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The association of WOMAC, HSS and isokinetic strength and fatigue of knee muscles in people with osteoarthritis following total knee replacement

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Abstract.
BACKGROUND: Osteoarthritis (OA) is the most prevalent joint pathology and an important cause of disability among people over 65 years of age. Following total knee replacement (TKR), which may be the only curative intervention, function is mainly affected by quadriceps weakness whose extent can accurately be assessed using isokinetic dynamometry.
AIM: To evaluate the association between the Western Ontario and McMaster Universities Arthritis Index (WOMAC) and the Hospital for Special Surgery Score (HSS) scores and knee muscle isokinetic strength and fatigue findings in TKR patients 2–5 years postoperatively as well as assess the reproducibility and validity of the isokinetic test findings in this cohort.
DESIGN: Twenty-four women who underwent TKR filled in the WOMAC and HSS questionnaires. The isokinetic test was carried out at 120 and 180°/s in concentric flexion/extension. The maximal isokinetic strength was evaluated as the peak torque (PT). Isokinetic fatigue was measured using the fatigue index and calculated based on 40 repetitions at 120°/s. The same protocol was performed 7 days apart. Test-retest reproducibility was analyzed using intraclass correlation coefficient (ICC), the standard error of measurement (SEM) and Bland Altman plots. HSS and WOMAC internal consistency was tested with Cronbach's alpha; questionnaire validity and correlations were obtained using Spearman's rho.
RESULTS: The HSS Function sub-score was significantly correlated with quadriceps PT but not with fatigue isokinetic scores. Excellent reproducibility was indicated for all outcome measures, with the exception of the HSS Knee subscore and the fatigue index.
CONCLUSIONS: Isokinetic dynamometry of the quadriceps can provide objective and useful information regarding the functional status of patients following TKR due to OA of the knee.

Keywords: Isokinetic testing, knee prosthesis, strength, reproducibility

1. Introduction

Osteoarthritis is the most prevalent joint disease and an important cause of disability among people over 65 years of age. Of those affected 10–30% have pain

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and functional impairment [1]. There are many palliative treatments for osteoarthritis, but currently the only curative treatment has been the introduction of arthroplasty, which substantially improves patient quality of life [2].

Total Knee Replacement (TKR) quality is usually assessed by the survival rate of the arthroplasty, which has been reported to be as high as 90–95% after 10 years. However, arthroplasty survival rate does not provide information about the functional performance of patients in their daily lives. Surgery goals are usually pain relief, deformity correction and functional improvement, which is the main factor in determining patient and surgeon satisfaction [3].

Most assessment scales and questionnaires measure pain and function related to patient reported outcomes. Following TKR, function is mainly affected by quadriceps weakness, which is usually not resolved even years after surgery, so characterization of post surgical quadriceps weakness is of paramount importance in orthopaedic and rehabilitation practice. Isokinetic dynamometry is an effective method for documenting post-TKR strength with objective, quantitative parameters in an accurate reliable and reproducible way [4–10].

The main objective of this study was twofold:

1) To examine the test-retest reproducibility of concentric flexion-extension findings in people following TKR due to OA of the knee;
2) To assess the association functionality scales (HSS and WOMAC) and isokinetic findings in this cohort.

2. Methods

2.1. Patients

This is a cross-sectional study of a group of patients who had undergone TKR performed by the same orthopedic surgeon at our hospital. Out of a cohort of 66 patients who had undergone knee arthroplasty, 7 had died, 26 were excluded from the study because of co-morbidity or inability to attend testing sessions and 3 did not complete the tests. The final cohort consisted therefore of 30 patients comprising 24 women and 6 men. Due to the gender asymmetry it was decided to focus only on the women's sub-group, which eventually served as the study group in this research. All participants met the following inclusion criteria: TKR with no patellar substitution (primary osteoarthritis), 2–6 years post-surgery, good overall condition and no history of traumatic injury in the knee that underwent surgery. Exclusion criteria consisted of pain that prevents the completion of the isokinetic test, comorbidity/ies, ipsilateral hip replacement and severe disability (non-ambulatory). All patients voluntarily agreed to take part in the study and gave their written informed consent to the study, which was approved by the local Ethics Committee. Of the 24 women, 13 (54%) had bilateral TKR, totaling 37 observations (37 TKR). The mean age was 72 years (57–86; SD 7.6 years). All patients had a high Body Mass Index (above 25) indicating overweight, with a mean of 33. Time since arthroplasty ranged between 2–6 years but 59.4% of TKR were between 2 and 3 years (mean 3.2 years).

