REV BRAS REUMATOL. 2014;54(6):441–445

REVISTA BRASILEIRA DE REUMATOLOGIA

www.reumatologia.com.br

Original article

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

*Wagner Costa Fernandes, Álvaro Machado, Caio Borella, Felipe P. Carpes**

Research Group on Applied Neuromechanics, Laboratory of Neuromechanics, Universidade Federal do Pampa, Uruguaiana, RS, Brazil

ARTICLE INFO

Article history:
Received 11 February 2014
Accepted 30 June 2014
Available online 25 October 2014

Keywords:
Center of pressure
Walking
Asymmetry
Elderly
Kinetics

ABSTRACT

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.

Influência da velocidade da marcha sobre a pressão plantar em sujeitos com osteoartrite unilateral de joelho

Palavras-chave:
Centro de pressão
Caminhada
Assimetrias
Idosos
Cinética

RESUMO

Objetivos: Alterar a velocidade da marcha é uma estratégia comum para manipular a intensidade de exercício de caminhada, mas pode repercutir em maiores forças de impacto e consequente sobrecarga articular. Neste estudo analisamos os efeitos do aumento da velocidade da marcha sobre a pressão plantar e assimetrias na marcha em idosos com osteoartrite (OA) unilateral de joelho. A hipótese do estudo era de que o membro acometido receberia maior sobrecarga que o acometido durante o andar nas diferentes velocidades.

DOI of original article: http://dx.doi.org/10.1016/j.rbr.2014.06.004.
* Corresponding author.
E-mail: carpes@unipampa.edu.br (F.P. Carpes).
http://dx.doi.org/10.1016/j.rbre.2014.06.004

Métodos: 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 autosselecionadas (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 ($p < 0,05$). Assimetrias 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 assimetrias.

Introduction

Chronic degenerative joint diseases such as osteoarthritis (OA) negatively affect mobility, with a negative impact on quality of life, especially in the elderly.[1,2] Radiographic studies suggest the existence of some joint abnormality in at least 30% of men and women over 65 years, and only one third of these are symptomatic.[3] OA leads to a decrease in the number of chondrocytes and in the ability to retain water, leading to cracks in the matrix and causing pain.[4,5] In addition, it can cause cartilaginous deformation and changes in the periarticular region, leading to an abnormal remodeling of cartilage and promoting subchondral bone attrition and the formation of osteophytes.[4,6] Together, these changes lead to significant changes in joint mechanics.

In the gait of subjects with knee OA, varus misalignment of the knee joint may decrease the capacity of impact absorption and the response to loads during the gait.[7] As with healthy individuals,[1] the increase of walking speed can mean an additional joint overload in elderly patients with OA, which was also shown for elderly persons without OA.[8,9] In comparison with studies that assessed pre-defined or fixed speeds,[10,11] a self-selected speed can allow more realistic results, because the subjects are not influenced to change their gait mechanics in order to fit into the parameters established by the researcher.[11]

Considering walking as an exercise modality often practiced among the elderly in order to improve their physical fitness, the manipulation of gait speed is a strategy widely used to control the intensity of the exercise.[12,13]

In the case of unilateral OA, it is possible that the contralateral limb receives a higher overload due to compensations during the gait, and this could contribute to an acceleration of the onset of bilateral OA. Faced with an increasing number of elderly people engaged in walking and running programs, the aim of this study was to analyze the effects of a change in gait speed on plantar pressure parameters and asymmetries in elderly patients with unilateral knee OA, comparing the responses of affected and unaffected limbs.

Methods

Participants

Twelve elderly patients with unilateral knee OA diagnosed by a physician (one male, 11 female) with a mean age of 71.58 ± 8.93 years, body mass 72.58 ± 11.11 kg, height 161 ± 8, 57 cm, body mass index 28 ± 3.86 kg/m^2 and WOMAC index 11.9 ± 4.92 were enrolled in the study. All participants were volunteers who contacted the researchers after advertise of the research project in the community, and signed an informed consent form. All procedures were approved by the ethics committee on human research of the local institution (protocol No. 0062011). The inclusion criteria for this study were: age of 65 years or older, diagnosis of unilateral OA established by a qualified physician, with imaging studies (radiography) of the knee joint, and ability to walk independently. The researchers did not perform diagnostic or clinical evaluations, the diagnosis was made by the patient's physician.

Experimental design

Subjects with unilateral OA diagnosed by a physician were evaluated for plantar pressure during gait in slow, preferred and fast speeds. Measures of average plantar pressure, peak pressure, center of pressure (COP) progression and single-leg stance time during walking were collected for the affected and contralateral limbs. The results were compared between the involved and contralateral limbs and among the three walking speeds.

