical analysis

The data were analysed by SPSS Statistical Software, version 11.0 (SPSS Inc; Chicago, IL). Independent *t*-tests were used to compare continuous variables between the groups. Categorical variables were compared with the chi-square test. The Mann–Whitney test was employed for comparison of the SF-36 PF scale scores between groups since the assumptions of normality were not met. Bivariate correlation using Spearman's rank correlation was performed to determine the strength of association between the subjective PF scores and objective performance tests of physical function, thereby evaluating the convergent validity between these two types of measures. Statistical significance was defined as $P < 0.05$ and tests were two tailed.

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Results

Twelve dialysis patients (seven male, five female) were recruited for the study and these were individually matched for age and sex with healthy, sedentary controls. Demographic and clinical characteristics of the participants are presented in Table 1. The median duration of renal replacement therapy was 11.5 (4–25) months, with seven (58%) of the dialysis group currently receiving haemodialysis (HD) and five (42%) receiving peritoneal dialysis (PD). Mean Kt/V in the HD patients was 1.29 ± 0.56 (URR $68 \pm 3\%$), while mean weekly Kt/V in the PD patients was 2.58 ± 0.17. Mean haemoglobin was 12.2 ± 1.6 g/dl and mean serum albumin was 40 ± 5.6 g/dl in the dialysis group as a whole. There was no significant difference in body mass index between dialysis and control groups. The employment rate was 58% in the dialysis group with seven of the 12 participants being engaged in paid employment and there was no significant difference in employment participation between the dialysis and control groups.

Subjective physical function

Self-reported, subjective physical function in the dialysis group (mean PF score = 85, median = 85) was higher that that reported by an earlier Irish dialysis cohort (median PF score = 75) [5] and the 'high functioning' dialysis group studied by DePaul *et al.* (mean PF score = 76) [9]. Nonetheless, these scores were still significantly poorer ($P < 0.001$) than those reported by the control group [mean PF score = 98, median = 100] (Table 2).

Objective physical performance measures

Comparison with controls revealed that the dialysis patients had significant deficits in all of the physical parameters tested (Table 2). VPT was significantly increased ($P < 0.01$) suggesting impaired sensory nerve function. Isometric and isokinetic muscle torque, expressed as a percentage of body mass, was significantly lower ($P < 0.05$, $P < 0.005$) by comparison with controls, indicating impaired static and dynamic muscle strength. Time taken to reach peak isometric torque was greater in the dialysis group but this was not statistically significant ($P = 0.10$). Static standing balance was found to be significantly poorer under both eyes open ($P < 0.01$) and closed ($P < 0.05$) conditions in

Table 1. Demographic and clinical characteristics

	Dialysis ($n = 12$)	Control ($n = 12$)	Significance level
Age (years) [mean (SD)]	42.0 (8.5)	42.0 (9.7)	n/s[a]
Sex (n)			
Male	7	7	
Female	5	5	n/s[b]
Height (m) [mean (SD)]	1.7 (0.1)	1.7 (0.1)	n/s[a]
Weight (kg) [mean (SD)]	74.8 (16.7)	73.8 (12.4)	n/s[a]
Body mass index (kg/m^2) [mean (SD)]	25.8 (3.7)	24.8 (2.5)	n/s[a]
Haemoglobin (g/dl) [mean (SD)]	12.2 (1.6)		
Serum albumin (g/dl) [mean (SD)]	40.0 (5.6)		
Primary diagnosis (n)			
ADPKD	4		
Glomerulonephritis	3		
Diabetes mellitus	3		
Nephrocalcinosis	1		
Interstitial disease	1		
Employment status (n)[c]			
Professional	2	2	
Managerial/technical	1	2	
Non-manual	4	5	
Home duties	4	2	
Student		1	
Unemployed	1		

ADPKD, autosomal dominant polycystic kidney disease.
[a]Independant t test
[b]χ^2 test.
[c]Occupations defined as in 'social class' classification in National Census.