2.2. Procedure

2.2.1. Scoring using the WOMAC and the HSS

The WOMAC questionnaire is a self-administered, disease-specific functional assessment for hip and/or knee osteoarthritis patients. It is currently the most frequently used questionnaire for this cohort, and is known to be a valid, reliable and responsive instrument for patients with hip or knee replacement as well as the best tool for assessing health-related quality of life following knee arthroplasty [11–13]. The higher the score, the worse are the patient's pain, stiffness and functional limitations [12–16]. WOMAC is validated for various languages, among them Spanish [17,18].

The HSS Score is a frequently used questionnaire [6,7,19–21]. A higher score reflects a better condition. It consists of 3 subscores: Pain, Knee, and Function. Subtractions are made for walking aids, extension lag, and varus or valgus deformity. Insall et al. [19] estimated that the clinical outcome is excellent for scores over 85, good between 70 and 84, poor between 60 and 69, and a failure below 60.

2.2.2. Isokinetic testing

Isokinetic testing was performed using a Biodex System 3 Pro® dynamometer. Equipment calibration was validated following manufacturer recommendations [22]. Patients did a 10-min warm up with a cycloergometer or step prior to the test. Positioning was as follows: patient was seated, with the chair back tilted back at 85°; straps were crossed over the trunk, pelvis, and thigh; the dynamometer axis of rotation was aligned to the external femoral condyle of the knee; the longitudinal adjustment of the pad was 2 centime-

Table 1
HSS-WOMAC correlation matrix

	WOMAC	Pain	Stiffness	Function
HSS	-0.53^{*}	-0.43^{*}	-0.50^{*}	-0.51^{*}
HSS pain	-0.54^{*}	-0.55^{*}	-0.44^{*}	-0.50^{*}
HSS knee	-0.20	-0.18	-0.33^{**}	-0.18
HSS function	-0.18	-0.00	-0.21	-0.20

$^{*}p < 0.01$; $^{**}p < 0.05$.

Table 2
Test-Retest ICC[SEM] for the HSS and WOMAC questionnaires

	HSS	WOMAC
Total	0.78 [6.8]	0.94 [3.9]
Pain	0.73 [4.3]	0.80 [1.5]
Knee (HSS) stiffness (WOMAC)	0.68 [4.5]	0.80 [0.7]
Function	0.77 [2.2]	0.91 [3.7]

ters above the upper edge of the peroneal malleolus; the global range of movement was set at 90°, from 10° to 100° of flexion according to tolerance [23]. Gravity was corrected for each test. In order to familiarize the subject with the procedure, two sets of five repetitions were done at the protocol-specified speed before testing.

In order to measure quadriceps and hamstring strength, the following protocol was used: concentric-concentric knee flexion-extension torque was recorded over a range of motion of 10–100°, with 5 repetitions at 120°/s and another 5 at 180°/s [24]. Also, a previously validated fatigue protocol [25] was used, with 40 repetitions at 120°/s after a 10-min rest. The same procedure was performed 7 days later in order to determine intra-tester reproducibility.

2.2.3. Outcome variables

'Pain', 'Stiffness' and 'Function' were measured with the WOMAC, and 'Pain'. 'Knee score' and 'Function' were measured with the HSS. For isokinetic testing, the following strength and fatigue variables were measured: Peak Torque (PT) at 120 and 180°/s for extension and flexion.Fatigue Index: it was calculated using the following formula: [(the sum of work in repetitions 4.5.6 – the sum of work in the last 3 repetitions)/the sum of work in repetitions 4.5.6] * 100.