Experimental procedures

All participants had their health assessed by the Westerm Ontario and McMaster Universities (WOMAC) questionnaire[14] and then underwent an evaluation of plantar pressure during the gait, using a computerized baropodometry system (Matscan Versatek, Tekscan Inc., Boston, USA) with 5 mm of thickness and measuring 432×368 mm, with a sampling rate of 400 Hz. Walking was assessed in a self-selected speed, and the participant was asked to walk at his/her 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 3×2 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 speed 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 ($F = 0.461$, $P = 0.511$).

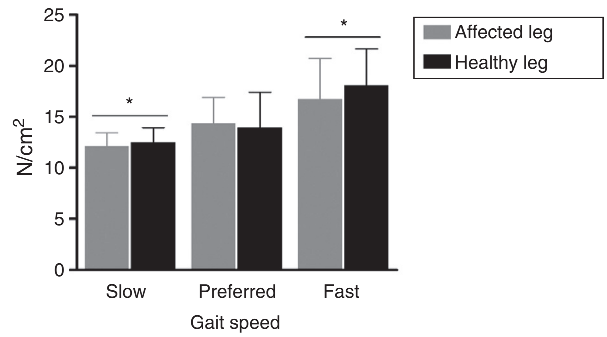

Figure 2 – Peak plantar pressure expressed as mean (bars) and standard deviation (vertical lines) in N/cm^2. *Indicates significant differences of the results of peak pressure between gait speed ($P < 0.01$).

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

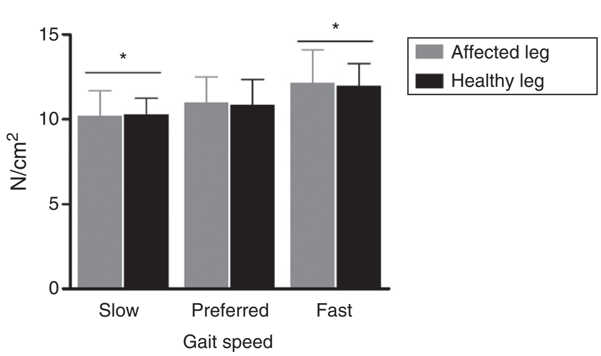

Figure 1 – Mean plantar pressure expressed as mean (bars) and standard deviation (vertical lines) in N/cm^2. *Indicates statistically significant differences from the results of pressure between each gait speed ($P < 0.05$).

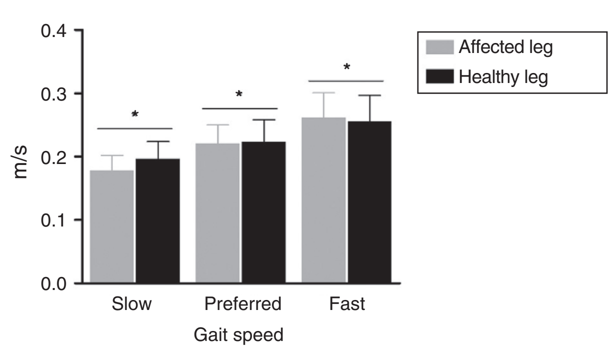

Figure 3 – COP speed expressed as mean (bars) and standard deviation (vertical lines) in N/cm^2. *Indicates statistically significant differences of COP velocity among walking speeds ($P < 0.05$).

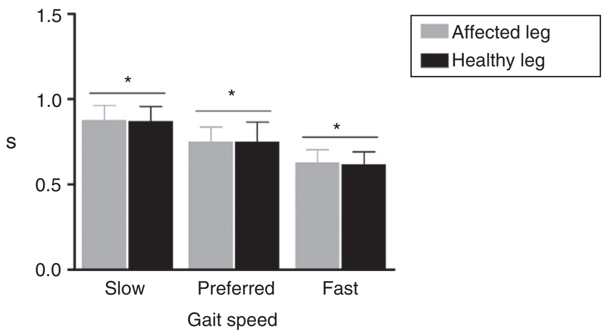

Figure 4 – Single-limb-support time expressed as mean (bars) and standard deviation (vertical lines) for the group, in seconds.
***Indicates statistically significant differences of single-limb-support time among gait speeds (P < 0.05).**

contralateral limb. A change in gait speed has been demonstrated as determinant of changes in ground reaction forces,[15] and this could be reflected on plantar pressure parameters in subjects with OA.[7] 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.[8,13] 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,[16] 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.[14,16]

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.[8] 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.[17,18] The changes in the velocity of the center of pressure (COP) are associated with the changes of gait speed,[19] 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.[20]

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,[20] 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.[8]

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.[4] 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.[16]

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.

Acknowledgements

The authors acknowledge the support of the Research Group on Applied Neuromechanics, Universidade Federal do Pampa, during the development of this study. This study was funded by FAPERGS (Case No. 1013100).

