The impact of a hip orthosis on gait biomechanics, pain perception, hip proprioception, and the functional abilities of patients suffering from mild to moderate osteoarthritis of the hip

Steingrebe, H.[1,2], Stetter, B.[1,2], Sell, S.[2,3†], Stein, T.[1†]

BACKGROUND

Hip osteoarthritis (HOA) is a common joint condition that has serious consequences for those affected. Pain and restricted hip function have a negative impact on quality of life. In addition, research has frequently demonstrated that HOA patients exhibit changes in gait biomechanics (Constantinou et al., 2017; Diamond et al., 2018). An artificial hip joint is recommended only for HOA that has progressed significantly. Therefore, the development of effective non-surgical treatment methods is of great importance. However, very little is currently known about the effectiveness of orthoses when treating HOA. Previous studies about hip orthoses designed to provide mechanical relief to the hip joint had some positive results (Sato et al., 2008, 2012; Nérot & Nicholls, 2017). Orthosis concepts designed to provide mechanical relief to the hip joint may possibly result in restricted freedom of movement and limited wearing comfort, which reduces its suitability for patients with mild to moderate symptoms. Modern definitions of osteoarthritis emphasize that it is not exclusively a condition of the joint cartilage but that all other joint structures are also affected (Block & Shakoor, 2009). For this reason, orthosis concepts that focus on treatment, for example, of the surrounding muscles or the joint capsule, without the need for rigid design elements for mechanical relief, can have a positive effect during the treatment of HOA. Owing to the many mechanoreceptors in the joint area, an effect on proprioception is also possible.

In a comprehensive study design, the goal of this study was therefore to examine the influence of unilateral HOA and a functional hip orthosis on gait biomechanics, pain perception, hip proprioception, and the functional abilities of patients suffering from mild to moderate HOA.

STUDY DESIGN

This study is a combination of a case control study to compare patients with HOA to healthy test subjects, and an intervention study to examine the effects of the orthosis.

1) BioMotion Center, Institute of Sports and Sports Science, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
2) Sports Orthopedics, Institute of Sports and Sports Science, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
3) Joint Center Black Forest, Hospital Neuenbürg, Neuenbürg, Germany
† These authors share senior authorship

Front. Bioeng. Biotechnol. 2022

METHODOLOGY

Sample:	n= 42 (21 HOA, 21 healthy) (details see Tab. 1)
Test orthosis:	**CoxaTrain®** (Bauerfeind AG)
Inclusion criteria:	- Radiologically proven HOA (Kellgren Lawrence Score 2–4) - Functional deficits, measured using the Harris Hip Score; (65-95 of 100) - Hip pain in the last three months during everyday movements - Asymptomatic contralateral hip joint
Exclusion criteria:	- Additional damage and/or pain of a musculoskeletal and/or neurological nature in the area of the lower extremities and the torso - Secondary HOA
Objective criteria:	- Biomechanical movement analysis: spatial/temporal gait parameters, joint kinematics (joint angle), joint dynamics (joint torque) - VAS 10-point scale: pain level - Joint angle reproduction test: hip joint proprioception - 6 minute walking test (6MWT): functional abilities
Study period	1st measurement date: test without orthosis Reference period: recording pain for 7 days without orthosis 2nd measurement date: test with orthosis after a brief period of getting used to the medical aid Intervention period: recording pain for 7 days with orthosis 3rd measurement date: test with orthosis after wearing it for one week
Data analysis	Variance analysis or T-test (or non-param. alternative) with a significance level of 5%

Tab. 1. Average values (standard deviations) of test subject characteristics for the HOA group and control group (CG).

