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Isokinetic Strength in Peritoneal Dialysis Patients: A Reliability Study

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Abstract: Although there are studies assessing the effects of interventions on the knee strength of patients undergoing dialysis, there are no previous studies investigating the test–retest reliability of isokinetic measures in people undergoing peritoneal dialysis. The objective of this study was to determine the relative and absolute reliability of peak torque and work measurements for isokinetic concentric knee and elbow extension and flexion in peritoneal dialysis patients. Thirty-one patients undergoing peritoneal dialysis (19 males) participated in the current study. All isokinetic tests were performed using a Biodex System 3. Participants performed three concentric repetitions of each test (flexion or extension) with the dominant limb (knee and elbow) at 60°/s. Peak torque (Nm) and work (J) were extracted. The intraclass correlation coefficient (ICC), standard error of measurement (SEM), and smallest real difference (SRD) were calculated. The results showed that all knee peak torque and work measures had an ICC of >0.90. On the other hand, the ICC for peak torque and work in the elbow concentric extension was <0.90, while the remaining elbow-related variables achieved an excellent reliability. Therefore, isokinetic dynamometry is a reliable technique to evaluate peak torque and work for concentric flexion and extension in both the knee and elbow joints in patients undergoing peritoneal dialysis.

Keywords: kidney; torque; exercise; physical fitness; peritoneal dialysis

1. Introduction

Peritoneal dialysis (PD) patients present a condition resulting from multiple physiological and behavioral changes which contribute to muscle wasting [1]. Recent studies showed that PD patients often present decreased levels of physical activity (PA) matching a sedentary lifestyle [2]. These circumstances significantly affect the health condition of those patients and are associated with significant morbimortality [3]. Moreover, the nutritional status and sedentary behavior directly affect muscle function, exercise performance, physical function, strength, and health-related quality of life [4–6]. Although the proportion of patients active during leisure time is low [4], they need adequate levels of strength to accomplish daily life activities such as the need to displace, walking up and down stairs, maintaining a standing position, etc.

Exercise programs are recommended to increase lean body mass, strength, and physical functioning in frail elderly persons and those with chronic diseases, including PD patients [5]. Precise and sensitive strength tests are required to appropriately extract conclusions in studies focused on the evaluation of strength. Among these tests, the hand grip dynamometer and the isokinetic dynamometer are two of the most reliable and widely used devices. In this regard, the handgrip dynamometer has been previously used to evaluate muscle strength of the upper limb in patients undergoing dialysis [4,7]. Isokinetic dynamometry has been previously used to evaluate the effects of different interventions and therapies on knee flexion and extension strength in dialysis patients [8,9], whereas, to our knowledge, there is no study evaluating upper limb strength using an isokinetic dynamometer in this population.

Although there are studies assessing the effects of interventions on the knee strength of patients undergoing dialysis, to our knowledge, no previous study has investigated the reliability of knee isokinetic procedures adapted for use in PD patients with poor muscle strength. In healthy individuals, the use of isokinetic dynamometry to evaluate the knee strength when subjects receive adequate instructions and are familiar with the equipment is sufficiently reliable [10,11], but the reliability in PD patients still remains unknown, which impairs and limits the appropriate interpretation of results. In this regard, reliability is considered an important prerequisite for the correct interpretation of isokinetic dynamometry data, which allows the clinician to identify whether or not a genuine change has occurred [12]. Therefore, the aim of the current study was to determine the relative and absolute intra-session reliability of peak torque and work measurements for isokinetic concentric knee and elbow extension and flexion in PD patients.

2. Materials and Methods

2.1. Participants

Patients were recruited from the Nephrology Unit from the Espírito Santo Hospital of Évora, Portugal. The inclusion criteria to participate in the study were as follows: (1) be a peritoneal dialysis patient for at least 6 months; (2) do not have any impediment to perform the strength tests according to the physician's criteria; and (3) give their informed consent to participate in the study. A total of 49 patients fulfilled the first two inclusion criteria and were invited to participate. Of them, 31 (12 women and 19 men) agreed to participate in the study and signed the informed consent. The University of Évora ethics committee approved the protocol of this study, which was conducted in accordance with the updated World Medical Association's Declaration of Helsinki for human studies [13]. Of the 31 participants, 18 were on continuous ambulatory peritoneal dialysis while 14 were on automated peritoneal dialysis. Patients were having PD for a mean of 943 ± 552 days.

