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Assessment of quadriceps muscle weakness in patients after total knee arthroplasty and total hip arthroplasty: Methodological issues

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ABSTRACT

The aim of this exploratory study was to verify whether the evaluation of quadriceps muscle weakness is influenced by the testing modality (isometric vs. isokinetic vs. isoinertial) and by the calculation method (within-subject vs. between-subject comparisons) in patients 4–8 months after total knee arthroplasty (TKA, $n = 29$) and total hip arthroplasty (THA, $n = 30$), and in healthy controls ($n = 19$). Maximal quadriceps strength was evaluated as (1) the maximal voluntary contraction (MVC) torque during an isometric contraction, (2) the peak torque during an isokinetic contraction, and (3) the one repetition maximum (1-RM) load during an isoinertial contraction. Muscle weakness was calculated as the difference between the involved and the uninvolved side (within-subject comparison) and as the difference between the involved side of patients and controls (between-subject comparison). Muscle weakness estimates were not significantly affected by the calculation method (within-subject vs. between-subject; $P > 0.05$), whereas a significant main effect of testing modality ($P < 0.05$) was observed. Isometric MVC torque provided smaller weakness estimates than isokinetic peak torque ($P = 0.06$) and isoinertial 1-RM load ($P = 0.008$), and the clinical occurrence of weakness (proportion of patients with large strength deficits) was also lower for MVC torque. These results have important implications for the evaluation of quadriceps muscle weakness in TKA and THA patients 4–8 months after surgery.

1. Introduction

In the last few years, quadriceps muscle function has received considerable attention in patients with knee and hip osteoarthritis (OA), both before (Mizner et al., 2005b; Rasch et al., 2007) and after joint replacement surgery (Judd et al., in press; Meier et al., 2008; Mizner et al., 2005a). Quadriceps muscle strength has been shown to be related to patient-reported outcomes and physical functioning in both total knee arthroplasty (TKA) and total hip arthroplasty (THA) patients, therefore indicating a strong predictive relation to daily functional activities such as walking and stair climbing (Meier et al., 2008; Mizner et al., 2005a; Suetta et al., 2004; Walsh et al., 1998). In addition, reduced quadriceps strength (i.e., muscle weakness) has been identified as a mediator of knee OA development and progression (Slemenda et al., 1997). Although total joint arthroplasty reduces pain and improves subjective physical function in older adults with knee and hip OA (Ethgen et al., 2004), quadriceps muscle weakness is usually not resolved even years after surgery (Meier et al., 2008; Suetta et al., 2007). Characterization of post-surgical quadriceps weakness is therefore of paramount importance in orthopaedic practice and research (Maffiuletti, 2010).

The maximal force-generating capacity of the quadriceps muscle is commonly measured in one of three ways (Enoka, 2002): (1) as the highest force/torque that can be produced during an isometric maximal voluntary contraction (MVC), (2) as the peak torque generated during an isokinetic concentric contraction, or (3) as the maximum load that can be lifted once, i.e., the 1-repetition maximum (1-RM) load, on a dynamic constant external resistance machine (hereafter referred to as "isoinertial"). Isometric, isokinetic, and isoinertial modalities are frequently used interchangeably to evaluate strength in clinical settings, despite the fact that their respective outcomes could provide different estimates of muscle weakness.

Besides testing modalities, two distinct calculation methods are generally used to evaluate the extent of muscle weakness. The between-subject approach consists in calculating the difference (usually as a percentage) in muscle strength between patients and healthy controls, whereas within-subject comparisons encompass the calculation of side-to-side (involved vs. uninvolved) asymmetry ratios. Since both approaches have limitations (Meier et al.,

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2008), and consensus on the best calculation method is far from being established, their combination has recently been recommended for an unbiased and more complete characterization of muscle weakness in orthopaedic patients (Maffiuletti, 2010). However, this is time consuming and therefore quite unrealistic for use in clinical practice.

The main purpose of this exploratory study was to verify whether the evaluation of quadriceps muscle weakness is influenced by the testing modality (isometric vs. isokinetic vs. isoinertial) and by the calculation method (within- vs. between-subject comparisons) in TKA and THA patients 4–8 months after surgery. A secondary aim was to compare isometric, isokinetic and isoinertial muscle strength of the involved and uninvolved quadriceps between patients with TKA, patients with THA and healthy controls.

