

# EFFECT OF BILATERAL, SEVERE KNEE OSTEOARTHRITIS ON BALANCING ABILITY AFTER SUDDEN UNIDIRECTIONAL PERTURBATION

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## ABSTRACT

The gait parameters, the variability of gait, the balancing ability are influenced by unilateral knee osteoarthritis. The aim of this study is to analyze balancing ability after sudden perturbation characterized Lehr's damping ratio measured by provocation test stance on both and on single limb at patient with bilateral knee osteoarthritis.

20 controls, 20 patients with unilateral and 20 with bilateral knee osteoarthritis. Balancing ability was characterized by the Lehr's damping ratio determined by provocation test during double leg and single leg stance. For patients with bilateral knee osteoarthritis, the results of provocation test while standing on both limbs, on dominant and non-dominant limb did not differ significantly each other. No significant difference found between the results of males and females. Our results showed that, the lateral dominance and the gender did not affect the balancing ability, if the knee osteoarthritis is bilateral. Our results showed that the most dominant impact is the severity of osteoarthritis.

## KEY WORDS

Medical measurement, biomechanics, balancing capacity, bilateral, severe knee osteoarthritis, sudden perturbation.

## 1. Introduction

The gait parameters [1-7], the variability of gait [8-10], joint proprioception [10-20] and the balancing ability during stance [20-25] are influenced by unilateral knee osteoarthritis. Our research group have established that the unilateral knee osteoarthritis decreased the balancing ability after sudden perturbation characterized by Lehr's damping ratio measured by a provocation test [26, 27]. Only few research are found in subject of effect of bilateral

knee osteoarthritis on gait. Creaby et al [24] established the gait parameters of patients with bilateral knee osteoarthritis significantly differ from the parameters of healthy, age-matched subjects, however they are symmetrical. In contrast the results of Creaby et al [28] Mills et al [29] found asymmetry during the gait for patients with bilateral mild and moderate knee osteoarthritis. Liu et al [30] established that the knee extensor, the sagittal total support moment significantly reduced at the patients with bilateral severe knee osteoarthritis. The patients compensated the reduced knee moment by increased moment of ankle and hip joints.

To our knowledge, no research has studied the effect of bilateral knee osteoarthritis on balancing capacity. The goal of this study is to analyze balancing ability after sudden perturbation characterized Lehr's damping ratio measured by provocation test stance on both and on single limb at patient with bilateral knee osteoarthritis. Our hypothesis was that, in patients with bilateral knee osteoarthritis the balancing capacity of stance on both and single limb decreased compared to control group, but the decreased balancing capacity should be symmetrical.

## 2. Subjects and Methods

### 2.1 Subjects

Ten patients with bilateral knee osteoarthritis, twelve patients with unilateral knee osteoarthritis and ten normal controls involved in this study. The anthropometrical data were summarized in Table 1. All patients have severe osteoarthritis, Kellgren and Lawrence radiographic index [31] was grade 4.

Exclusion criteria were in patients groups the following:

- walking with aids,
- any lesion and/or surgery affecting a lower limb or the lumbar spine,
- osteoarthritis affecting hip,
- neurological alterations,
- uncontrolled hypertonia,
- unstable angina.

The orthopaedic examination performed before motion analysis established that the motion range and stability of joints in the lower limbs as well as the axial position, muscular strength, and muscular tension of the lower limbs were physiologically adequate at healthy subjects. Exclusion criteria for the analysis corresponded to those for the osteoarthritis, and the existence of osteoarthritis in all joints

Table 1

The mean  $\pm$  standard deviation of anthropometrical data

| Groups          | Bilateral knee OA | Unilateral knee OA | Control         |
|-----------------|-------------------|--------------------|-----------------|
| Male/female     | 9/11              | 8/12               | 10/10           |
| Age [years]     | 67.2 $\pm$ 10.1   | 69.7 $\pm$ 8.1     | 68.4 $\pm$ 6.22 |
| Body mass [kg]  | 90.4 $\pm$ 19.7   | 86.4 $\pm$ 18.1    | 81.5 $\pm$ 15.6 |
| Body height [m] | 1.71 $\pm$ 0.13   | 1.63 $\pm$ 0.10    | 1.68 $\pm$ 0.12 |

OA osteoarthritis

Before the provocation test, each participant's dominant side was determined by a balance recovery test [32]. In the healthy group, the left side was dominant for 3 females and 2 males. In patients with unilateral knee osteoarthritis, the healthy side was dominant in all subjects. In patients with bilateral knee osteoarthritis, the left side was dominant for 4 females and 1 male.

All participants were informed in writing about the risks and benefits of the study; each gave signed informed consent and was given the opportunity to withdraw from the study at any time. The study was approved by the National Science and Research Ethics Committee (114/2004).