2.2.4. Data processing

The ICC was used for assessing the consistency between the tests. The standard error measurement (SEM) was calculated as a measure of dispersion and charted with the Bland-Altman difference plot, which outlines the extent of disagreement (difference) between the two measurements as a function of the measurement magnitude. Validity for both questionnaires was evaluated using the Spearman correlation matrix (multi-trait multi-method matrix). Correlations for isokinetic and fatigue test results were also calculated with the Spearman coefficient. Finally, a bivariate analysis was performed to analyze the linear relationship between age and years since arthroplasty with the results of the tests. Repeated measures were taken into account for bilateral TKR subjects.

The analysis was performed using the SAS v9.2®. (SAS Institute Inc.. Cary. NC. USA).

The significance threshold was set at 0.05.

3. Results

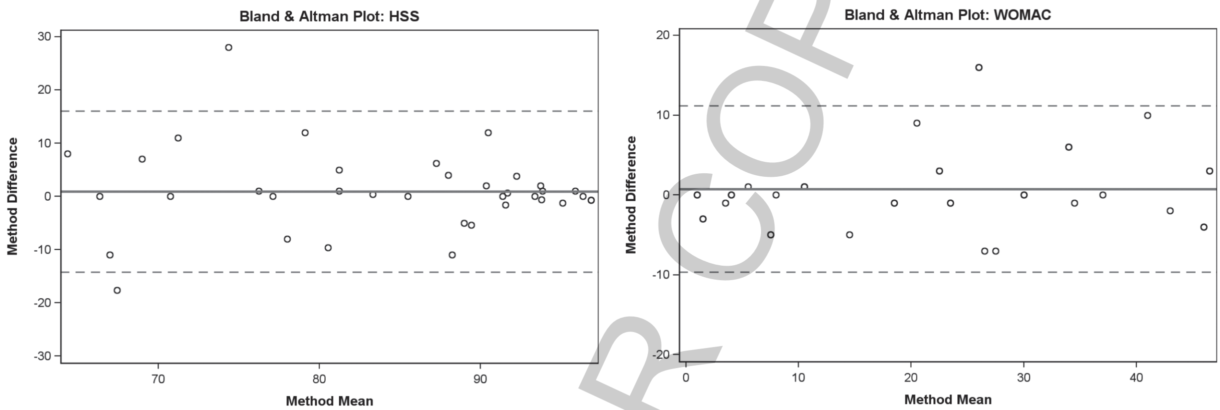
The mean score for HSS was 84.7 (good-excellent) and the vast majority of the observations were good-excellent (80%), with 65% free of pain and 54% excellent in Function subscore. Results for the Knee subscore were less stable. The WOMAC questionnaire indicated a mean Pain score of 3.9, with 97% less than 10/20 points. The mean function score was 17.1/68 points. Obviously, because HSS and WOMAC scores have an opposite interpretation, there was a negative and significant correlation between the two. When the Pain subscores of each scale were evaluated. a Spearman value of -0.55 ($p < 0.05$) was the highest score (Table 1).

Test-retest reliability was good for HSS and WOMAC scores as shown in Table 2, with the exception of the HSS Knee sub-score which includes values with high inter-observer variability such as manual quadriceps strength. The Bland-Altman plots for both questionnaires evidenced homoscedasticity shown by Figs 1a and 1b.

The test-retest reliability of the isokinetic test showed high ICC and relatively low SEM for PT in flexion an extension, but low ICC for fatigue index. The PT values and fatigue index results and their ICC [SEM] values are detailed in Table 3. The distribution of the differences as indicated by the Bland-Altman was homoscedastic (Figs 2a and 2b) for the lower speed only. The only significant correlation between the HSS Function sub-score and an isokinetic variable was related to the extension PT at 120°/s: 0.53 ($p < 0.01$). The bivariate analysis showed a negative significant correlation between age and the following parameters: HSS Function and PT in flexion and extension. No significant correlation was found between time since surgery, functional scores, dynamometric strength and fatigue values.