2.2. Instrumentation

All isokinetic tests were performed using a Biodex System 3 quick-set isokinetic dynamometer (Biodex Corp., Shirley, NY, USA) and System 3 software (version 3.40). Body fat and lean percentage were assessed by dual-energy X-ray absorptiometry (DXA—Hologic QDR, Hologic, Inc., Bedford, MA, USA). Finally, physical activity level was assessed using the ActiGraph accelerometer device with dimensions 3.8 × 3.7 × 1.8 cm (27 g). All participants were asked to use an accelerometer on the right hip, near the iliac crest, during seven consecutive days.

2.3. Procedures

The procedure is depicted in Figure 1. The intra-session reliability of the measurements was evaluated. All tests were conducted by the same researcher. Only the dominant arm and knee were tested. The dominant arm was defined as the arm used to write and the dominant knee was defined as that of the preferred kicking leg. Knee and elbow protocols followed the Biodex Isokinetic System 3 quick-set application/operation manual instructions [11]. Prior to the implementation of the protocols, all the subjects performed 15 min of warm-up with joint mobilization and stretching.

1. Knee protocol: Participants were seated in a seatback tilt at 85°. The dynamometer orientation and dynamometer tilt were 45° and 0°, respectively. The participant's axis of rotation of the knee was aligned with the dynamometer shaft. All patients were informed about the tasks

they were going to perform and performed two familiarization and warm-up repetitions. The weight of the leg was recorded using the dynamometer software, and gravity adjustments were made. All participants were asked to perform three concentric movements of the knee involving alternative extension and flexion at 60°/s. Reliability was calculated between the second and the third repetition. The rest interval was 2 min long. This protocol has been used previously in the scientific literature [14,15]. The participants were verbally encouraged during the tests.

2. Elbow protocol: Participants were seated in a seatback tilt at 85°. The seat orientation was 15°. The dynamometer orientation and dynamometer tilt were 15° and 0°, respectively. Participants were stabilized with shoulder, waist, and thigh straps. They were informed about the tasks and performed two repetitions, aimed to warm-up and also to get used to the position, the angular speed, and the proposed task. The weight of the arm was recorded using the dynamometer software, and gravity adjustments were made. All participants were asked to perform three concentric movements of the elbow involving alternative extension and flexion at 60°/s. Reliability was calculated between the second and the third repetition. The rest interval was 2 min long. The participants were verbally encouraged during the tests.

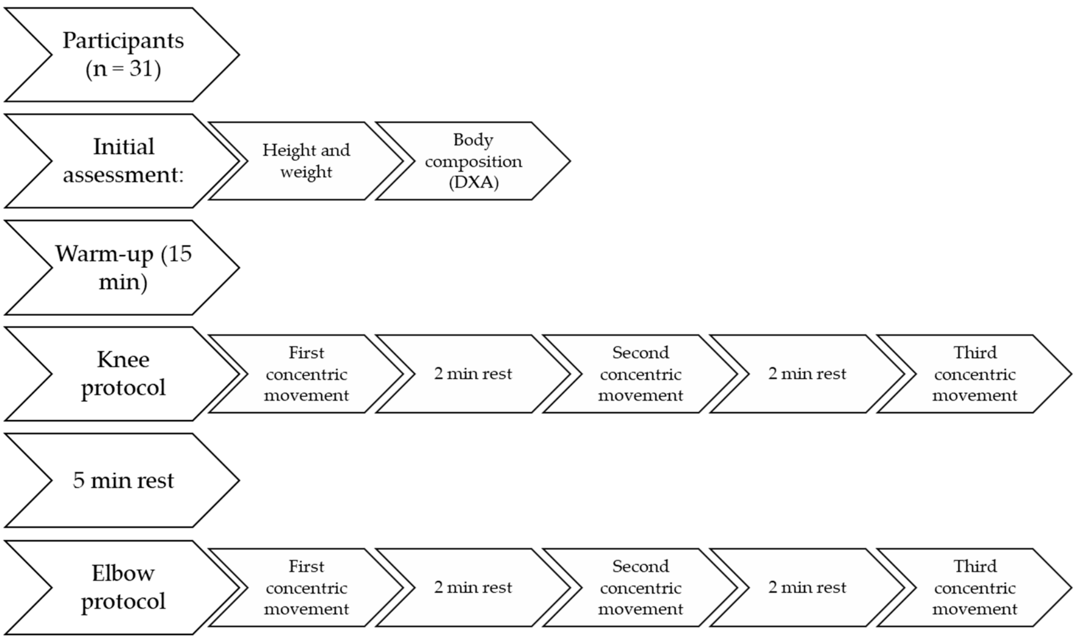

Figure 1. Study procedure. DXA: dual-energy X-ray absorptiometry.

