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The effect of knee arthroplasty on balancing ability in response to sudden unidirectional perturbation in the early postoperative period

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ABSTRACT

Introduction and objective: Total knee arthroplasty (TKA) affects 1–3% of the entire population. The effectiveness of surgery and rehabilitation are of great significance. The goal of this study was to determine how different surgical methods (i.e., conventional and minimally invasive) influence balancing ability in response to sudden unidirectional perturbation during the first 12 weeks of the postoperative period. *Materials and methods:* The balancing capacity after sudden unidirectional (horizontal) perturbation of 10 patients who had undergone TKA operations via the conventional method and 10 patients who had undergone TKA operations via the minimally invasive method were examined before and six and 12 weeks after TKA. Forty-five health age-matched participants composed the control group. The balancing capacities following unidirectional perturbation were characterised by the Lehr's damping ratio, which was calculated based on the results of the provocation tests that were performed with the patients standing on both the affected and non-affected limbs. *Results:* In both patient groups, the Lehr's damping ratios increased during the postoperative period. However, in both patient groups, the Lehr's damping ratios calculated from the results of all three of the testing methods decreased compared to values obtained from the controls even at 12 weeks postoperatively. Six and 12 weeks after TKA, the Lehr's damping ratios of the patients who underwent operations utilising the minimally invasive exposure method were significantly higher than the values obtained from the patients who underwent operations by conventional exposure. *Discussion and conclusions:* In both patient groups, the balancing capacities continuously improved over the first 12 weeks of the postoperative period, but the dynamic balancing capacities while standing on both limbs, on the affected limb and on the non-affected limb significantly differed from those of the controls. The balancing capacities of the patients who underwent the minimally invasive exposure procedures improved more rapidly than did the capacities of the patients who underwent operations utilising the conventional exposure method. This reduced balancing capacity should be considered when developing dynamic balancing abilities and abandoning therapeutic aids, and the difference in dynamic balancing abilities between the two patient groups should also be considered.

1. Introduction

Due to the ageing of the population, the frequency of knee osteoarthritis is increasing in a manner similar to that observed for hip osteoarthritis in recent decades. Knee osteoarthritis affects nearly 3% of the entire population. In greater than 5% of the elderly population, knee osteoarthritis is sufficiently serious that total knee arthroplasty is a reasonable option (Dillon et al., 2006; Felson and Zhang, 1998). Total knee arthroplasty (TKA) reduces pain and partially restores functional abilities; however, gait parameters (i.e., spatial, temporal and angular parameters; Bejek et al., 2011; Fuchs et al., 2002; Smith et al., 2006), including gait variability and stability (Kiss et al., 2012; McClelland et al., 2009; Yakhdani et al., 2010) do not return to normal values even over one-year long postoperative periods.

The effects of TKA on joint proprioception that have been reported in previous studies remain contradictory because some authors have reported decreases (Barrack et al., 1983; Simmons

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et al., 1996; Skinner et al., 1984), but other authors have reported positive changes (Attfield et al., 1996; Barrett et al., 1991; Ishii et al., 1997; Swanik et al., 2004; Warren et al., 1993) in joint proprioception after TKA.

Balance control is a complex sensorimotor function that involves components of movement detection and the control of coordinated voluntary and reflexive motor responses. Postural control is influenced not only by proprioceptive, visual and vestibular inputs and outputs but also by the conditions of the different joints (Fitzpatrick and McClosky, 1994). Seventeen days after TKA, the areas and paths of centre of pressure (COP) sway are much larger amongst patients than amongst control groups (Gauchard et al., 2010). Although the postural parameters improve significantly 6 weeks after TKA relative to the preoperative measurements, these measurements do not reach the values of control groups (Gauchard et al., 2010). Six months after TKA, balancing capacities during bipedal stances on instable plates (Swanik et al., 2004) and during bipedal and monopedal stances on stable plates (Isaac et al., 2007) significantly improve compared to the results obtained prior to TKA. The postural parameters measured during bipedal stances improve significantly during later postoperative periods (i.e., after 6 months), but these values do not reach those of control groups even one year after TKA (Quagliarella et al., 2011).

In everyday life, people often encounter balancing after being bumped into while walking or standing. Highly complex coordination is required to attempt to regain balance after a sudden impulse or change in direction during standing, sitting, walking and running (Winter, 1995). This means that the examination of balancing capacity following sudden perturbation is more sensitive than the examination of balance control during standing (Kiss, 2011). Decreases in equilibrium might also be associated with an increased risk of falling (Robbins et al., 1989). The results of previous research have established that balancing capacity following sudden perturbation amongst patients with knee osteoarthritis is reduced compared to control participants (Kiss, 2012).