Table 3
Isokinetics values

	Fatigue index	Peak torque 120° Nm	Peak torque 180° Nm
Extension			
Mean	37.911	41.851	36.830
	SD10.0479 (12.8–51.4)	SD12.6421 (18.6–72.5)	SD10.7770 (20.2–68.4)
ICC	0,49	0.84	0.79
SEM	13,55	6.40	5.99
Flexion			
Mean	46.524	23.362	23.292
	SD 15.8480 (3–78.6)	SD 7.9210 (10.4–43.5)	SD 7.1687 (10.8–39.6)
ICC	0.24	0.77	0.78
SEM	36.71	5.07	4.50



(a) (b)

Fig. 1. a. Bland-Altman Plots for HSS scores; b. Bland-Altman Plots for WOMAC scores.

4. Discussion

The main findings of this study indicate clinically acceptable reproducibility for the HSS and WOMAC scores as well as for the isokinetic PT in both extension and flexion. On the other hand, the test-retest ICCs for the isokinetic fatigue index were low to poor. In particular, this study suggests a significant association and concurrent validity between the HSS functional sub-score and extension PT in patients with OA following TKR. This finding supports the paradigm that quadriceps strength is essential for viable biomechanical function after TKR. Surprisingly, no significant correlation between the WOMAC questionnaire and isokinetic PT values was found.

Regarding the reproducibility of the two questionnaires the ICC for the HSS was 0.78, slightly below the 0.82 found by Bach et al. [21]. However, 80% of the HSS scores were good-excellent which is a higher figure than the abovementioned study. The HSS score provides a clinically sound outcome measure for TKR patients and reflects patient satisfaction. However, HSS assessment has the disadvantage that it includes functional items related to walking and transfers along with variables such as pain and muscle strength. As a result scores tend to get worse as patients become older in spite of a lack of change in range of movement and/or pain [19–21]. In the present study, a negative correlation between age, HSS Function and isokinetic parameters was found, consistent with findings obtained from other studies [26,27]. The mean WOMAC function score was 17/68 points, comparable to the values noted by Boonstra et al. [3], although their mean follow-up was 16 months post-surgery. Boonstra et al. [3] did not consider the WOMAC Function a valid measurement because it was influenced by pain. In the present study, the lower pain variable was associated with a higher functional result. Escobar et al. [18] found that the WOMAC Function was better correlated with the Bodily Pain and Function subscales of the SF-36 (Health-Related Quality of Life Scale). The WOMAC advantages are derived from the fact that they are focused on the illness or impairment under the study (i.e. osteoarthritis) and hence are better poised to detect changes resulting from treatment than questionnaires that are not disease-specific [1,18].