2.4. Measures

Peak torque (Nm) and work (J) were extracted from the System 3 software for knee and elbow flexion/extension. Peak torque is defined as "the single highest torque output recorded throughout the range of motion of each repetition". Work is defined as "the output of mechanical energy" and is represented by the area under the curve of torque versus angular displacement [16].

2.5. Statistical Analysis

The statistical analysis was performed following the criteria used in previous studies [12,14,15]. Absolute values for peak torque and work were obtained as means and standard deviations. Differences in the descriptive characteristics between men and women were evaluated using independent samples *t*-test.

Relative reliability was estimated using the ICC3,1 (intraclass correlation coefficient, two-way mixed single measures) with 95% confidence intervals across the two test repetitions [17]. An ICC higher than 90 was interpreted according to Munro et al. as excellent [18]. A paired sample *t*-test was performed to analyze differences in the mean values of the isokinetic variables between Repetitions 2 and 3.

Absolute reliability was determined by calculating the standard error of measurement (SEM; SEM = SD, where SD is the mean SD of Repetition 2 and Repetition 3) and the smallest real difference (SRD; SRD = 1.96) [19]. Additionally, the SEM and SRD were converted to percentages in order to facilitate the comparability of errors of measurement with those in other studies. These percentages were calculated as follows: SEM% = (SEM/mean peak torque or work of the two repetitions)·100 and SRD% = SRD/(mean peak torque or work of the two repetitions)·100.

Isokinetic variables were also correlated with anthropometric and body composition variables using bivariate Pearson's correlation.

3. Results

The characteristics of patients undergoing PD are reported in Table 1. The mean age was 48.45 (13.39) and the mean body mass index (BMI) was 24.35 (3.67), which is close to the overweight threshold. Differences between men and women were observed in age, body composition, height, and weight. In general terms, there was sedentary behavior, with more than 18 h/day of sedentary time and about 5000 daily steps.

Table 1. Characteristics of patients undergoing peritoneal dialysis (*N* = 31).

	All	Men (*N* = 19)	Women (*N* = 12)
Anthropometric and Body Composition Measurements			
Age (years)	48.45 ± 13.39	52.42 ± 11.54 *	42.16 ± 14.16
Height (cm)	162.19 ± 9.67	167.63 ± 6.80 *	153.58 ± 6.89
Weight (kg)	64.29 ± 9.45	67.40 ± 7.88 *	59.37 ± 9.95
BMI (kg/m^2)	24.35 ± 3.67	23.82 ± 3.37	25.20 ± 4.10
Body fat percentage	27.79 ± 8.49	23.23 ± 5.25	35.01 ± 7.65 *
Body lean percentage	68.58 ± 8.23	72.92 ± 5.14 *	61.70 ± 7.58
Physical Activity Levels			
Sedentary time (h/day)	19.34 ± 1.61	19.44 ± 1.86	19.15 ± 1.11
Light physical activities (h/day)	3.50 ± 1.54	3.43 ± 1.77	3.63 ± 1.09
Moderate and vigorous activities (h/day)	0.28 ± 0.26	0.27 ± 0.26	0.29 ± 0.27
Number of daily steps	5157.18 ± 2483.80	5005.63 ± 2698.69	5429.98 ± 2149.99
Lipid Profile and Other Parameters			
Serum cholesterol (mg/dL)	182.12 ± 31.42	183.00 ± 31.22	180.75 ± 33.09
Serum high-density lipoprotein (mg/dL)	45.35 ± 13.63	45.42 ± 14.08	45.25 ± 13.49
Serum low-density lipoprotein (mg/dL)	107.64 ± 39.05	112.68 ± 34.71	99.66 ± 45.53
Serum triglycerides (mg/dL)	167.29 ± 70.94	171.68 ± 74.31	160.33 ± 67.84
Haemoglobin, (g/dL)	11.66 ± 1.47	11.98 ± 1.51	11.15 ± 1.32
Serum albumin (g/dL)	3.90 ± 0.41	3.94 ± 0.41	3.83 ± 0.43
Serum sodium (mEq/L)	137.58 ± 3.91	137.73 ± 3.44	137.33 ± 4.71
Serum potassium (mEq/L)	4.34 ± 0.75	4.36 ± 0.64	4.30 ± 0.92

Data reported as mean ± SD. * Significantly higher compared to the other group based on results from independent samples *t*-test. BMI: body mass index.