## 2.2 Methods

Balancing ability after sudden unidirectional perturbation was examined by provocation tests, using the platform of the PosturoMed<sup>©</sup> device (Figure 1). In this research four springs worked and four springs were fixed. The measurement frequency was 100 Hz. At healthy subjects and for

patients with bilateral knee osteoarthritis tests were performed during stance on double leg (double leg scenario), stance on dominant leg (dominant leg scenario), and stance on non-dominant leg (non-dominant leg scenario); for patients with unilateral knee osteoarthritis on stance on double leg (double leg scenario), stance on unaffected/healthy leg (unaffected leg scenario), and stance on affected leg (affected leg scenario). Details of

provocation tests and measuring method are included in [27].

The Lehr's damping ratio modelled the second-order damped motion of the rigid plate parallel with the direction of motion [27]. Calculation of the Lehr's damping ratio from the movement of the plate is summarized in [27].

The mean and the standard deviation were calculated for each group from the results of the Lehr's damping ratios for individuals. The data were statistically analysed using the MS Excel Analysis Tool Pak software. A one-sample t-test applying a symmetrical critical range was used for the comparison of results in the same group, and a two-sample t-test applying a symmetrical critical range was used for the comparison of results in different groups.

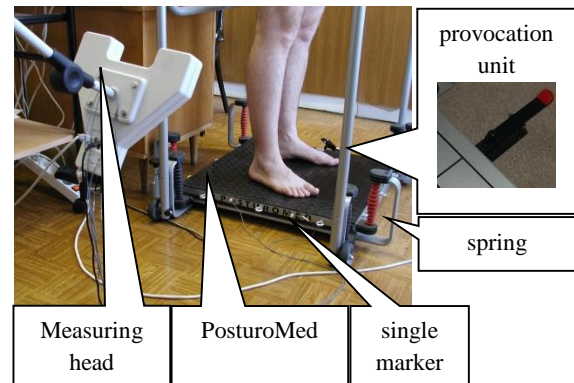


Figure 1: Measurement arrangement. PosturoMed<sup>®</sup> plate secured by springs in different directions but with the same strength in each direction. The ultrasound-based measuring head was located at 30 degrees to the side of the subject; the motion of the plate was recorded by single markers attached to the side of the platform.

## 3. Results

The results are summarized in Table 2. The control subjects and the patients with unilateral knee osteoarthritis completed all three parts of the tests (stance on both, on right and left limb. 4 patients with bilateral knee osteoarthritis completed provocation test neither stance on dominant limb nor on non-dominant limb, 3 patients could not completed provocation test stance on non-dominant leg. In that cases the values of the Lehr's damping ratio was 0.

For control subjects, the Lehr's damping ratio determined while stance on non-dominant limb decreased significantly compared to the determined while stance on dominant ( $p_{female} = 0.006$ ;  $p_{male} = 0.009$ ) and on both limb ( $p_{female} = 0.004$ ;  $p_{male} = 0.002$ ) (Table 2). Significant differences was found compared the Lehr's damping ratio of males and females ( $p_{both} = 0.009$ ;  $p_{dominant} = 0.006$ ;  $p_{non-dominant} = 0.002$ ) (Table 2). This results are similar, which are summarized in [27].

For patients with severe, unilateral knee osteoarthritis, the tendency of lateral dominance is similar to controls: the Lehr's damping ratio determined while stance on affected

limb was significantly smaller than Lehr's damping ratio determined while standing on both limb ( $p_{female} = 0.0005$ ;  $p_{male} = 0.00011$ ) and on healthy limb ( $p_{female} = 0.0013$ ;  $p_{male} = 0.0014$ ) (Table 2) [26]. The gender did not influence significant the Lehr's damping ratio ( $p_{both} = 0.087$ ;  $p_{dominant} = 0.078$ ;  $p_{non-dominant} = 0.20$ ) (Table 2) [26]. The Lehr's damping ratio was significant smaller compared to male controls ( $p_{both} = 0.0021$ ;  $p_{dominant} = 0.0007$ ;  $p_{non-dominant} = 0.00002$ ) to female controls ( $p_{both} = 0.0032$ ;  $p_{dominant} = 0.0006$ ;  $p_{non-dominant} = 0.00005$ ) (Table 2) [26].

For patients with severe bilateral knee osteoarthritis, the lateral dominance did not influence the Lehr's damping ratio in male controls ( $p_{both-dominant} = 0.21$ ;  $p_{dominant-nondominant} = 0.37$ ;  $p_{both-nondominant} = 0.09$ ); and in female controls ( $p_{both-dominant} = 0.21$ ;  $p_{dominant-nondominant} = 0.37$ ;  $p_{both-nondominant} = 0.09$ ) (Table 2). The gender did not influence significant the Lehr's damping ratio ( $p_{both} = 0.13$ ;  $p_{dominant} = 0.17$ ;  $p_{non-dominant} = 0.09$ ) (Table 2). The Lehr's damping ratio significant smaller in both gender compared to healthy subjects ( $p_{both} < 0.00007$ ;  $p_{dominant} < 0.000004$ ;  $p_{non-dominant} < 0.00007$ ) (Table 2). Significant differences were found between the patients with unilateral and patients with bilateral knee osteoarthritis in both gender ( $p_{both} < 0.0001$ ;  $p_{dominant} < 0.0006$ ) (Table 2). However, in case of stance on non-dominant limb the differences were not significant ( $p_{male} = 0.07$ ;  $p_{female} = 0.09$ ) (Table 2). The differences were not significant, if the Lehr's damping ratio determined while stance on affected limb of patients with unilateral knee osteoarthritis was compared to Lehr's damping ratio while stance on both limbs ( $p_{male} = 0.09$ ;  $p_{female} = 0.11$ ) and it while stance on dominant limb ( $p_{male} = 0.17$ ;  $p_{female} = 0.28$ ) (Table 2)

