ABSTRACT
Knee osteoarthritis (OA) is one of the most widespread orthopedic disease that affects the elderly. The present study aims to evaluate the biomechanical effects of bilateral osteoarthritis on elderly patients compared to a control group using stabilometry parameters. The used parameters were center of pressure (CoP) 95% confidence ellipse area, CoP path length and maximum path velocity, CoP range ratio and spectral power ratio in anteroposterior (AP) and mediolateral (ML) directions, load distribution between legs, largest amplitudes in AP and ML direction during a 30s bilateral quite standing trial on a Zebris FDM-S force distribution plate. Significant differences to the control group in path length, ML largest amplitude and spectral power ratio showed that bilaterally involved OA degrades postural stability as reported earlier, but new finding is that more intense CoP motions can be observed in ML direction in case of bilateral knee osteoarthritis.

KEY WORDS
bilateral knee osteoarthritis, stabilometry, balance, statistical analysis

1. Introduction
Knee osteoarthritis is one of the most widespread orthopedic disease that affects about 10% of the elderly population [1]. Its biomechanical effects on gait and postural stability are widely studied by researchers [2]. Relatively fewer studies documented the analysis of specifically bilaterally involved knee osteoarthritis on gait [3]–[6] and on postural control [7]–[10]. Most of the studies analyzing static and dynamic [10] balance of the bilaterally involved knee osteoarthritis (OA) patients concluded that just as unilateral patients they have degraded postural stability. However their alterations reflected by the observed postural control parameters could differ from the unilateral OA patients. The present study aims to analyze the differences of bilateral OA patients compared to age matched asymptomatic control group using stabilometry i.e. the analysis the motion of foot center of pressure (CoP). Recent studies offered new CoP parameters [11], [12] that could reveal so far undiscovered strategy differences in the postural control of bilaterally involved knee osteoarthritis patients. Our aim was to find alterations in some of the studied CoP parameters between the OA and control group in addition to the so far reported differences.

2. Methods
2.1 Subjects
Subjects involved in the study were elderly (age > 60 years) patients with bilaterally involved knee osteoarthritis and age matched healthy control group. Bilateral osteoarthritis involvement was classified by two-ways X-ray examination. Measurements were taken from eight bilateral OA patients and eleven control subjects, however through the data evaluation one statistically outlier measurement had to be excluded from the OA group, while measurements were randomly sorted out from the control group to match the sample size of the two groups. Anthropometrical data of the final groups is summarized in Table 1. 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 Experimental procedure
Postural stability data was collected using a Zebris FDM-S force distribution measuring plate (ZEBRIS GmbH, Isny, Germany) with the original WinPDMS (v1.2.1.) measuring software. Participants performed one 30 second long bipedal quite standing trial on the force distribution plate. They were asked to stand as still as possible while resting their arms by their side and looking straight ahead onto the wall. The subject’s basic anatomical data were registered prior the stabilometry measurement: body height was measured and recorded in cm; body mass was measured to the nearest 0.1 kg with an electronic weight scale with the participant wearing shorts and a T-shirt. The measurements were performed in the MAV Hospital Department of Orthopaedics (Szolnok, Hungary).
2.3 Data processing

Measurements were recorded at 100 Hz sampling frequency. Raw measurement data was exported from the WinPDMS software for custom processing and parameter calculation. Foot center of pressure (CoP) point was calculated from the force distribution data for each time frame. A 10 Hz Butterworth digital low pass filter was applied on the calculated CoP coordinate time series as recommended by Ruhe et al. [13]. The calculations of the parameters were carried out in a custom processing software written in LabVIEW 2013 (National Instruments, Austin, Texas, USA). The calculated parameters were selected from the recommended parameter sets from [11] and [12]. These studies have evaluated several CoP parameters to recommend independent and sensitive parameters for stabilometry measurements. The selected parameters are the following:

- 95% Confidence Ellipse Area (CE Area)
- Path length
- Maximum path velocity (Max. velocity)
- AP-ML Range Ratio
- Load Distribution Difference between legs, absolute value (LDD)
- Largest Amplitude in AP (AP LA) and ML directions (ML LA)
- Spectra power ratio (SPR) between AP and ML directions

These parameters can analyze different aspects of postural stability, therefore this parameter set is applicable to show deviations of balancing capability in the bilateral OA patients on a wide scope.