Table 2 shows the peak torque and work at 60°/s in each of the two repetitions for all variables. There were no statistically significant differences in any test. In general, the mean peak torque and work of male patients were higher than values from female participants.

Table 3 summarizes the ICC values and the 95% confidence intervals, as well as the SEM and SRD in absolute values and percentages. All knee peak torque and work measures had an ICC greater than 0.90, which is excellent according to the classification by Munro, Visintainer, and Page [18]. On the other hand, peak torque in the elbow concentric extension in males and work in the elbow concentric extension in males and the general population showed an ICC lower than the threshold for excellent reliability. The remaining elbow-related variables achieved an excellent reliability. Regarding peak torque, the SRD% in the general population ranged between 18.41% in the elbow concentric flexion and 29.44% in the knee concentric extension. Regarding work, the SRD% in the general population ranged between 26.15% in the elbow concentric extension and 33.63% in the knee concentric flexion.

Table 2. Summary of isokinetic peak torque and work at 60°/s in two repetitions ($N = 31$).

		Test Measurement	Peak Torque (Nm)			Work (J)		
			Repetition 2	Repetition 3	p *	Repetition 2	Repetition 3	p *
General (n = 31)	Knee	Concentric Extension	77.57 ± 31.40	78.27 ± 32.56	0.747	76.89 ± 34.98	79.06 ± 36.34	0.258
		Concentric Flexion	43.32 ± 21.57	43.43 ± 22.93	0.922	43.80 ± 29.92	44.85 ± 31.17	0.448
	Elbow	Concentric Extension	20.77 ± 8.00	19.92 ± 7.26	0.061	26.86 ± 13.48	25.66 ± 12.64	0.055
		Concentric Flexion	35.69 ± 9.65	35.57 ± 10.18	0.842	51.62 ± 13.39	49.63 ± 15.90	0.170
Men (n = 19)	Knee	Concentric Extension	80.77 ± 34.03	83.86 ± 32.95	0.317	82.25 ± 38.69	87.45 ± 37.62	0.062
		Concentric Flexion	48.67 ± 23.85	49.48 ± 25.56	0.626	50.18 ± 34.26	51.83 ± 36.16	0.437
	Elbow	Concentric Extension	24.84 ± 6.95	23.88 ± 5.78	0.182	33.25 ± 12.38	31.66 ± 11.55	0.116
		Concentric Flexion	39.93 ± 9.41	40.31 ± 9.49	0.697	58.27 ± 11.93	55.77 ± 16.52	0.280
Women (n = 12)	Knee	Concentric Extension	72.50 ± 27.35	69.40 ± 31.24	0.244	68.40 ± 27.57	65.77 ± 31.15	0.203
		Concentric Flexion	34.85 ± 14.50	33.85 ± 14.19	0.364	33.69 ± 18.42	33.80 ± 17.14	0.939
	Elbow	Concentric Extension	14.33 ± 4.65	13.65 ± 4.39	0.063	16.75 ± 7.91	16.15 ± 7.52	0.122
		Concentric Flexion	28.98 ± 5.37	28.07 ± 5.95	0.072	41.09 ± 7.65	39.91 ± 8.63	0.242

Note: Values are mean ± standard deviation; * Paired sample *t*-test was performed to analyze differences in the mean values of the isokinetic variables between Repetitions 2 and 3.

Table 3. Reliability of isokinetic concentric knee measurements ($N = 31$).