	HOA group (n=21)	Control group (n=21)
Gender	11 men, 10 women	11 men, 10 women
Age [years]	64.0 (9.6)	63.1 (9.2)
Weight [kg]	71.3 (11.9)	74.4 (12.7)
Height [cm]	171.2 (6.7)	171.1 (8.8)
Body Mass Index (BMI) [kg/m^2]	24.2 (2.9)	25.2 (2.7)
Harris Hip Score	74.6 (11.8)	98.4 (2.3)
Hip Osteoarthritis Outcome Score (HOOS)	62.0 (16.4)	97.7 (5.1)
Tegner Activity Score	4.7 (0.8)	4.9 (1.2)
Affected/examined side	11 right, 10 left	11 right, 10 left
	Stage 2 = 9	
	Stage 3 = 7	
	Stage 3/4 = 1	
	Stage 4 = 4	

RESULTS

Without the orthosis, the test subjects from the HOA group exhibited much worse performance during the 6MWT than the control group. After the one-week intervention phase, the distance covered was significantly greater than that without the orthosis or after brief orthosis use (compare Fig. 1). The orthosis had no impact on the pain level before or after being subjected to strain during the 6MWT.

The average wearing duration of the orthosis during the intervention period was 10.1 ± 3.5 hours per day. During the intervention phase, pain perception during activities involving walking as well as pain at night (walking: 18.4 ± 18.1; pain at night: 13.9 ± 15.9) were much lower than during the reference period (walking: 25.7 ± 15.3; pain at night: 17.0 ± 17.6) (Fig. 2). 18 of 21 test subjects showed a reduction in pain during activities involving walking.

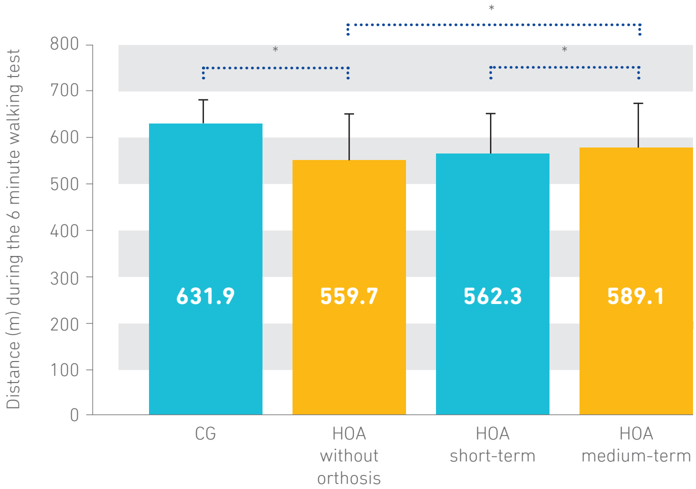

Fig. 1: Average values of distance covered [m] during the 6 minute walking test for the control group (CG) and the HOA group under different orthosis conditions.
*indicating significant differences for α<0.05.

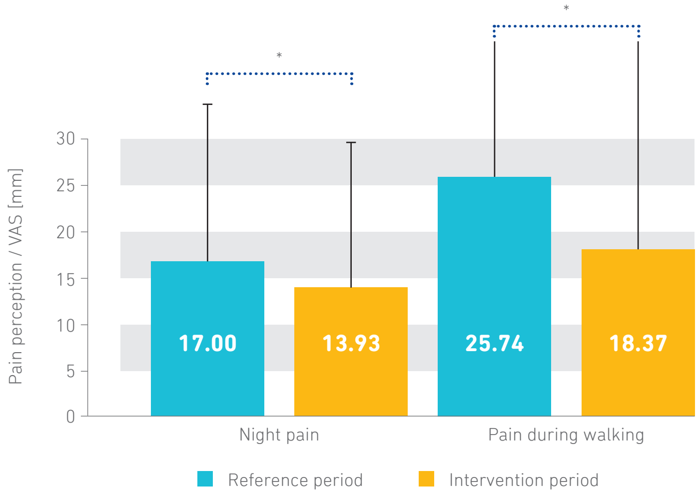

Fig. 2: Comparison of pain perception of the HOA group without a hip orthosis (reference period, 7 days) with the pain perception of the HOA group with a hip orthosis (intervention period, 7 days); 10-point visual analog scale depicted in mm, VAS 10=100 mm.
*indicating significant differences for α<0.05.

During the angle reproduction test, no significant effect of either the HOA or the orthosis could be substantiated.

During the biomechanical movement analysis, test subjects from the HOA group not wearing the orthosis exhibited a much lower walking speed and shorter step length compared with the control group. Furthermore, the movement radius in a sagittal and transverse plane as well as the maximum extension angle were reduced in the HOA group. During the analysis of joint dynamics, reduced maximum flexion, extension, adduction, and internal rotation torques were recorded. An increased movement radius of the pelvic tilt as a result of HOA was also identified.