2.4 Statistical analysis

To determine overall difference between the bilateral OA and the control group considering every parameter multivariate ANOVA was used. To separately test the between subject effect of each parameter univariate test results were also considered in our evaluation. Statistical analysis was carried out using SPSS Statistic v22 (IBM, 2013) software. Level of significance was set to \( p = 0.05 \).

3. Results

Considering every studied parameters the ANOVA found the difference between the bilateral OA group and the control group statistically not significant (\( p_{\text{multivariate}} = 0.106 \)). However, the applied parameters must be studied individually as well, as the possible differences might be reflected only on some specific parameters. When considered CoP parameters individually significant differences can be found in Path length \( (p < 0.01) \), ML LA \( (p = 0.018) \) and SPR \( (p=0.016) \). CoP Path length was significantly longer in the bilateral OA group. Largest amplitudes in ML direction were also significantly larger in the OA group. On the other hand spectral power ratio was significantly smaller in the bilateral OA group compared to the control group. Figure 1 shows the distribution of these parameters separately in the two groups through box plots. In the remaining parameters there was no significant difference between the bilateral OA and the control group. Table 2 summarizes the discussed statistical significance values \( (p) \), the observed statistical power and the descriptive statistics of the individual parameters for both group separately (mean value and standard deviation).

![Figure 1. Box plots of parameters showing significant differences](image)

4. Discussion

The fact that the result of the multivariate ANOVA could not be considered statistically significant does not mean that there is no difference between the bilateral knee OA group and the control group as it could be well observed when studying the effect of bilateral OA in each

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Bilateral OA group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/Female</td>
<td>1/6</td>
<td>4/3</td>
</tr>
<tr>
<td>Age (years)</td>
<td>64.57 (4.15)</td>
<td>62.42 (2.07)</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>81.28 (14.27)</td>
<td>77.57 (11.14)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.14 (3.13)</td>
<td>163.85 (10.66)</td>
</tr>
<tr>
<td>Body Mass Index (kg/m(^2))</td>
<td>30.92 (5.27)</td>
<td>28.99 (4.12)</td>
</tr>
</tbody>
</table>

Table 1. Anthropometry of participants
parameter independently. According to [11], [12] the used parameters are non correlating thus the observed differences reflect deviations on different interpretations of postural stability. For instance the large difference in the CoP Path length shows that similarly to unilateral OA patients [14] the bilateral OA group applies more motion on average during their balancing in bipedal stance. According to Takacs [15] path length is one of the most reliable CoP parameters, therefore the current finding is remarkable.

The Largest Amplitude parameter shows us the amplitude of the largest continuous CoP movement that is the largest peak to valley or valley to peak transition in the CoP coordinate analyzed in both biomechanical direction (AP, ML). This feature remains hidden when the averages or extremities are analyzed of the CoP trajectory. ML LA showed significantly larger average value in the bilateral group which means these patients applied larger uninterrupted sideways motions. This is possible due to smaller load balancing processes between the supporting lower limbs. However, measurement protocol required equal load distribution between legs, it is possible that bilateral OA patients were not able to statically maintain this state resulting the larger amplitudes in ML direction. This sideways oscillation happened around the equal load distribution point, because LDD showed no difference between the two group. Similarly to the bilateral OA patients’ gait performance as reported by Liu et al [4] the bilateral knee OA group of this study could not maintain constant symmetrical inter-limb load-sharing.

The SPR parameter justifies this theory as its value is much smaller in the bilateral group. SPR is the ratio of the energy content of the AP and ML directional CoP motions. This means higher SPR value corresponds to relatively more motion in AP direction compared to the ML direction. 4.79 (2.26) SPR in the control group means they sway in the AP direction four times larger than in the ML direction. In contrast, the 2.14 (1.12) value in the bilateral OA group represents relatively more ML directional motion.

The used methods allow an affordable, simple and reliable evaluation of treatment efficiency and patient condition monitoring, thus could be useful for evaluation of other orthopedic diseases.

5. Conclusion

The present study used stabilometry measurements to statistically analyze the differences in postural stability of elderly bilaterally involved osteoarthritis patients compared to healthy age matched control group. Significant differences were found for certain stabilometry parameters, but not for variance analysis considering every parameter together. Significantly longer path length showed worse balancing in the OA group as reported earlier in the literature [15]. Largest CoP amplitudes in ML direction and SPR confirmed that bilateral OA patients apply more motion in ML direction compared to the healthy control group, which considered a new result.

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References