		Peak Torque (Nm)					
		Test	ICC (95% CI)	SEM (Nm)	SEM (%)	SRD (Nm)	SRD (%)
General (n = 31)	Knee	Concentric Extension	0.933 (0.868–0.967)	8.27	10.62	22.94	29.44
		Concentric Flexion	0.965 (0.930–0.983)	4.16	9.59	11.53	26.60
	Elbow	Concentric Extension	0.945 (0.890–0.973)	1.78	8.79	4.95	24.37
		Concentric Flexion	0.943 (0.887–0.972)	2.36	6.64	6.56	18.41
Men (n = 19)	Knee	Concentric Extension	0.923 (0.816–0.970)	9.29	11.28	25.75	31.29
		Concentric Flexion	0.961 (0.903–0.985)	4.87	9.94	13.52	27.55
	Elbow	Concentric Extension	0.885 (0.730–0.954)	2.15	8.86	5.98	24.56
		Concentric Flexion	0.909 (0.784–0.964)	2.85	7.10	7.90	19.69
Women (n = 12)	Knee	Concentric Extension	0.954 (0.855–0.986)	6.28	8.85	17.41	24.54
		Concentric Flexion	0.968 (0.897–0.990)	2.56	7.47	7.11	20.70
	Elbow	Concentric Extension	0.960 (0.872–0.988)	0.90	6.46	2.50	17.91
		Concentric Flexion	0.952 (0.849–0.986)	1.24	4.27	3.43	11.84
		Work (J)					
		Test	ICC (95% CI)	SEM (J)	SEM (%)	SRD (J)	SRD (%)
General (n = 31)	Knee	Concentric Extension	0.957 (0.913–0.979)	7.39	9.48	20.49	26.28
		Concentric Flexion	0.969 (0.938–0.985)	5.37	12.13	14.90	33.63
	Elbow	Concentric Extension	0.964 (0.927–0.982)	2.47	9.43	6.86	26.15
		Concentric Flexion	0.853 (0.719–0.926)	5.61	11.09	15.56	30.74
Men (n = 19)	Knee	Concentric Extension	0.949 (0.875–0.980)	8.61	10.15	23.88	28.14
		Concentric Flexion	0.968 (0.920–0.987)	6.29	12.34	17.45	34.22
	Elbow	Concentric Extension	0.934 (0.839–0.974)	3.07	9.47	8.52	26.25
		Concentric Flexion	0.767 (0.498–0.903)	6.86	12.04	19.03	33.37
Women (n = 12)	Knee	Concentric Extension	0.972 (0.910–0.992)	4.91	7.32	13.61	20.29
		Concentric Flexion	0.967 (0.894–0.990)	3.22	9.57	8.95	26.53
	Elbow	Concentric Extension	0.985 (0.952–0.996)	0.94	5.74	2.61	15.92
		Concentric Flexion	0.915 (0.743–0.974)	2.37	5.85	6.57	16.24

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient; SEM, standard error of measurement; SEM%, standard error of measurement as a percentage; SRD, smallest real difference; SRD%, smallest real difference as a percentage.

Table 4 shows the correlations between isokinetic strength and different variables such as age, height, weight, BMI, fat mass, and lean mass. The variable "height" was significantly correlated with all isokinetic strength outcomes, while BMI was not correlated with any variable.

Table 4. Correlations between isokinetic strength and anthropometric and body composition variables.

	Age	Height	Weight	BMI	Fat Mass %	Lean Mass %
Knee Concentric Extension Peak Torque	−0.314	0.450 *	0.015	−0.327	−0.290	0.279
Knee Concentric Extension Work	−0.199	0.554 **	0.143	−0.279	−0.337	0.319
Knee Concentric Flexion Peak Torque	−0.040	0.436 *	0.268	−0.082	−0.258	0.249
Knee Concentric Flexion Work	−0.071	0.455 *	0.221	−0.150	−0.297	0.285
Elbow Concentric Extension Peak Torque	0.087	0.748 **	0.455 *	−0.185	−0.522 **	0.508 **
Elbow Concentric Extension Work	0.075	0.647 **	0.396 *	−0.129	−0.414 *	0.393 *
Elbow Concentric Flexion Peak Torque	0.266	0.506 **	0.529**	0.041	−0.269	0.274
Elbow Concentric Flexion Work	0.132	0.634 **	0.509 **	−0.021	−0.363 *	0.342

* $p < 0.05$; ** $p < 0.01$; BMI, Body mass index.

4. Discussion

The main finding of this study was that the test–retest reliability of elbow and knee concentric flexion is good or excellent in PD patients. These results were similar to those observed in sit-to-stand-to-sit, six-minute walk, one-leg heel-rise, and handgrip strength tests in people undergoing hemodialysis [20] or in the incremental shuttle walk test, the estimated maximum repetition for quadricep strength, and VO_2peak by cardiopulmonary exercise testing in non-dialysis chronic kidney disease [21]. However, little was known about the reliability of physical function tests in PD patients and, to our knowledge, this is the first study aimed to evaluate the test–retest reliability of isokinetic measures in this population.

The evaluation of physical function is relevant since it is strongly related to quality of life, independence, and the ability to perform activities of daily living. Patients suffering from chronic kidney disease may have a higher risk of having low strength levels and low muscular mass, which is commonly associated with a higher risk of mortality [22]. However, most of the studies aimed to evaluate physical function in patients undergoing dialysis have been conducted with hemodialysis patients [23], while further research is needed in PD patients.