After medium-term orthosis use, a significant increase in walking speed and step length was detected compared with patients not wearing an orthosis or when the orthosis was worn for a short time only. In the sagittal plane, short-term orthosis use resulted in a reduction in the maximum flexion angle and, under both orthosis conditions, in an increase in maximum extension torque compared with not wearing an orthosis (Fig. 3). Additionally, under both conditions when wearing the orthosis, there was a significant increase in the movement radius of the pelvic tilt as well as pelvic rotation.

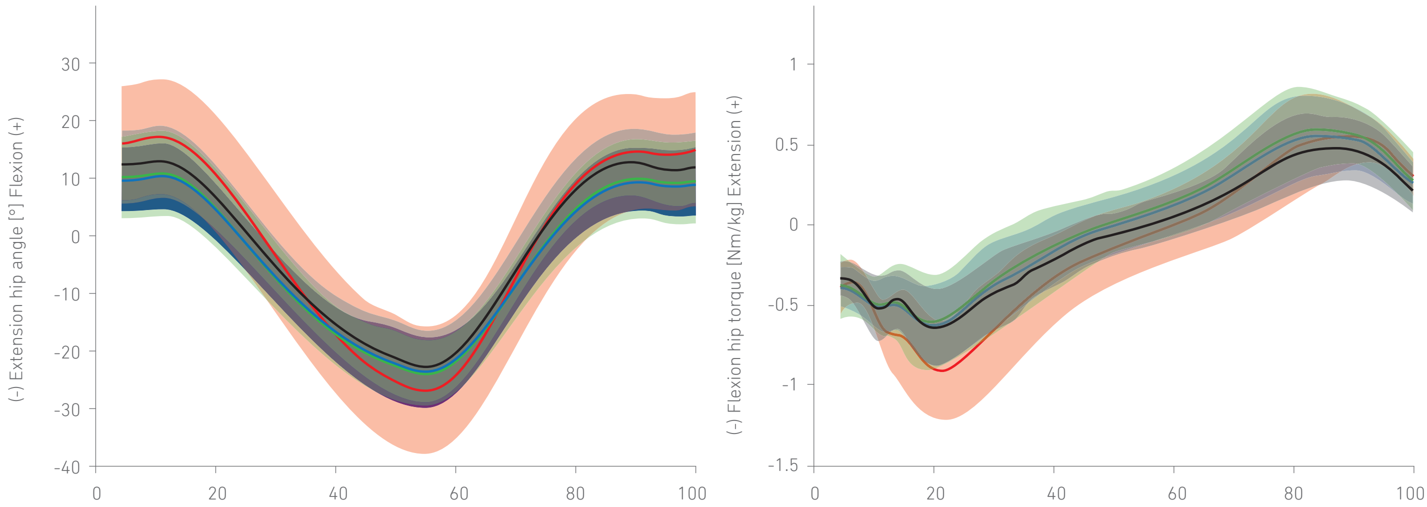

Fig. 3: Progression of time of the hip angle [°] as well as external hip torque [Nm/kg] in the sagittal plane normalized in relation to the walking cycle or a standing phase. Red = control group, black = HOA group without orthosis, blue = HOA group with short-term orthosis use, green = HOA group with medium-term orthosis use.

DISCUSSION

The sample group examined in this study exhibited, during gait analysis, typical characteristics of patients suffering from HOA, such as reduced maximum hip extension. In addition, increased pelvic movement in the sagittal plane was recorded, which is used as a compensatory mechanism for restricted hip extension function (Lee et al., 1997). Changes in gait biomechanics resulted in a decrease in walking speed and step length, which was highlighted in reduced functional abilities during the 6MWT. As opposed to studies with patients suffering from osteoarthritis of the knee (Barrett et al., 1991; Knoop et al., 2011), no impact of HOA on hip joint proprioception was substantiated.

