Hip range of motion requirements during straight walking and 90° turns in healthy elderlies and hip osteoarthritis patients

Hannah Steingrebe [1], Stefan Sell [1,2], Thorsten Stein [1]

[1] Institute of Sports and Sports Science, Karlsruhe Institute of Technology, Germany;

[2] Joint Center Black Forest, Clinic Neuenbürg, Germany

Introduction

Patients with hip osteoarthritis (HOA) suffer from limitations in passive and active hip range of motion (ROM) (Baker et al., 2016). Previous analyses have focused on the hip motion during straight walking (e. g. Constantinou et al., 2017). However, joint mobility requirements might be larger during other movements of daily living. Turning movements are encountered frequently during everyday life (Glaister et al., 2007) and can be conducted in a spin or step turn manner (Hase & Stein, 1999). Analyses of healthy young adults show that turning overall requires more external rotation of the hip, step turning larger hip abduction and spin turning larger hip adduction than straight walking (Taylor et al., 2005). Patients with HOA have demonstrated decreased peak hip abduction and adduction during 45° turns (Tateuchi et al., 2014). Yet, knowledge of transverse plane kinematics of healthy elderlies and HOA patients is lacking and turning angles between 76° and 120° might be more relevant in everyday life (Sedgman et al., 1994).

This study aims to compare hip kinematics during straight walking and 90° step and spin turns in healthy elderlies and patients with mild to moderate HOA. We expected turning to require larger frontal and transverse plane hip mobility than straight walking and that mobility deficits of HOA patients would be more apparent during turning than straight walking.

Methods

In total, 42 subjects participated in this study, thereof 21 subjects with mild to moderate unilateral HOA (10 females; age: 64.0 ± 9.6 years; BMI: 24.2 ± 2.9 kg/m^2) and 21 healthy elderlies (10 females; age: 63.1 ± 9.2 years; BMI: 25.2 ± 2.7 kg/m^2).

Subjects performed straight walking and pre-planned 90° step and spin turns at a self-selected speed. Turning was conducted with the affected limb for the HOA group and a matched limb for the healthy group. Subjects were instructed to perform the turn in an abrupt manner.

Motion analysis was conducted with a 16-camera motion capturing system (Vicon; 200 Hz) and two 3D force plates (AMTI; 1.000 Hz). A full-body marker set (42 markers) was applied and 3D hip joint angles were calculated using an inverse kinematics approach (ALASKA Dynamicus; Härtel & Hermsdorf, 2006). Hip ROM and peak joint angles during the stance phase of straight walking or the turning step of 90° turns, forward-oriented centre of mass velocity at initial contact and toe-off as well as stance phase duration were analysed.

After verification of the prerequisites, statistical differences were assessed using a mixed-model ANOVA. Post-hoc analyses were conducted using t-tests for dependent samples with Bonferroni corrections. The level of significance was set a priori to $\alpha < 0.05$.

Results

For all analysed parameters a significant main effect for movement task ($p < 0.001$) was found. Post hoc comparisons showed that straight walking and step turn differed significantly for all parameters ($p < 0.001$). Likewise, straight walking and spin turn differed significantly in all parameters (p between < 0.001 and 0.004) except for frontal hip ROM ($p = 1.00$). A significant main effect for group was found for peak hip extension angle ($p = 0.002$), hip sagittal ROM ($p = 0.001$) and hip transverse ROM ($p < 0.001$). Significant interaction effects were found for hip peak adduction ($p < 0.001$), abduction ($p = 0.001$), internal rotation ($p = 0.046$), sagittal ROM ($P = 0.041$) and transverse ROM ($p = 0.006$).

Discussion

As hypothesized both 90° turns require larger hip external rotation, internal rotation and transverse hip ROM than straight walking. Analyses of young adults found larger external but not internal rotation (Taylor et al., 2005). This discrepancy might stem from differences in foot placement strategy adopted by different age groups. HOA subjects have a reduced transverse ROM during all analysed movements compared to healthy elderlies. Yet, the group differences in transverse ROM and peak internal rotation were largest during the step turn.