According to Zuo et al. [24], exercise capacity may be reduced in about 96% of PD patients. This reduction in exercise tolerance could be partially determined by age, sex, and body composition and is strongly associated with health-related quality of life in this population [25]. In this regard, the reduced quality of life and physical function may be similar in patients undergoing hemodialysis or PD [26]. However, Kang et al. [27] observed more favorable mental and physical components in hemodialysis patients compared with PD patients. Although the differences between the two dialysis modalities in terms of physical function and quality of life still remain unclear, patient satisfaction is commonly higher in patients undergoing PD [26,27]. Therefore, physical function is a relevant measure that should be included in comprehensive health assessments in dialysis patients. The current study provides test–retest reliability parameters that should be used to interpret health-related physical function evaluations in this population.

Isokinetic dynamometry is considered the gold standard for dynamic muscle performance testing [28,29]; thus, clinicians and researchers should be encouraged to use this device to conduct their physical function evaluations. Previous studies have reported the test–retest reliability of isokinetic measures in several populations different from patients undergoing dialysis. In this regard, reliability results obtained in the current study are similar to those obtained in postmenopausal women with osteopenia [30], women with fibromyalgia [15], patients with knee osteoarthritis [31], or persons with chronic stroke [32]. Furthermore, the current study not only reports the reliability parameters of measures of the lower limb but also assesses the reliability of the elbow flexion and extension strength tests. Therefore, future research may use both the absolute and the relative reliability parameters reported here to evaluate whether an observed change in lower or upper limb strength represents a true change or not.

Almost every measure achieved an excellent reliability according to the classification by Munro, Visintainer, and Page [18]. The ICC in elbow flexion in men was lower than 0.90; thus, it was classified as "good" but not "excellent". On the other hand, the reliability of this measure was excellent among women. Regarding the SRD, which is the parameter that defines the threshold to consider an observed change as "true" or "real", the values for the knee peak torque ranged between 20.70% in the knee concentric flexion of women and 31.29% in the knee concentric extension of men. Regarding the elbow's peak torque, it ranged between 11.84% in the concentric flexion of women and 24.56% in the concentric extension of men. Overall, higher reliability was observed in women compared to men, and the SRD was lower in the concentric flexion compared to the concentric extension. This was also observed when assessing the work. Although hypothetical, these sex differences might be related to the significant differences between men and women observed at baseline, i.e., age, height, weight, fat mass, and lean mass. However, given the relatively low sample size, this finding must be taken with caution.

The current study has some limitations. First, the participants did not undergo a familiarization session because of time and financial constraints. Second, although the sample size was similar to or even higher than those from previous studies [15,30,31], results from the stratification by men and women must be taken with caution. Third, the mean age of males was 52.42, which means that they were more than 10 years older than the women; thus, comparison between males and females could be influenced by that age difference. Despite these three limitations, the current study provides useful information about the reliability of isokinetic measures in people undergoing PD.

5. Conclusions

Isokinetic dynamometry is a reliable technique to evaluate peak torque and work for concentric flexion and extension in both the knee and the elbow joints in patients undergoing PD. Although results from division by sex must be taken with caution, higher reliability was observed in women compared to men and in the concentric flexion compared to the concentric extension. In addition to the reported good or excellent reliability based on ICC values, the present study provided novel SRD data which are associated to measurement error and individual variability and will assist healthcare professionals in interpreting treatment effects on isokinetic strength in this population.

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References

1. Carrero, J.J.; Stenvinkel, P.; Cuppari, L.; Ikizler, T.A.; Kalantar-Zadeh, K.; Kaysen, G.; Mitch, W.E.; Price, S.R.; Wanner, C.; Wang, A.Y. Etiology of the protein-energy wasting syndrome in chronic kidney disease: A consensus statement from the International Society of Renal Nutrition and Metabolism (ISRNM). *J. Renal Nutr.* **2013**, *23*, 77–90. [CrossRef] [PubMed]
2. Broers, N.J.; Martens, R.J.; Cornelis, T.; van der Sande, F.M.; Diederen, N.M.; Hermans, M.M.; Wirtz, J.J.; Stifft, F.; Konings, C.J.; Dejagere, T. Physical Activity in End-Stage Renal Disease Patients: The Effects of Starting Dialysis in the First 6 Months after the Transition Period. *Nephron* **2017**, *137*, 47–56. [CrossRef] [PubMed]

