Influence of gait speed on plantar pressure in subjects with unilateral knee osteoarthritis

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Objective: Changing gait speed is a common strategy to manipulate exercise intensity during physical exercise, but may elicit higher impact forces and consequent joint loading. Here we analyzed the effects of increasing walking velocity on plantar pressure and asymmetries in elderly with knee osteoarthritis (OA). Our hypothesis was that the contralateral limb could receive higher loading compared to the OA limb in the different walking speeds tested.

Methods: Twelve elderly with unilateral knee OA walked at different self-selected speeds along a 10 m pass way stepping on an instrumented mat for measurement of plantar pressure at preferred, slow and fast gait speeds. Five steps were recorded for each speed. Plantar pressure data were compared between the speeds and legs.

Results: speeds were significantly different between them (p < 0.05). Mean and peak plantar pressure increased when speed changed from slow to fast (p < 0.05). Velocity of the center of pressure increased and the single stance time decreased when walk speed was increased (p < 0.05). Any asymmetries were observed.

Conclusion: Increasing gait speed from slow to fast in subjects with unilateral knee OA significantly affected variables of plantar pressure, but asymmetries between committed and contralateral leg were not detected.

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Methods: Doze idosos com OA unilateral de joelho caminharam por um corredor de 10 m onde pisavam em um tapete instrumentado para medidas de pressão plantar. Cada participante caminhou cinco vezes em três diferentes velocidades autoselecionadas (preferida, lenta e rápida). Os resultados foram comparados entre as velocidades e entre os membros inferiores.

Resultados: As velocidades avaliadas diferiram entre si (p<0.05). A pressão média e o pico de pressão aumentaram com as mudanças entre as velocidades lenta e rápida (p<0.05); a velocidade do centro de pressão aumentou e o tempo de apoio simples diminuiu com o aumento da velocidade (p<0.05). Assimmetrias não foram observadas entre o membro acometido e o contralateral.

Conclusões: O aumento na velocidade da marcha lenta para rápida em sujeitos com OA unilateral afeta a pressão plantar tanto no membro acometido quanto no contralateral, sem a observação de assimmetrias.

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normal walking speed, at a slower speed and at a faster speed.

The protocol for collecting the plantar pressure was to walk barefoot along a 10-meter long straight corridor. Measurements were made every time the subject stepped on the mat, considering the averages of five footsteps for each of the lower limbs, at each selected speed. The data of mean and peak pressures during single-limb-support phase, average velocity of the COP and single-limb-support time were calculated for each footstep, and then grouped into mean and standard deviation for each subject, at each speed and for each leg.

### Statistical analysis

Results were subjected to descriptive statistics and to Shapiro-Wilk normality test, besides the Mauchly sphericity test and the test of Levene for homogeneity of variances, where relevant. The plantar pressure variables, velocity of the center of pressure and single-limb-support time were compared among gait speeds and between legs by means of an analysis of variance (ANOVA), considering the three gait speeds and measures of both legs in a mixed model $3 \times 2$ with Bonferroni corrections for multiple comparisons. The effects were analyzed by a paired t test (as for the legs) or one-way ANOVA (as for the speeds) with post hoc Bonferroni analysis. The significance level for all statistical procedures was 0.05, and we used a commercial statistical package.

### Results

The walking speeds in the different conditions tested differed ($P < 0.05$). The mean speed for slow gait was 0.66 ± 0.06 m/s; for preferred gait, 0.82 ± 0.12 m/s; and for fast gait, 1.07 ± 0.14 m/s. We noted a speed effect for mean pressure ($F = 4.087$, $P < 0.05$); the mean pressure at low speed differed from that at fast speed ($P = 0.020$). The mean pressure (Fig. 1) at slow speed did not differ from that at preferred speed ($P = 0.796$), and the mean pressure at preferred speed did not differ from that at fast speed ($P = 0.292$). No effect of the leg was observed for mean pressure ($F = 0.26$, $P = 0.875$).

The plantar pressure peak (Fig. 2) showed a speed effect ($F = 7.919$, $P < 0.05$). The post hoc analysis indicated that the peak pressure at slow speed was lower versus fast speed ($P = 0.001$) and the pressure peak at preferred speed was similar to that at slow speed ($P = 0.189$). Likewise, the peak pressure at preferred speed was similar to that at fast speed ($P = 0.144$). No leg effect was observed for peak pressure ($F = 0.778$, $P = 0.397$).