2. Methods

2.1. Participants

Twenty-nine TKA and 30 THA patients were retrospectively selected (convenience sampling) from the medical database of the Schulthess Clinic (Zurich, Switzerland). Inclusion criteria were primary unilateral joint replacement (TKA or THA), follow up of 4–8 months, age from 50 to 80, ability to walk without aids and asymptomatic knee and hip on the uninvolved side. Exclusion criteria were musculoskeletal disease other than OA for which they received their prosthesis, neuromuscular disease, and cardiovascular problems. After surgery, all the patients received the same post-operative medical care and were advised to complete individual physical therapy sessions supervised by one therapist (usually 1–4 cycles of 9 sessions). Even if rehabilitation guidelines were given to all patients, physical therapy was not standardized in any patient group. Rehabilitation guidelines included weight-bearing with crutches as tolerated, range of motion, balance and strengthening exercises to initiate after discharge. The control group consisted of 19 healthy elderly individuals recruited at the local university of the third age. They were included if their age was comprised between 50 and 80 years, and if they had asymptomatic knees and hips. Exclusion criteria were musculoskeletal, neuromuscular, and cardiovascular diseases or any other condition influencing normal gait. Demographic and anthropometric characteristics of the three groups of participants are provided in Table 1. The study protocol was approved by the local Ethics Committee in Zurich (KEK-ZH-NR: 2010-0095/0), and written informed consent was obtained from all participants.

2.2. Experimental procedure

Participants were asked to attend a testing session that entailed the unilateral assessment of involved and uninvolved quadriceps muscle strength with isometric, isokinetic and isoinertial modalities. The involved side corresponded to the operated one for patients and to the one with the lowest isometric MVC torque for controls. To avoid a treatment order effect, all testing procedures were randomized, first by modality and then by side. Muscle weakness was estimated as the side-to-side asymmetry in quadriceps muscle strength (within-subject comparison) and as the difference between involved quadriceps strength of patients and strength data of healthy controls (between-subject comparison).

Table 1
Demographic and anthropometric data by group.

	TKA	THA	Controls
n (men/women)	29 (17/12)	30 (18/12)	19 (11/8)
Age (years)	62 (58–66)	64 (56–68)	68 (66–69)[a]
Weight (kg)	79 ± 18	70 ± 12	75 ± 15
Height (cm)	170 ± 8	169 ± 8	170 ± 7
Body mass index (kg m^{-2})	26 (23–32)	24 (22–26)	26 (23–28)
Follow-up (months)	6 ± 2	7 ± 2	–

Values are mean ± SD for normally distributed data and median (interquartile range) for non-normally distributed data.

[a] Controls > TKA and THA ($P < 0.05$); TKA, total knee arthroplasty; THA, total hip arthroplasty.

2.3. Assessment of quadriceps muscle strength and weakness

For each testing modality, participants received standardized verbal instructions and completed several familiarization trials at a submaximal intensities (50–80% of their estimated maximal strength) on both sides. Rest periods of approximately 3 min separated the test series conducted in the different modalities and for the different sides. Strong and standardized verbal encouragement was consistently provided during testing.

2.3.1. Isometric strength

Isometric MVC torque was assessed with an isokinetic dynamometer (Biodex System 2, Biodex Medical Systems, Shirley, NY, USA) at a knee flexion angle of 60° (0° = full knee extension). Participants were seated on the dynamometer chair with a trunk-thigh angle of 90°. They were firmly strapped at the shoulder and pelvis levels, and were asked to consistently maintain their arms folded across the chest. The axis of rotation of the dynamometer was visually aligned to the lateral femoral condyle, and the shin pad was positioned 2–3 cm above the lateral malleolus. Participants performed 3 MVC separated by 45 s, during which they were asked to contract their quadriceps muscle as forcefully as possible for 5 s. Visual feedback was provided to the participants as a real-time display of the isometric torque output. The gravity compensation procedure was performed according to the manufacturer's instructions. We extracted the highest MVC torque from each of the three trials, as recorded by the Biodex software (sampling frequency: 100 Hz), and then averaged them.

2.3.2. Isokinetic strength

Isokinetic concentric peak torque was evaluated on the same dynamometer and in the same position as the isometric assessment. Knee extension/flexion range of motion was 80°, from 90° to 10° of knee flexion, and angular velocity was set at 60°/s. Participants were asked to complete three consecutive knee extension trials (Wrigley and Strauss, 2000) as forcefully as possible, and to fully relax during the flexion phase. Visual feedback was provided to the participants as a real-time display of the isokinetic torque output. The gravity compensation procedure was performed according to the manufacturer's instructions. We extracted the peak torque from each of the three consecutive trials, as recorded by the Biodex software (sampling frequency: 100 Hz), and then averaged them.

2.3.3. Isoinertial strength

Isoinertial concentric 1-RM load was assessed on a leg extension machine (Technogym, Gambettola, Italy) applying a conventional test protocol (Tracy and Enoka, 2002). Participants were seated on the chair of the leg extension machine, with a trunk-thigh angle of 90°. Knee extension/flexion range of motion was 70°, from 80° to 10° of knee flexion. Participants were firmly fixed to the seat with a strap applied on the pelvis, and were asked to consistently fold their arms across the chest. The axis of rotation of the leg extension machine was visually aligned to the lateral femoral condyle. The shin pad was positioned 2–3 cm above the lateral malleolus. Identification of the 1-RM load began with a load