To our knowledge, no study has examined the effects of the surgical technique of TKA on balancing abilities after sudden perturbations. The aim of this study was to specify the dynamic balancing ability in response to sudden unidirectional perturbation following different surgical techniques during TKA (conventional: total anterior exposure with medial parapatellar incision; minimal invasive technique: quadsparing or midvastus incision depending on the anatomical situation with computer-assisted navigation). The joint capsule and muscles around the joints are affected differently depending on the method of surgery; consequently, the method of surgery in the case of TKA has a considerable impact on gait parameters (Bejek et al., 2011) and gait variability (Kiss et al., 2012). Therefore, it can be presumed that postoperative changes in dynamic balancing ability will be different. If the method of surgery technique affects not only the gait parameters but the dynamic balancing ability as well, it could be an important issue for the consideration of different surgical methods and their post-operative treatments. For this purpose, balancing capacity tests after sudden perturbation were conducted prior to, as well as at 6 and 12 weeks and 6 months after TKA.

2. Materials and methods

2.1. Participants

Patients with severe knee osteoarthritis (OA) were selected randomly from amongst the patients of the Department of Orthopaedics of Semmelweis University (Budapest, Hungary), with the inclusion and exclusion criteria taken into account. The inclusion criteria were unilateral knee OA as evidenced by X-ray, patients who were ambulatory without the use of an assisting device, and patients with less than 15° varus and 10° valgus axis deviations and less than 15° flexion contracture. The exclusion criteria included any clinical history of lesion or surgery affecting a lower limb or the lumbar spine, OA affecting any other joint of a lower limb (i.e., the opposite knee joint or either hip joint), neurological alterations (e.g., Parkinson's, dementia, vertigo, or cerebral apoplexy), uncontrolled hypertonia, unstable angina, or vision correction greater than ±5.0 dioptres.

Twenty patients were randomly allocated into two groups of 10 patients each. All TKA patients were operated on at the Orthopaedics Clinic of Semmelweis University (Budapest, Hungary) by one experienced surgeon who was blinded to the procedure each patient was to receive until a few hours before surgery, when a sealed envelope revealed which technique was to be used. Four women (age 64.3 ± 5.1 years; body mass 77.5 ± 11.3 kg; body height 166.3 ± 5.2 cm) and 6 men (age 71.7 ± 4.2 years; body mass 89.4 ± 9.3 kg; body height 173.1 ± 9.4 cm) composed the first group and underwent operations involving conventional methods of exposure; 5 women (age 67.2 ± 3.4 years; body mass 75.9 ± 5.9 kg; body height 163.6 ± 7.1 cm) and 5 men (age: 68.3 ± 3.5 years; body mass 88.4 ± 14.3 kg; body height 168.2 ± 8.8 cm) composed the second group who underwent operation involving the minimally invasive method that utilises an imageless Stryker–Leibinger navigation system. The patients were provided with the same preoperative and postoperative treatments (e.g., anaesthesia and pain relief), and the rehabilitation of all the patients was supervised based on a previously arranged protocol by the same physiotherapist until the 12th postoperative week.

Twenty-two women (age 60.4 ± 4.1 years; body weight 69.7 ± 10.2 kg; body height 166.7 cm ± 3.8 cm) and 23 men (age 60.9 ± 3.2 years; body weight 70.4 ± 9.8 kg; body height 170.4 cm ± 5.8 cm) composed the control group that was involved in the study of the effects of knee osteoarthritis (Kiss, 2012). The healthy controls had no histories of osteoarthritis of the knee or hip joint, knee instability, or major lower extremity joint surgery. The controls also exhibited normal strength, full lower extremity ranges of motion, and no neurological or balance deficiencies. With the exception of the existence of knee osteoarthritis, the inclusion and exclusion criteria corresponded to the criteria for the patient group. The dominant sides (used for kicking a ball with maximum force) were the left in 4 females and 6 males and the right in 18 females and 17 males.

Each of the examined participant had no special sport, physical activity. Each of the examined participants provided written informed consent regarding the risks and benefits of the study and were given the opportunity to withdraw at any time. This study was authorised by the Science and Research Ethics Committee of Semmelweis University (111/2004).

2.2. Experimental procedure

The PosturoMed® device (Haider-Bioswing, Weiden, Germany) included a rigid platform (12 kg, 60 cm × 60 cm) connected to a rigid frame with eight 15-cm steel springs of identical strength; this allowed the platform to shift freely in two dimensions along the horizontal plane (Fig. 1). The four-spring condition was selected, which allows only unidirectional movement in the horizontal plane. A fastening unit (provocation unit) locked the platform into a fixed position (Fig. 1). The rigid plate was set into motion by releasing the unit out of a locked position, because the platform would swing back into the resting position, simulating a sudden unidirectional disturbance in the horizontal plane while standing. The participant had to counter this sudden disturbance to the