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Effects of joint effusion on quadriceps muscles in patients with knee osteoarthritis

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ABSTRACT

Objectives: To evaluate the effect of knee effusion on the quadriceps muscle in patients with knee osteoarthritis (OA).
Design: Single-blind, randomized, controlled clinical trial.
Setting: Single medical center.
Participants: Forty subjects with knee OA were assigned to a experimental ($n = 20$) or control ($n = 20$) group.
Main outcome measures: Quadriceps torque and root mean square (RMS) values of surface electromyography (EMG) of the vastus medialis and vastus lateralis muscles were measured during a maximal isometric contraction at 60° knee flexion. Thereafter, 20 mL of normal saline was injected into the knee joint of the experimental group. Quadriceps torque and RMS values were again measured.
Results: Five subjects did not complete the study. No significant difference in quadriceps peak torque or RMS of EMG activity was observed at baseline, pre-effusion, or post-effusion measures in either group. The experimental group showed no significant change in quadriceps peak torque or RMS of EMG activity in any period compared with the control group.
Conclusions: These results demonstrate that a 20 ml joint effusion did not affect peak torque or RMS values of the quadriceps muscle in patients with knee OA.

1. Introduction

Osteoarthritis (OA) is characterized by a loss of articular cartilage, leading to pain and loss of function (Richmond et al., 2009). It may affect intracapsular tissues and periarticular tissues, such as ligaments, capsule, tendons, and muscle (Amin et al., 2009; Palmieri-Smith, Kreinbrink, Ashton-Miller, & Wojtys, 2007; D. Rice, McNair, & Dalbeth, 2009). Several studies have investigated the mechanisms underlying OA and treatment options.

Strengthening the quadriceps muscle is an important element of an effective therapeutic strategy for OA (Amin et al., 2009; Richmond et al., 2009). Several studies have shown that knee effusion induced quadriceps arthrogenic muscle inhibition (AMI) in normal volunteers (Palmieri-Smith et al., 2007; Rice et al., 2009) and OA patients (Deandrade, Grant, & Dixon, 1965). After menisectomy, aspiration of fluid from the knee has been found to consistently reduce quadriceps AMI (Stokes & Young, 1984). In knee OA patients with chronic effusion, aspiration of the effusion decreased the AMI (Fahrer, Rentsch, Gerber, Beyeler, Hess, & Grunig, 1988). However, few patients with OA have been included in these studies (Deandrade et al., 1965; Fahrer et al., 1988).

The present study investigated whether the presence of 20 ml fluid in the joint affected peak torque and the root mean square (RMS) values of surface electromyography (EMG) in patients symptomatic for OA. The primary aim of the present study was to evaluate the effect of 20 ml effusion on the peak torque of the knee extensors and a secondary aim was to evaluate the effect of 20 ml effusion on the RMS of the vastus medialis (VM) and vastus lateralis (VL) muscles in patients with OA. We hypothesized joint effusion would produce AMI considering previous studies showed that joint aspiration increased the strength of knee extensor (Fahrer et al., 1988; Stokes & Young, 1984).

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2. Methods

2.1. Study design and participants

The study was a single-blind (blinded examiner), randomized parallel-group controlled clinical trial. Female subjects with knee OA were recruited from the department of Rehabilitation Medicine at Seoul St. Mary's Hospital. All subjects were 50 years old or older and had knee pain without joint effusion confirmed by ultrasonography (US). US examination has been shown to be one of the best available tools for the measurement of joint effusion (Scheel, 2005; Tarhan & Unlu, 2003). At least 4.26 ml of solution is needed to be detected as knee effusion by US (Hong, Lee, Kim, Cho, Lim, & Ko, 2011). Knee effusion was confirmed by midline and lateral longitudinal scan. During the examination, the subject was lying supine both with the knees in the extended and flexed positions. All subjects were diagnosed by criteria of the American College of Rheumatology (Altman et al., 1986). Exclusion criteria were 1) the presence of knee joint effusion determined using US, 2) a history of knee injury or surgery, 3) a history of knee injection within 3 months, 4) a history of inflammatory arthritis, 5) taking anticoagulants, 6) balance or gait disturbance, and 7) diabetes mellitus.

The 40 female subjects recruited to the study were randomly assigned, by randomized block design, to the control ($n = 20$) or experimental group ($n = 20$). In cases of bilateral knee OA, the most symptomatic leg without fluid collection was tested. All subjects were tested three times in total; two times before and one time after joint infusion or placebo injection. All procedures were performed by one examiner to maintain blinding for injection.