Owing to the use of a hip orthosis, a reduction in pain perception during walking was recorded for 18 of 21 test subjects. Furthermore, an increase in walking speed and step length was observed during the biomechanical movement analysis. These changes resulted in an increase of distance covered during the 6MWT of 5% on average. Despite the increase in walking distance during the 6MWT, the level of pain remained the same after patients were subjected to strain. Similarly, a positive effect of a hip orthosis on performance in a "Timed up and go test" was corroborated, which increased with an increasing wearing duration (Sato et al., 2012). A longer-term orthosis use could potentially increase the positive effect of using an orthosis on functional abilities even more.

As opposed to results from using knee supports (Beynnon et al., 2002; Baltaci et al., 2011), using hip orthoses had no influence on hip joint proprioception. While this complies with the result that no deterioration in proprioception caused by HOA was recorded, it contradicts results relating to the knee joint. Baltic et al. (2011) substantiated positive effects of a knee support on proprioception in young, healthy test subjects. The angle reproduction test while standing upright demands, in addition to perceiving the joint angle position, a high degree of motor control from the test subjects, which may mask changes in proprioception. Other methods for recording hip proprioception may therefore be needed to identify minor changes in hip proprioception.

Generally, the use of an orthosis did not lead to a "normalization" of the gait because typical movement characteristics (e.g. reduced maximum hip extension and decreased movement radius in the sagittal plane) remained even after one week of wearing the orthosis. Similar results are known from studies about total endoprostheses, which demonstrate changed gait biomechanics after up to two years following surgery (Beaulieu et al., 2010; Foucher et al., 2007; Zügner et al., 2018). Reasons for this could include learned movement patterns to avoid pain which persisted after the end of treatment. Existing muscle weaknesses could also be the cause for changes in gait. A wearing duration of only one week may not be enough for a normalization of the gait patterns. Therefore, long-term effects should be examined in future studies.

Conversely, the use of the orthosis triggered additional changes in gait biomechanics. On the one hand, wearing an orthosis resulted in a direct reduction in the maximum hip flexion angle, which may be caused by the orthosis' passive resistance. On the other hand, changes in movements of the pelvis were recorded which was increasingly tilted and rotated during walking. Both movements allow an increase in step length despite limited extension and internal rotation capabilities of the hip joint (Leigh et al., 2016). Owing to the close connection of the pelvis and the lumbar spine (Thurston & Harris, 1983; Whittle & Levine, 1999; Ike et al., 2018), it is likely that changes in pelvis kinematics have an impact on lumbar spine mobility (Hurwitz et al., 1997; Watelain et al., 2001). Particularly the long-term effects of orthosis use on the lumbar/pelvic region should therefore be examined in more detail.

To sum up, a positive effect of orthosis use on pain perception and the functional abilities of patients suffering from mild to moderate unilateral HOA was substantiated. The effects usually did not occur immediately but after wearing the orthosis for a week. The underlying mechanisms, however, remain partly unclear because, even after wearing an orthosis, typical changes in gait persisted in patients suffering from HOA. Analyses of whole-body movement, muscle activity, and recording of data after long-term orthosis use could supply additional insight in the future.

CONCLUSIONS

- CoxaTrain® reduces pain at night
- CoxaTrain® reduces pain during walking
- CoxaTrain® improves mobility

REFERENCES

Baltaci, G., Aktas, G., Camci, E., Oksuz, S., Yildiz, S., and Kalaycioglu, T. (2011). The effect of prophylactic knee bracing on performance: Balance, proprioception, coordination, and muscular power. Knee Surg Sports Traumatol Arthrosc 19, 1722–1728. doi: 10.1007/s00167-011-1491-3

Barrett, D. S., Cobb, A. G., and Bentley, G. (1991). Joint proprioception in normal, osteoarthritic and replaced knees. J Bone Joint Surg Br 73, 53–56. doi: 10.1302/0301-620X.73B1.1991775

Beaulieu, M. L., Lamontagne, M., and Beaulé, P. E. (2010). Lower limb biomechanics during gait do not return to normal following total hip arthroplasty. Gait Posture 32, 269–273. doi: 10.1016/j.gaitpost.2010.05.007

Beynnon, B. D., Good, L., and Risberg, M. A. (2002). The effect of bracing on proprioception of knees with anterior cruciate ligament injury. J Orthop Sports Phys Ther 32, 11–15. doi: 10.2519/jospt.2002.32.1.11

Block, J. A., and Shakoor, N. (2009). The biomechanics of osteoarthritis: Implications for therapy. Curr Rheumatol Rep 11, 15–22.