Table 2. Subjective and objective physical limitations

	Dialysis ($n = 12$)	Control ($n = 12$)	Significance level
Subjective	Median (range)	Median (range)	
SF-36 PF score	85 (75–95)	100 (90–100)	$P < 0.001$[a]
Objective	Mean (SD)	Mean (SD)	
Sensory function			
VPT (microns of motion)	3.08 (2.88)	0.37 (0.14)	$P < 0.01$[b]
Muscle performance			
Isometric (Static) Peak torque (Nm/kg*100)	134.3 (62.8)	203.0 (59.8)	$P < 0.05$[b]
Time to peak torque (s)	6.8 (2.7)	5.0 (2.8)	$P = 0.10$[b]
Isokinetic (dynamic) peak torque (Nm/kg*100)	61.8 (33.3)	111.8 (43.3)	$P < 0.005$[b]
Balance—CoP displacement			
A/P displacement (eyes open) (cm)	0.52 (0.17)	0.35 (0.09)	$P < 0.01$[b]
A/P displacement (eyes closed) (cm)	0.81 (0.30)	0.49 (0.23)	$P < 0.05$[b]
Change in A/P displacement (eyes closed – eyes open)	0.29 (0.26)	0.14 (0.19)	$P = 0.13$[b]
Walking ability (10 m walk test)			
Self-selected walking speed (m/s)	1.31 (0.12)	1.59 (0.21)	$P < 0.005$[b]
Maximal walking speed (m/s)	1.74 (0.18)	2.05 (0.29)	$P = 0.01$[b]
Walking ability (kinematic analysis)			
Duration of gait cycle (s)	1.17 (0.13)	1.04 (0.13)	$P < 0.05$[b]
STST (s)	10.1 (1.6)	7.3 (1.1)	$P < 0.001$[b]

[a]Mann–Whitney test.
[b]Independent t-test.

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dialysis patients. Furthermore, the dialysis group demonstrated a greater, albeit non-significant ($P = 0.13$), increase in body sway when the eyes were closed. Walking performance was poorer in dialysis patients as evidenced by slower self-selected ($P < 0.005$) and maximum walking speed ($P = 0.01$) and the longer duration of gait cycle on kinematic analysis ($P < 0.05$). The dialysis group was also significantly slower in the STST ($P < 0.01$). Subgroup analysis was carried out to determine the relationship between physical performance measures and sex, dialysis modality and diabetic status, but no significant associations were found.

Analysis of agreement between the objectively measured physical performance variables and subjective PF scale scores revealed several significant correlations (Table 3). Higher PF scores were associated with lower vibration threshold, greater quadriceps isokinetic strength and less body sway as well as faster self-selected walking speed and STST performance.

Discussion

The strict inclusion criteria ensured that the dialysis patients in this study were younger, asymptomatic and functioning at a higher level than the majority of their dialysis peers. However, even this select group presented with significant subjective and objective limitations in the physical dimensions of health by comparison with age and sex matched sedentary controls. Undeniably, the patients studied were a specific sub-sample of the dialysis population at large, yet they clearly demonstrated deficits in physical function on formal assessment, giving further confirmation of the early onset, extent and functional consequences of uraemia on the nervous and musculoskeletal systems. These findings support routine assessment of subjective and objective physical function in all dialysis patients and illustrate the need to consider the impact of ESRD on physical well-being and quality of life in dialysis patients even before they present with overt signs and symptoms of physical dysfunction.

Table 3. Correlation between subjective SF-36 physical function scale score and objective physical performance measures

	Physical function score (Rho)
VPT	−0.69**
Isometric peak torque	0.34
Isokinetic peak torque	0.55*
Balance (eyes open)[a]	−0.48*
Balance (eyes closed)[a]	−0.51*
Self-selected walking speed	0.57**
Maximal walking speed	0.33
STST	−0.69**

*$P < 0.05$.
**$P < 0.01$.
[a]Body sway measured by CoP displacement.

The PF scale of the SF-36 was able to discriminate between patients and controls and moderate to good correlations (rho = 0.48–0.69) were noted between the subjective PF score and the objective measures of physical function. These findings support the validity of the PF scale as a brief clinical measure of dialysis patients' physical status.

The subjective limitations reported by these dialysis patients were reflected in objective testing where significant deficits in sensation, muscle performance, balance and functional ability were evident. VPT was significantly increased in all dialysis patients regardless of diabetic status suggesting sub-clinical sensory nerve dysfunction and supporting the notion that, while the overt clinical features of peripheral neuropathy are controlled with renal replacement therapy, mild or sub-clinical nerve dysfunction persists.