3. Oliveira, E.A.; Cheung, W.W.; Toma, K.G.; Mak, R.H. Muscle wasting in chronic kidney disease. *Pediatr. Nephrol.* **2018**, *33*, 789–798. [CrossRef] [PubMed]
4. Rosa, C.S.; Bueno, D.R.; Souza, G.D.; Gobbo, L.A.; Freitas, I.F.; Sakkas, G.K.; Monteiro, H.L. Factors associated with leisure-time physical activity among patients undergoing hemodialysis. *BMC Nephrol.* **2015**, *16*, 192. [CrossRef] [PubMed]
5. Rhee, C.M.; Kalantar-Zadeh, K. Resistance exercise: An effective strategy to reverse muscle wasting in hemodialysis patients? *J. Cachexia Sarcopenia Muscle* **2014**, *5*, 177–180. [CrossRef] [PubMed]
6. Van Den Ham, E.C.; Kooman, J.P.; Schols, A.M.; Nieman, F.H.; Does, J.D.; Franssen, F.M.; Akkermans, M.A.; Janssen, P.P.; Van Hooff, J.P. Similarities in skeletal muscle strength and exercise capacity between renal transplant and hemodialysis patients. *Am. J. Transplant.* **2005**, *5*, 1957–1965. [CrossRef] [PubMed]
7. Wang, A.Y.-M.; Sea, M.M.-M.; Ho, Z.S.-Y.; Lui, S.-F.; Li, P.K.-T.; Woo, J. Evaluation of handgrip strength as a nutritional marker and prognostic indicator in peritoneal dialysis patients. *Am. J. Clin. Nutr.* **2005**, *81*, 79–86. [CrossRef] [PubMed]
8. Dziubek, W.; Bulińska, K.; Rogowski, Ł.; Gołębiowski, T.; Kusztal, M.; Grochola, M.; Markowska, D.; Zembroń-Łacny, A.; Weyde, W.; Klinger, M. The effects of aquatic exercises on physical fitness and muscle function in dialysis patients. *Bio. Med. Res. Int.* **2015**, *2015*, 912980. [CrossRef]
9. Blake, C.; O'meara, Y.M. Subjective and objective physical limitations in high-functioning renal dialysis patients. *Nephrol. Dial. Transplant.* **2004**, *19*, 3124–3129. [CrossRef]
10. Sole, G.; Hamrén, J.; Milosavljevic, S.; Nicholson, H.; Sullivan, S.J. Test-retest reliability of isokinetic knee extension and flexion. *Arch. Phys. Med. Rehabil.* **2007**, *88*, 626–631. [CrossRef]
11. Perrin, D.H. *Isokinetic Exercise and Assessment*; Human Kinetics: Charlottesville, VA, USA, 1993.
12. Adsuar, J.C.; Olivares, P.R.; Parraca, J.A.; Hernández-Mocholí, M.A.; Gusi, N. Applicability and test-retest reliability of isokinetic shoulder abduction and adduction in women fibromyalgia patients. *Arch. Phys. Med. Rehabil.* **2013**, *94*, 444–450. [CrossRef] [PubMed]
13. Association, W.M. World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA* **2013**, *310*, 2191.
14. Collado-Mateo, D.; Dominguez-Munoz, F.J.; Batalha, N.; Parraca, J.; Tomas-Carus, P.; Adsuar, J.C. Test-Retest Reliability of Isokinetic Arm Strength Measurements in Competitive Swimmers. *J. Hum. Kinet.* **2018**, *65*, 5–11. [CrossRef] [PubMed]
15. Adsuar, J.C.; Olivares, P.R.; del Pozo-Cruz, B.; Parraca, J.A.; Gusi, N. Test-retest reliability of isometric and isokinetic knee extension and flexion in patients with fibromyalgia: Evaluation of the smallest real difference. *Arch. Phys. Med. Rehabil.* **2011**, *92*, 1646–1651. [CrossRef] [PubMed]
16. Kannus, P.; Beynnon, B. Peak torque occurrence in the range of motion during isokinetic extension and flexion of the knee. *Int. J. Sports Med.* **1993**, *14*, 422–426. [CrossRef]
17. Shrout, P.E.; Fleiss, J.L. Intraclass correlations: Uses in assessing rater reliability. *Psychol. Bull.* **1979**, *86*, 420–428. [CrossRef]
18. Munro, B.H.; Visintainer, M.A.; Page, E.B. *Statistical Methods for Health Care Research*; JB Lippincott: Philadelphia, PA, USA, 1986.
19. Weir, J.P. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J. Strength Cond. Res.* **2005**, *19*, 231–240. [CrossRef]
20. Segura-Orti, E.; Martinez-Olmos, F.J. Test-retest reliability and minimal detectable change scores for sit-to-stand-to-sit tests, the six-minute walk test, the one-leg heel-rise test, and handgrip strength in people undergoing hemodialysis. *Phys. Ther.* **2011**, *91*, 1244–1252. [CrossRef]
21. Wilkinson, T.J.P.; Xenophontos, S.M.; Gould, D.W.P.; Vogt, B.P.P.; Viana, J.L.P.; Smith, A.C.P.; Watson, E.L.P. Test-retest reliability, validation, and "minimal detectable change" scores for frequently reported tests of objective physical function in patients with non-dialysis chronic kidney disease. *Physiother. Theor. Pract.* **2019**, *35*, 565–576. [CrossRef]
22. Pereira, R.A.; Cordeiro, A.C.; Avesani, C.M.; Carrero, J.J.; Lindholm, B.; Amparo, F.C.; Amodeo, C.; Cuppari, L.; Kamimura, M.A. Sarcopenia in chronic kidney disease on conservative therapy: Prevalence and association with mortality. *Nephrol. Dial. Transplant.* **2015**, *30*, 1718–1725. [CrossRef]
23. Cheema, B.S.; Singh, M.A. Exercise training in patients receiving maintenance hemodialysis: A systematic review of clinical trials. *Am. J. Nephrol.* **2005**, *25*, 352–364. [CrossRef] [PubMed]