Unexpectedly, frontal hip ROM is lower (step turn) or equal (spin turn) to those during straight walking. However, peak angles are shifted towards abduction during the step turn and adduction during the spin turn. Previous studies on straight walking did not find altered frontal peak hip angles in subjects with mild to moderate HOA (Constantinou et al., 2017; Rutherford et al., 2015; Steingrebe et al., 2022) and only partly for those with severe HOA (Rutherford et al., 2015; Tateuchi et al., 2014). Likewise, no main effect of HOA on frontal plane kinematics is found in this study. But significant interaction effects for peak hip adduction and abduction show that frontal plane mobility deficits are most noticeable during the spin and step turn, respectively. Tateuchi et al. (2014) also reported reduced hip abduction during 45° step turns and reduced hip adduction during 45° spin turns. However, subjects in their study suffered from end-stage HOA. Thus, analysing 90° step and spin turns might allow evaluation of limitations in frontal hip mobility already at an earlier disease stage.

Both turning movements require lower peak angles and ROM in the sagittal plane than straight walking. Nevertheless, HOA subjects have a reduced ROM and peak extension across all movement tasks. Yet, as group differences for sagittal hip ROM are largest during straight walking, sagittal plane hip mobility is best evaluated with this task.

Conclusion

While straight walking imposes largest requirements on sagittal plane hip mobility, 90° turns overall require more transverse hip mobility and task-specific increases in frontal hip mobility. Therefore, the inclusion of 90° turns during clinical gait analysis might allow the identification of frontal and transverse hip mobility deficits at an early HOA disease stage.

Literature

[1] Baker, M., Moreside, J., Wong, I., & Rutherford, D. J. (2016). Passive hip movement measurements related to dynamic motion during gait in hip osteoarthritis. Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society, 34(10), 1790–1797. https://doi.org/10.1002/jor.23198

[2] Constantinou, M., Loureiro, A., Carty, C., Mills, P., & Barrett, R. (2017). Hip joint mechanics during walking in individuals with mild-to-moderate hip osteoarthritis. Gait & Posture, 53, 162–167. https://doi.org/10.1016/j.gaitpost.2017.01.017

[3] Glaister, B. C., Bernatz, G. C., Klute, G. K., & Orendurff, M. S. (2007). Video task analysis of turning during activities of daily living. Gait & Posture, 25(2), 289–294. https://doi.org/10.1016/j.gaitpost.2006.04.003

[4] Härtel, T., & Hermsdorf, H. (2006). Biomechanical modelling and simulation of human body by means of DYNAMICUS. Journal of Biomechanics, 39, S. 549. https://doi.org/10.1016/S0021-9290(06)85262-0

[5] Hase, K., & Stein, R. B. (1999). Turning strategies during human walking. Journal of Neurophysiology, 81(6), 2914–2922. https://doi.org/10.1152/jn.1999.81.6.2914

[6] Rutherford, D. J., Moreside, J., & Wong, I. (2015). Hip joint motion and gluteal muscle activation differences between healthy controls and those with varying degrees of hip osteoarthritis during walking. Journal of Electromyography and Kinesiology: Official Journal of the International Society of Electrophysiological Kinesiology, 25(6), 944–950. https://doi.org/10.1016/j.jelekin.2015.10.010

[7] Sedgman, R., Goldie, P., & Iansek, R. (1994). Development of a measure of turning during walking. In Advancing rehabilitation: Inaugural conference of the Faculty of Health Sciences, Melbourne, Australia.

[8] Steingrebe, H., Stetter, B. J., Sell, S., & Stein, T. (2022). Effects of Hip Bracing on Gait Biomechanics, Pain and Function in Subjects With Mild to Moderate Hip Osteoarthritis. Frontiers in Bioengineering and Biotechnology, 10, 888775. https://doi.org/10.3389/fbioe.2022.888775

[9] Tateuchi, H., Tsukagoshi, R., Fukumoto, Y., Akiyama, H., So, K., Kuroda, Y., & Ichihashi, N. (2014). Compensatory turning strategies while walking in patients with hip osteoarthritis. Gait & Posture, 39(4), 1133–1137. https://doi.org/10.1016/j.gaitpost.2014.01.021

[10] Taylor, M. J. D., Dabnichki, P., & Strike, S. C. (2005). A three-dimensional biomechanical comparison between turning strategies during the stance phase of walking. Human Movement Science, 24(4), 558–573. https://doi.org/10.1016/j.humov.2005.07.005