#### 4. Discussion

At healthy subjects the results shown that dominance and gender significantly influence balancing ability after sudden perturbation. This findings are similar to our earlier results [27] and the results of Boer et al [33], Mueller et al [34].

For patients with unilateral knee osteoarthritis the results showed that the non-affected side was always the dominant side. The balancing capacity after sudden perturbation deteriorated following knee osteoarthritis, it strengthened the results of earlier research in stabilometry [21-25]. However the gender did not effect on balancing ability after sudden perturbation. The results shown that the impact of osteoarthritis is more dominant that the impact of gender [27].

For patients with bilateral knee osteoarthritis the gender did not influence the balancing capacity after sudden perturbation, which strengthen our earlier findings. In that cases the lateral dominance did not influence the balancing capacity, it means the balancing capacity while stance on single limb was symmetrical. This finding was similar to findings from results of gait analysis [28]. The results shown that the impact of knee osteoarthritis is more

dominant not only than effect of gender but effect of lateral dominance. For

patients with bilateral knee osteoarthritis, the Lehr's damping ratio determined while stance on single leg did not differ from results determined while stance on affected side of patients with unilateral knee osteoarthritis. It means the degree of severity of osteoarthritis was the most dominant effect on balancing capacity after sudden perturbation.

The limitation of this study was that balancing ability after sudden perturbation in patients was analyzed only before TKA. Muscle activation during the provocation test was not analyzed; it should also be analyzed in the future.

#### 5. Conclusion

In patients with bilateral severe knee osteoarthritis, the balancing capacity after sudden perturbation deteriorated compared to controls. Significant differences were found in Lehr's damping ratio while stance on both limb and on dominant limb compared the results of patients with unilateral, severe knee osteoarthritis. This could be taken into account in the use of different aids.

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Table 2  
The mean  $\pm$  standard deviation of Lehr's damping ratio (D) calculated from the results of the provocation test

|   | Stance on                      |                                |                                  |
|---|--------------------------------|--------------------------------|----------------------------------|
|   | both limbs                     | dominant/<br>unaffected limb   | non-dominant/<br>affected limb   |
| <i>Male controls N=10</i>                   | 4.63 $\pm$ 0.32                | 4.50 $\pm$ 0.31                | 2.87 $\pm$ 0.36 <sup>a,b</sup>   |
| <i>Female controls N=10</i>                 | 5.01 $\pm$ 0.30 <sup>g</sup>   | 4.89 $\pm$ 0.29 <sup>g</sup>   | 3.45 $\pm$ 0.33 <sup>a,b,g</sup> |
| <i>Males with unilateral knee OA N=8</i>    | 3.13 $\pm$ 0.51 <sup>c</sup>   | 2.95 $\pm$ 0.47 <sup>c</sup>   | 0.89 $\pm$ 0.37 <sup>a,b,c</sup> |
| <i>Females with unilateral knee OA N=12</i> | 3.26 $\pm$ 0.47 <sup>c</sup>   | 3.02 $\pm$ 0.49 <sup>c</sup>   | 0.93 $\pm$ 0.47 <sup>a,b,c</sup> |
| <i>Males with unilateral knee OA N=9</i>    | 0.79 $\pm$ 0.57 <sup>c,d</sup> | 0.62 $\pm$ 0.41 <sup>c,d</sup> | 0.59 $\pm$ 0.39 <sup>c</sup>     |
| <i>Females with unilateral knee OA N=11</i> | 0.81 $\pm$ 0.55 <sup>c,d</sup> | 0.70 $\pm$ 0.37 <sup>c,d</sup> | 0.68 $\pm$ 0.33 <sup>c</sup>     |

OA osteoarthritis

dominant/unaffected limb: dominant limb in healthy subjects and in patients with bilateral knee OA; unaffected (healthy) limb in patients with unilateral knee OA

non-dominant/affected limb: non-dominant limb in healthy subjects in patients with bilateral knee OA; affected limb in patients in patients with unilateral knee OA

<sup>a</sup> Significant differences in values of D compared to parameters measured while stance on both limbs

<sup>b</sup> Significant differences in values of D compared to parameters measured while stance on dominant/unaffected limb

<sup>c</sup> Significant differences in values of D of patients with OA compared to parameters of the healthy control group

<sup>d</sup> Significant differences in values of D of patients with bilateral OA compared to parameters of patients with

<sup>g</sup> Significant differences in values of D between the genders