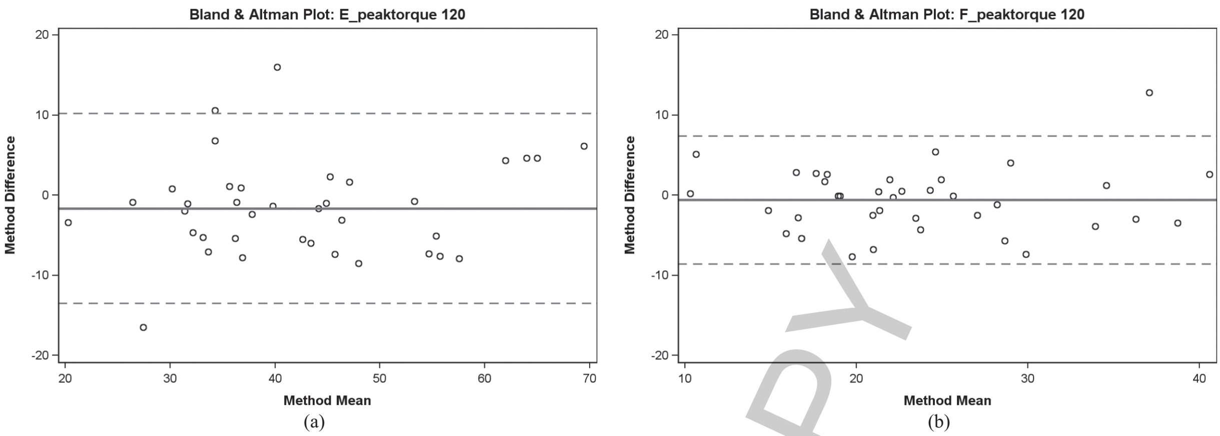


Fig. 2. a. Bland-Altman Plots for Extension PT at 120°/s; b. Bland-Altman Plots for Flexion PT at 120°/s.

Isokinetic dynamometry is widely considered the standard for assessing muscle mechanical parameters [4–8,21]. To the best of our knowledge, only a few studies have been published on isokinetic dynamometry in patients undergoing total knee arthroplasty [4–10]. According to Berman et al. [8], pioneers of TKR isokinetic studies in this particular field, quadriceps deficit persists 2 years after TKR, while flexion deficit subsides after one year. There are different hypothesis that point out to muscle atrophy due to lack of use, the long-term consequences of OA on knee structures, the severe damage of soft tissues (muscle, tendon and nerves) induced by TKA surgery [28] and considerable arthrogenic muscle inhibition classically observed in patients after TKA [29].

Worth noting is the heterogeneity of these papers and the methodological problems (such as the lack of separate presentations of men and women) and controversial issues found in most of them. Catasus et al. [5] have indicated lower extension PT values compared to the present findings in patients following TKR (Table 3). However, it should be noted that these results are not exactly comparable, since the aforementioned study was conducted with a different dynamometer and was based on mixed gender sample of 16 subjects.

Previous literature regarding isokinetics and TKR is quite lacking. Only one study could be compared to the present in terms of reproducibility and the relation with quadriceps strength and physical function [10], where it was indicated that quadriceps strength was significantly correlated to WOMAC function. However, there are differences between both studies. It should be underlined that our study focuses on long-term functional results of TKR. On the other hand methodological variations such as translation of WOMAC function into a 0–100 scale, make results difficult to interpret. Additionally the angular velocity was different in our study, and therefore PT results are not comparable. We have also introduced the fatigue index as an outcome parameter and therefore the present paper is of a wider scope in terms of TKR long-term functional results, isokinetic strength and fatigue analysis and their reproducibility in this cohort of patients.

Muscular endurance in dynamic conditions using isokinetic dynamometry is assessed by computing a Fatigue Index. However, there is no standardized testing protocol and definition for the fatigue index [30]. Moreover. Surakka et al. [31] measured the patient's subjective fatigue with the Fatigue Severity Scale (FSS) and reported that none of the fatigue indices correlated with the FSS.

An interesting review on the topic [32] examines three issues that constrain a more complete understanding of muscle: the diversity of measures that have been used to quantify fatigue, the specificity of the impairments that cause fatigue and the lack of knowledge of the mechanisms that limit performance. In our study, no significant correlation was found between the fatigue index and clinical scales. This may have been due too to the poor reliability of the fatigue test in this cohort of patients.

The main limitation of this study is the lack of a true baseline to compare the results to. We therefore suggest comparing all values with preoperative ones in future studies. Another limitation can be related to the use of an open chain-mono-articular testing movement (knee flexion-extension) while functional activities of daily living actually combine open and closed chain movements. Finally. the sample size can affect SEM confidence intervals. From 66 initial patients, our sample was restrained to 26 (34 knees) due to the gender restriction.

5. Conclusions

The isokinetic strength, but not fatigue, of the quadriceps can provide objective and useful information regarding the functional status of patients following TKR due to OA of the knee. We suggest that together with questionnaire-based functional scores, isokinetic test findings of the quadriceps may serve as primary outcome measures in the design of rehabilitation programs of these patients.

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Conflict of interest and funding

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