The dialysis group also showed significantly poorer quadriceps strength during isometric and isokinetic testing than controls, suggesting that these high functioning patients suffer from uraemic muscle impairment, as has been identified in other dialysis cohorts [10,11]. In addition to reduced strength, the dialysis patients also showed delayed muscle recruitment, taking on average 1.8 seconds longer than controls to generate isometric peak torque. This delay in muscle activation may reflect the selective atrophy of type II fast twitch fibres found in patients with ESRD [11], but given the evidence of sensory nerve dysfunction it is reasonable to suggest that impaired motor nerve conduction might also be a factor.

Static balance was significantly impaired in dialysis patients since they demonstrated poorer stability of CoP, i.e. greater body sway than controls, under both eyes open and closed conditions. They also showed a trend for balance to deteriorate more than controls when visual input was eliminated and greater reliance was placed on the somatosensory and vestibular systems. It can therefore be postulated that proprioceptive sensory dysfunction plays a part in impaired balance in dialysis patients.

The ability to walk at an acceptable speed is important for social and functional activities, being central to independence in the community [8]. The dialysis group studied here were significantly slower than controls at self-selected and maximum walking speeds and this was reflected in the longer duration taken to complete each gait cycle during kinematic analysis. The sit to stand manoeuvre is another key functional activity of daily life and again the dialysis patients took significantly longer to complete the STST than did controls. It is interesting to note however, that despite being significantly slower in the walking tests than controls, the current dialysis patients scored better (self selected walk speed = 1.31 m/s) than previous dialysis cohorts where self-selected walk speed ranged from 0.905 to 1.21 m/s [12,13], emphasizing their relatively high level of function.

The findings of this study have implications for the assessment and management of patients on maintenance dialysis. Dialysis patients suffer physical

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limitations which interfere with self-reported health status and quality of life, and even asymptomatic individuals who report that they function well in the community experience significant deficits in objectively measured physical performance. This underscores the need to consider physical rehabilitation measures early in the course of the disease in an effort to prevent deconditioning as well as countering the negative effects of renal failure. Already there is evidence that exercise interventions have positive benefits for predialysis patients [14] and so if optimal care is to be provided, physical rehabilitation must be a management priority once renal impairment is diagnosed.

This study also highlights the impact of ESRD on the nervous and musculoskeletal systems, with impairments in sensory function, balance, muscle strength and speed of muscle recruitment being evident, which in turn are associated with poorer ability to walk and rise from sitting. These findings provide a more detailed dissection of physical abnormalities in ESRD and illustrate the broad spectrum of objective physical measures that can be assessed. The value of physical performance testing is clear, providing quantitative information of the patient's status which might not be detected through subjective report. Such concrete functional data can complement existing clinical measures for patient evaluation and outcome tracking as well as providing a background against which to prescribe and measure the effects of targeted interventions. The physical performance variables measured in this study can be readily assessed in the clinical situation constituting a useful panel of reliable and sensitive tests. Such tests are tangible and easily observed by the patients themselves and may therefore constitute meaningful outcome measures from the patient's perspective.

The safety and feasibility of exercise programmes targeted at cardiorespiratory and muscle function in dialysis patients has already been established [12,13,15–20]. Reported benefits of exercise include improved: muscle morphology and strength [11,13,17], functional status [12,13,18] and quality of life [12,19]. Data from randomised controlled trials indicate that aerobic exercise training is effective in improving peak oxygen consumption, exercise capacity and self reported physical functioning [19,20], while a combination of aerobic and strength training is effective in improving aerobic and strength parameters [9,16]. The identification here of sensory, neuromuscular and balance deficits suggest that exercise focussed on improving these functions may also be beneficial and should be tested. While the optimal intensity, frequency and content of exercise remains to be determined, the association between sedentary behaviour and mortality is unequivocal in this patient group, supporting the routine provision of physical rehabilitation programmes and the use of objective physical tests as outcome measures.

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Conflict of interest statement. Catherine Blake and Yvonne M. O'Meara declare that they have no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated.

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