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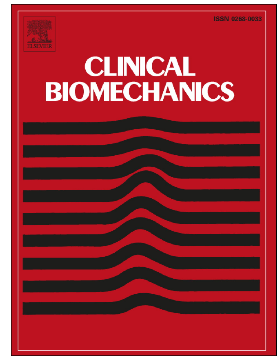

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Mild-to-moderate hip osteoarthritis and hip bracing influence hip and knee biomechanics during 90° turns while walking

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Abstract

Background Turning movements are frequently encountered during daily life and require more frontal and transverse hip mobility than straight walking. Thus, analysis of turning might be an insightful addition in the evaluation of conservative treatment approaches for hip osteoarthritis patients. The study objective was to quantify the effects of mild-to-moderate symptomatic hip osteoarthritis on lower-body turning biomechanics and evaluate the effects of hip bracing in this cohort.

Methods Biomechanical analysis of 90° step and spin turns in 21 persons with hip osteoarthritis and 21 healthy controls (case-control-study) and intervention study on the effects of hip bracing in hip osteoarthritis participants. Hip and knee kinematics and dynamics were compared using independent sample t-tests or one-way repeated measure ANOVAs.

Findings Persons with hip osteoarthritis have reduced peak hip extension and sagittal and transverse hip range of motion during turning. During the spin turn reduced hip adduction and frontal hip range of motion were found. Bracing increased the movement velocity at turn initiation and limited the transverse hip range of motion during both turns but increased knee peak adduction and internal rotation moments during spin turns.

Interpretation Persons with hip osteoarthritis present altered hip kinematics during 90° spin turns in all movement planes. Their inclusion during clinical movement analysis might facilitate the detection of mobility deficits at an early disease stage. Bracing led to higher movement velocity at turn initiation without increasing load at the hip joint and reduced transverse hip range of motion, avoiding the painful reaching of range of motion endpoints.

1 Introduction

Persons with hip osteoarthritis (HOA) suffer from pain and loss of function leading to a decrease in quality of life [1]. Studies have shown that half of persons with HOA undergo hip replacement surgery within 2.5 years after initial consultation [2], and hip replacement rates increased by 22% between 2009 and 2019 [3]. If this trend continues, the economic burden might become unsustainable [4]. Therefore, there is an urgent need for effective conservative treatment strategies to reduce pain and enhance quality of life to avoid or postpone hip surgery. One conservative treatment option is the use of braces which has been found to decrease hip pain and improve function [5-7]. Thereby, increased overall Harris Hip Scores (HHS) of 21.6 points or 37% [5] and reduced time taken for the Timed Up and Go test (TUG) [6] were reported after one month of using the rigid WISH-type hip brace. Reduced pain during walking and reduced night pain by about 28% and 18%, respectively, and a 5% increase in the distance covered during the 6-minute walking test were found after one week of using the elastic CoxaTrain hip brace. Additionally, biomechanical analyses of straight walking showed a significant increase in gait speed and step length [7]. However, the underlying mechanisms of these benefits remain unclear. Analysis of straight walking has shown the effects of bracing on pelvic tilt and pelvic rotation range of motion (RoM) but no effects on hip joint loading or frontal or transverse hip kinematics were found [7]. However, loading and joint mobility requirements in the frontal and transverse planes might be larger during other movements of daily living such as turning. Turning movements are encountered frequently during activities of daily living [8, 9] and are a risk factor associated with falls [10]. Turning can be conducted either in a spin or step turn manner [11]: compared to straight walking, the step turn requires larger hip external rotation around terminal stance and abduction throughout the stance phase, and the spin turn requires larger hip external rotation throughout the stance phase and adduction around mid stance[12]. People with HOA have demonstrated decreased peak hip abduction and adduction during 45° turns [13]. The turning angle has been found to impact lower body joint moments in the frontal and transverse planes [14] and previous research has shown that the majority of turns are between 76° and 120° [15]. Therefore, analysing turns in this angle range is more relevant for activities of daily living. Additionally, in previous studies analyses of transverse plane biomechanics are lacking.

Therefore, the first aim of this study was to quantify the effect of unilateral mild-to-moderate HOA on 3D hip and knee biomechanics during 90° turns while walking. We hypothesized that persons with HOA would demonstrate reduced hip adduction during a spin turn, reduced hip abduction during a step turn and reduced peak hip extension during both turning tasks. The second aim was to identify changes in turning biomechanics imposed by short- and medium-term application of a hip brace in a cohort of persons with mild-to-moderate unilateral HOA. We expected bracing to modify hip biomechanics, especially in the frontal and transverse planes during both turning conditions.

2 Methods

2.1 Participants

The study was conducted in a cohort of 21 persons with mild-to-moderate unilateral primary HOA (10 females; age: 64.0 ± 9.6 years; BMI 24.2 ± 2.9) and 21 healthy control participants (10 females; age: 63.1 ± 9.2 years; BMI 25.2 ± 2.7) matched to the mean age, weight and height of the HOA group. HOA was defined radiologically and functionally: Participants from the HOA group had an ipsilateral Kellgren-Lawrence (K-L) grade of two or above on a standing anterior-posterior X-ray, evaluated by the same experienced orthopaedist, and showed mild to moderately decreased hip function based on an HHS between 65 and 95. Detailed inclusion and exclusion criteria can be found elsewhere [7]. The study protocol was approved by the ethical committee of the Karlsruhe Institute of Technology and conforms to the Declaration of Helsinki. All participants gave their written informed consent before study participation.