The study was approved by the Ethics Committee of the Catholic University of Korea. Written consent was obtained from all subjects according to the Declaration of Helsinki.

2.2. Joint injection procedures

A volume of 20 mL of normal saline was injected into the knee joint cavity of the subjects in the experimental group under US guidance, and the presence of fluid in the joint was confirmed by US examination (Scheel, 2005; Tarhan & Unlu, 2003). The needle was inserted into the joint cavity of the subjects in the control group, but no saline was infused. All injections were performed without local anesthesia under sterile condition. Intra-articular injection of 20 ml saline was performed with the transduced fixated at the midline longitudinal scan. After a 20 ml infusion, knee effusion was confirmed by midline and lateral longitudinal scan. The absence of visualization with a 20-ml infusion or severe pain precluding further infusion to 20 ml was regarded as injection failure (Hong et al., 2011).

2.3. Measurements of peak torque for quadriceps muscle

Subjects were positioned in an isokinetic dynamometer (Primus RS, BTE Technologies, CO, USA) for maximal isometric contraction. The lateral epicondyle of the femur was aligned with the axis of rotation of the dynamometer. Straps were firmly secured over the distal tibia, the distal third of the thigh, and waist to limit extraneous movement. With the knee positioned at 60° of flexion, submaximal contractions were performed as a warm up prior to data collection. Thereafter, a set of three maximal isometric quadriceps contractions (4 s each) were performed at each measurement time point. The subjects rested for 1 min after each maximal contraction in the set. All subjects were tested in a total of three sets. Subjects rested for 10 min between each set. The highest peak force was calculated by multiplying the averaged data from the three trials by the lever length, which was then normalized by body mass (Nm/kg) (Rice et al., 2009). Subjects received a consistent level of verbal encouragement and were blinded to the torque levels they produced.

2.4. Measurement of quadriceps muscle RMS values

All studies were performed using a Synergy electromyograph (Medelec, Ltd., Surrey, UK) at the following settings: low-frequency filter of 20 Hz, high-frequency filter of 1000 Hz, and common mode rejection ratio over 110 dB. A custom-designed disposable electrode (CareFusion, Hoechberg, Germany) was used to measure EMG activity. Active electrodes were placed over the motor points of the VM and VL muscles, and reference electrodes were placed over the VM and VL tendons. Ground electrodes were positioned over an electrically silent area, generally the medial malleolus (Dumitru, Amato, & Zwarts, 2001; Fahrer et al., 1988; Lim, Hong, Oh, & Lee, 2015; D. Rice et al., 2009).

EMG activity was measured simultaneously with the quadriceps torque test. We measured EMG signals in three sets (2 s each, three tests per set) and used the averaged value of each set: baseline, pre-intervention (10 min after baseline), and post-intervention. We analyzed EMG activity as the root mean square (RMS) for the EMG amplitude in the VM and VL muscles.

2.5. Statistical analyses

Statistical analyses were performed using the SPSS software (ver. 11.5; SPSS Inc., Chicago, IL, USA). All tests were two-tailed, and a P-value < 0.05 was deemed to indicate statistical significance. We calculated that a sample size of 20 subjects per group was necessary to detect a mean percentage change in 20% of peak torque for quadriceps muscle between the intervention and the control groups, given an anticipated injection failure of 20% and a power of more than 80% (D. Rice et al., 2009). The normal distribution was evaluated using the Shapiro–Wilk test. For normally distributed variables (age, height, body weight, body mass index), independent t-tests were used to test between-group differences in baseline characteristics. The non-normally distributed numeric rating scale (NRS) for pain scores were assessed using the Mann–Whitney U-test. Between-group comparisons of the K/L grade were made using Fisher's exact test. A two-factor (group*time) repeated measures analysis of variance (ANOVA) was performed to determine the stability of the baseline measures and the effect of joint effusion on quadriceps peak torque and RMS values (D. Rice et al., 2009).

3. Results

Of the 40 subjects initially recruited, five in the experimental group were unable to complete the study because of injection failure (Fig. 1). All subjects in the experimental group reported a feeling of tightness or fullness in the joint during the injection procedure. We assessed 13 right knees (seven left knees) in the control group and seven right knees (eight left knees) in the experimental group. Baseline characteristics of the 35 subjects who completed all procedures are shown in Table 1. No significant between-group difference was found in baseline age, height, body weight, body mass index, NRS or K/L grade ($P > 0.05$).

3.1. Quadriceps torque measurement

A summary of normalized peak torque values at each measurement interval is shown in Table 2 and Fig. 2. No significant difference in peak torque was observed in the baseline, pre-effusion, or post-effusion measures of torque in either group