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

Diamond, L. E., Allison, K., Dobson, F., and Hall, M. (2018). Hip joint moments during walking in people with hip osteoarthritis: A systematic review and meta-analysis. Osteoarthritis Cartilage. doi: 10.1016/j.joca.2018.03.011

Foucher, K. C., Hurwitz, D. E., and Wimmer, M. A. (2007). Preoperative gait adaptations persist one year after surgery in clinically well-functioning total hip replacement patients. J Biomech 40, 3432–3437. doi: 10.1016/j.jbiomech.2007.05.020

Hurwitz, D. E., Hulet, C. H., Andriacchi, T. P., Rosenberg, A. G., and Galante, J. O. (1997). Gait compensations in patients with osteoarthritis of the hip and their relationship to pain and passive hip motion. J Orthop Res 15, 629–635. doi: 10.1002/jor.1100150421

Ike, H., Dorr, L. D., Trasolini, N., Stefl, M., McKnight, B., and Heckmann, N. (2018). Spine-Pelvis-Hip Relationship in the Functioning of a Total Hip Replacement. J Bone Joint Surg Am 100, 1606–1615. doi: 10.2106/JBJS.17.00403

Knoop, J., Steultjens, M. P. M., van der Leeden, M., van der Esch, M., Thorstensson, C. A., Roorda, L. D., et al. (2011). Proprioception in knee osteoarthritis: a narrative review. Osteoarthritis Cartilage 19, 381–388. doi: 10.1016/j.joca.2011.01.003

Lee, L. W., Kerrigan, D. C., and Della Croce, U. (1997). Dynamic implications of hip flexion contractures. Am J Phys Med Rehabil 76, 502–508. doi: 10.1097/00002060-199711000-00013

Leigh, R. J., Osis, S. T., and Ferber, R. (2016). Kinematic gait patterns and their relationship to pain in mild-to-moderate hip osteoarthritis. Clin Biomech (Bristol, Avon) 34, 12–17. doi: 10.1016/j.clinbiomech.2015.12.010

Nérot, A., and Nicholls, M. (2017). Clinical study on the unloading effect of hip bracing on gait in patients with hip osteoarthritis. Prosthet Orthot Int 41, 127–133. doi: 10.1177/0309364616640873

Sato, E., Sato, T., Yamaji, T., and Watanabe, H. (2012). Effect of the WISH-type hip brace on functional mobility in patients with osteoarthritis of the hip: Evaluation using the Timed Up & Go Test. Prosthet Orthot Int 36, 25–32. doi: 10.1177/0309364611427765

Sato, T., Yamaji, T., Inose, H., Sekino, Y., Uchida, S., Usuda, S., et al. (2008). Effect of a modified S-form hip brace, WISH type, for patients with painful osteoarthritis of the hip: a role in daily walking as a hip muscle exercise. Rheumatol Int 28, 419–428. doi: 10.1007/s00296-007-0455-x

Thurston, A. J., and Harris, J. D. (1983). Normal kinematics of the lumbar spine and pelvis. Spine 8, 199–205. doi: 10.1097/00007632-198303000-00012

Watelain, E., Dujardin, F., Babier, F., Dubois, D., and Allard, P. (2001). Pelvic and lower limb compensatory actions of subjects in an early stage of hip osteoarthritis. Arch Phys Med Rehabil 82, 1705–1711. doi: 10.1053/apmr.2001.26812

Whittle, M. W., and Levine, D. (1999). Three-dimensional relationships between the movements of the pelvis and lumbar spine during normal gait. Human Movement Science 18, 681–692. doi: 10.1016/S0167-9457(99)00032-9

Zügner, R., Tranberg, R., Lisovskaja, V., and Kärrholm, J. (2018). Different reliability of instrumented gait analysis between patients with unilateral hip osteoarthritis, unilateral hip prosthesis and healthy controls. BMC Musculoskelet Disord 19, 224. doi: 10.1186/s12891-018-2145-0