24. Zuo, M.L.; Yue, W.S.; Yip, T.; Ng, F.; Lam, K.F.; Yiu, K.H.; Lui, S.L.; Tse, H.F.; Siu, C.W.; Lo, W.K. Prevalence of and associations with reduced exercise capacity in peritoneal dialysis patients. *Am. J. Kidney Dis.* **2013**, *62*, 939–946. [CrossRef] [PubMed]
25. Uchiyama, K.; Washida, N.; Muraoka, K.; Morimoto, K.; Kasai, T.; Yamaki, K.; Miyashita, K.; Wakino, S.; Itoh, H. Exercise Capacity and Association with Quality of Life in Peritoneal Dialysis Patients. *Peritoneal. Dial. Int.* **2019**, *39*, 66–73. [CrossRef] [PubMed]
26. Iyasere, O.U.; Brown, E.A.; Johansson, L.; Huson, L.; Smee, J.; Maxwell, A.P.; Farrington, K.; Davenport, A. Quality of Life and Physical Function in Older Patients on Dialysis: A Comparison of Assisted Peritoneal Dialysis with Hemodialysis. *Clin. J. Am. Soc. Nephrol.* **2016**, *11*, 423–430. [CrossRef] [PubMed]
27. Kang, S.H.; Do, J.Y.; Lee, S.Y.; Kim, J.C. Effect of dialysis modality on frailty phenotype, disability, and health-related quality of life in maintenance dialysis patients. *PLOS ONE* **2017**, *12*, e0176814. [CrossRef] [PubMed]
28. Dvir, Z.; Muller, S. Multiple-Joint Isokinetic Dynamometry: A Critical Review. *J. Strength Cond. Res.* **2019**. [CrossRef] [PubMed]
29. Stark, T.; Walker, B.; Phillips, J.K.; Fejer, R.; Beck, R. Hand-held dynamometry correlation with the gold standard isokinetic dynamometry: A systematic review. *PM R J.* **2011**, *3*, 472–479. [CrossRef]
30. Eitzen, I.; Hakestad, K.A.; Risberg, M.A. Inter- and intrarater reliability of isokinetic thigh muscle strength tests in postmenopausal women with osteopenia. *Arch. Phys. Med. Rehabil.* **2012**, *93*, 420–427. [CrossRef]
31. Kean, C.O.; Birmingham, T.B.; Garland, S.J.; Bryant, D.M.; Giffin, J.R. Minimal detectable change in quadriceps strength and voluntary muscle activation in patients with knee osteoarthritis. *Arch. Phys. Med. Rehabil.* **2010**, *91*, 1447–1451. [CrossRef]
32. Ekstrand, E.; Lexell, J.; Brogardh, C. Isometric and isokinetic muscle strength in the upper extremity can be reliably measured in persons with chronic stroke. *J. Rehabil. Med.* **2015**, *47*, 706–713. [CrossRef]