REFERENCES

1. Nelson AE, Allen KD, Golightly YM, Goode AP, Jordan JM. A systematic review of recommendations and guidelines for the management of osteoarthritis: The Chronic Osteoarthritis Management Initiative of the U.S. Bone and Joint Initiative. Semin Arthritis Rheum. 2013. Epub ahead of print; doi: 10.1016/j.semarthrit.2013.11.012.
2. Liikavainio T. Biomechanics of Gait and Physical Function in Patients with Knee Osteoarthritis Thigh Muscle Properties and Joint Loading Assessment. Publications of the University of Eastern Finland Dissertations in Health Sciences. 2010.
3. Jordan KM, Arden NK, Doherty M, Bannwarth B, Bijlsma JW, Dieppe P, et al. EULAR Recommendations 2003: an evidence based approach to the management of knee osteoarthritis: Report of a Task Force of the Standing Committee for International Clinical Studies Including Therapeutic Trials (ESCISIT). Ann Rheum Dis. 2003;62:1145–55.

4. Creaby MW, Bennell KL, Hunt MA. Gait differs between unilateral and bilateral knee osteoarthritis. Arch Phys Med Rehabil. 2012;93(5):822–7.
5. Willick SE, Hansen PA. Running and osteoarthritis. Clin Sports Med. 2010;29:417–28.
6. Coimbra IB, Pastor EH, Greve JMDA, Puccinelli MLC, Fuller R, Cavalcanti FdS, et al. Consenso brasileiro para o tratamento da osteoartrite. Rev Bras de Reumatol. 2002;42:371–4.
7. Yang SW, Hsie CH, Hsieh LF. The plantar pressure characteristics of subjects with knee osteoarthritis. J Biomech. 2006;39:S116.
8. Burnfield JM, Few CD, Mohamed OS, Perry J. The influence of walking speed and footwear on plantar pressures in older adults. Clin Biomech (Bristol, Avon). 2004;19:78–84.
9. Zeni JA Jr, Higginson JS. Differences in gait parameters between healthy subjects and persons with moderate and severe knee osteoarthritis: a result of altered walking speed? Clin Biomech (Bristol, Avon). 2009;24:372–8.
10. Zammit GV, Menz HB, Munteanu SE. Reliability of the TekScan MatScan® system for the measurement of plantar forces and pressures during barefoot level walking in healthy adults. J Foot Ankle Res. 2010;18:11.
11. Baliunas AJ, Hurwitz DE, Ryals AB, Karrar A, Case JP, Block JA, et al. Increased knee joint loads during walking are present in subjects with knee osteoarthritis. Osteoarth Cartilage. 2002;10:573–9.
12. Monteiro WD, Araújo CGSd. Transição caminhada-corrida: considerações fisiológicas e perspectivas para estudos futuros. Rev Bras Med Esp. 2001;7:207–15.
13. Phethean J, Nester C. The influence of body weight, body mass index and gender on plantar pressures: results of a cross-sectional study of healthy children's feet. Gait Posture. 2012;36:287–90.
14. Mills K, Hettinga BA, Pohl MB, Ferber R. Between-limb kinematic asymmetry during gait in unilateral and bilateral mild to moderate knee osteoarthritis. Arch Phys Med Rehabil. 2013;94:2241–7.
15. Pataky TC, Caravaggi P, Savage R, Parker D, Goulermas JY, Sellers WI, et al. New insights into the plantar pressure correlates of walking speed using pedobarographic statistical parametric mapping (pSPM). J Biomech. 2008;41: 1987–94.
16. Marx FC, Oliveira LMd, BelliniI CG, Ribeiro MCC. Tradução e validação cultural do questionário algofuncional de Lequesne para osteoartrite de joelhos e quadris para a língua portuguesa. Revista Brasileira de Reumatologia. 2006;46:253–7.
17. Astephen Wilson JL. Challenges in dealing with walking speed in knee osteoarthritis gait analyses. Clin Biomech (Bristol, Avon). 2012;27:210–2.
18. Tanaka K, Miyashita K, Urabe Y, Ijiri T, Takemoto Y, Ishii Y, et al. Characteristics of trunk lean motion during walking in patients with symptomatic knee osteoarthritis. Knee. 2008;15:134–8.
19. Zammit GV, Menz HB, Munteanu SE, Landorf KB. Plantar pressure distribution in older people with osteoarthritis of the first metatarsophalangeal joint (hallux limitus/rigidus). J Orthop Res. 2008;26:1665–9.
20. Goryachev Y, Debbi EM, Haim A, Rozen N, Wolf A. Foot center of pressure manipulation and gait therapy influence lower limb muscle activation in patients with osteoarthritis of the knee. J Electromyogr Kinesiol. 2011;21:704–11.