The COP velocity (Fig. 3) showed a gait speed effect ($F = 21.321$, $P < 0.05$). The post hoc analysis indicated that COP velocity in slow gait was lower versus fast ($P = 0.000$) and preferred ($P = 0.007$) gait speeds. The measurement in preferred speed mode was lower versus fast speed mode ($P = 0.009$). No leg effect was observed for COP speed ($F = 4.655$, $P = 0.054$).

The single-limb-support time (Fig. 4) exhibited a speed effect ($F = 28.396$, $P < 0.05$). The post hoc analysis indicated that the single-limb-support time was greater at slow versus fast speed ($P = 0.000$) and also greater in low versus preferred speed ($P = 0.002$). The single-limb-support time was greater in preferred versus fast speed ($P = 0.002$). No leg effect was observed for single-limb-support time ($F = 0.461$, $P = 0.511$).

### Discussion

The aim of this study was to analyze the effects of change in gait speed on plantar pressure in elderly subjects with unilateral knee OA, considering measures of the affected and

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**Figure 1** – Mean plantar pressure expressed as mean (bars) and standard deviation (vertical lines) in N/cm². *Indicates statistically significant differences from the results of pressure between each gait speed ($P < 0.05$).

**Figure 2** – Peak plantar pressure expressed as mean (bars) and standard deviation (vertical lines) in N/cm². *Indicates significant differences of the results of peak pressure between gait speed ($P < 0.01$).

**Figure 3** – COP speed expressed as mean (bars) and standard deviation (vertical lines) in m/s. *Indicates statistically significant differences of COP velocity among walking speeds ($P < 0.05$).
contralateral limb. A change in gait speed has been demonstrated as determinant of changes in ground reaction forces, and this could be reflected on plantar pressure parameters in subjects with OA. Our results, considering self-selected speeds during the gait, demonstrate significant differences in the parameters analyzed among three walking speeds. However, they do not indicate asymmetries between OA affected limb and contralateral limb, regardless of the gait speed. Thus, the presence of unilateral knee OA did not cause changes in plantar pressure that were specific for the leg affected by the disease. Likewise, our results do not indicate that the contralateral leg may present some compensation in plantar pressure.

The increase in mean pressure observed from the increased speed may be associated with the increased ground reaction force. The greater mean pressure suggests an overload on lower limbs. Although the affected limb has difficulty in absorbing the impact, or may have a different pattern response to the load, we found no differences between the leg with OA and the contralateral leg. In our study, patients with unilateral OA maintained a similar pattern of plantar pressure for both legs during the gait. This result contradicts our hypothesis, that gait compensation could cause differences in the load experienced by the affected and the unaffected limbs.

The peak plantar pressure behaved similarly to mean pressure. We observed an increase in the peak pressure with a change of speed – from slow to fast. The increase in peak pressure may be associated with a combination of reduced area of contact due to increased walking speed, and greater contact force on the ground-foot interface during gait. With these results, we suggest that patients with unilateral knee OA adopt a gait pattern that assimilates the ground reaction force in the same way for the affected and the contralateral legs. The changes in the velocity of the center of pressure (COP) are associated with the changes of gait speed, and suggest that changes occurring in subjects with knee OA do not seem to reflect in changes in foot roll-over excursion speed during gait.

The single-limb-support time decreased with the increase in gait speed in patients with OA. This response to the increased gait speed is expected, and no asymmetries were found in this temporal gait parameter. The presence of OA did not influence the time of ground contact to the point of differing from the contralateral leg. However, it may be that the increased time of support result from the fact that individuals with OA are unable to compensate for the limitation of knee excursion because of the pain, which can happen by intrinsic factors such as joint stability and changes in frictional values of the diseased joint.

In our study, no asymmetries were found in plantar pressure variables in any of those speeds considered, although patients with unilateral OA have joint momentum asymmetries reported in the literature. This divergence can be explained by the hypothesis that patients with unilateral knee OA use a larger contact area to improve plantar pressure distribution, when considering a single gait speed. Another study also found significant associations among speed and gait variables in asymptomatic individuals.

Among the limitations of our study, it is worth mentioning the small number of patients included and the predominance of female subjects, which limits the generalization of our results. Additionally, we did not consider different degrees of deformity, limitation or pain, that may have specific effects on gait. Finally, we can suggest that, for the patients evaluated, the change in walking speed influenced plantar pressure variables, but did not cause any asymmetries between the affected and contralateral limbs. Thus, these patients did not exhibited specific adaptations to the impaired limb in response to the increased gait speed.

Conflict of interests

The authors declare no conflict of interests.

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