2.2 Testing protocol

All measurements were recorded from April 2019 until March 2021 at the same laboratory. HOA participants presented at the lab on three occasions: in the first session baseline measurements without bracing were conducted, in the second session participants were individually fitted with a hip brace (fig. 1; Coxatrain®, Bauerfeind AG, Zeulenroda-Triebes, Germany) and tested after a few minutes of brace familiarization (short-term brace effects). The third session was conducted after one week of brace wear (> 4 hours per day) during everyday activities (medium-term brace effects). Participants of the control (CON) group were tested on one occasion without bracing. The testing protocol was equal in all sessions: participants performed pre-planned 90° step and spin turns (fig. 2) while walking at a self-selected speed. Approach speed was controlled using light barriers and kept constant (within ± 5% of the first trial) across trials of the same turning condition within the same session. For each turning condition, five valid trials were recorded. Participants were allowed to initiate the turn within a marked corridor of 50 cm and instructed to perform the turn in an abrupt manner. Turning was always conducted with the affected limb for the HOA participants and a matched limb for the control participants.

2.3 Hip brace

The hip brace (fig. 1) applied in this study consists of an elastic pelvis and thigh belt connected by a rigid hinge joint with one degree of freedom (flexion/extension). The brace intends to stabilize the pelvis and stimulate trigger points around the gluteus medius and the sacroiliac joints using viscoelastic pads within the bandage. Additionally, a pad positioned above the greater trochanter moves vertically with extension/flexion of the brace joint and applies a friction massage to the muscle insertions at the greater trochanter.

2.4 Motion analysis

To assess hip and knee biomechanics, 3D motion analysis was conducted using a 16-camera infrared motion capturing system (200 Hz, Vicon Motion Systems, Oxford Metrics Group, Oxford, United Kingdom) and two 3D force plates (1000 Hz, BP600900, Advanced Mechanical Technology Inc., Watertown, MA, United States). A full-body marker set with 42 retroreflective markers was used, and markers were applied by the same experienced researcher for all participants [16]. Kinematic and GRF data were filtered using a 4th-order Butterworth low-pass filter with a cut-off frequency of 15 Hz. An inverse kinematics and dynamics approach using the multi-body model ALASKA Dynamicus [16], including the hip joint centre definition proposed by Harrington et al. [17, 18], was used to calculate 3D joint angles and external joint moments. Peak joint angles and RoM, as well as peak external joint moments of the hip and knee during the stance phase of turning, were assessed. Additionally, the foot-progression angle (FPA) at foot flat (positive values indicate outward rotation of the foot relative to the approach axis; fig.2), the forward-directed centre of mass (CoM) velocity at initial contact and toe-off and stance phase duration were assessed.

2.5 Statistical analysis

The sample size was calculated a priori based on the study of Nérot and Nicholls [19] on the effects of bracing on hip joint kinematics during straight walking in 14 participants with unilateral HOA using G*Power (version 3.1.9.3) [20]. The observed effect sizes in their study were 0.92 and 1.17 for peak hip adduction and internal rotation, respectively. With a significance criterion of $\alpha = 0.05$ and power = 0.95, the minimum sample size required was 18 and 12, respectively.

All statistical analyses were performed in R (version 4.2.2). Normal distribution and homogeneity of variance were assessed using the Shapiro-Wilk and Levene tests, respectively. Differences between the HOA and CON groups at baseline were analysed using independent sample t-tests. To assess the impact of HOA severity, parameters with significant group differences were subsequently correlated with the HHS within the HOA group using Spearman's rank correlation. Brace effects within the HOA group were assessed using univariate ANOVAs for repeated measures. If sphericity was violated, Greenhouse-Geisser estimates were used. Post-hoc analysis was conducted using t-tests for dependent samples with Holm-Bonferroni corrections. If the conditions for parametric testing were not fulfilled, nonparametric tests (Mann-Whitney-U, Friedman or Wilcoxon) were used. The level of significance was set a priori to $\alpha < 0.05$. Cohen's d [21] and partial eta squared were used to calculate effect sizes for between-group and within-group comparisons, respectively.

3 Results

Hip and knee joint angle time curves for the spin and step turn can be found in the Supplementary material (fig. S1-S4).

3.1 Effects of hip osteoarthritis on hip and knee biomechanics

All results on the comparison of hip and knee biomechanics during the step and spin turn between the HOA group at baseline and the CON group are presented in Tables 1 and 2, respectively. During the step turn, HOA participants demonstrated reduced peak hip extension (Mean difference (MD) = -4.82°; $p = 0.01$; $|d| = 0.84$) and decreased sagittal (MD = 6.27°; $p = 0.005$; $|d| = 0.91$) and transverse (MD = 9.96°; $p < 0.001$; $|d| = 1.43$) hip RoM. For the knee joint, increased peak flexion (MD = -3.70°; $p = 0.02$; $|d| = 0.78$) was found.

During the spin turn, reduced peak hip extension (MD = -4.64°; $p = 0.01$; $|d| = 0.84$) and adduction (MD = -1.99°; $p = 0.02$; $|d| = 0.75$), as well as reduced hip RoM in all movement planes (sagittal: MD = 5.10°; $p = 0.008$; $|d| = 0.86$; frontal: MD = 1.76°; $p = 0.03$; $|d| = 0.71$; transverse: MD = 6.01°; $p = 0.03$; $|d| = 0.70$), were found in the HOA group. No differences in knee biomechanics were observed.

All results from the correlation analyses assessing the impact of HOA severity on turning biomechanics can be found in the Supplementary material (Table S1 and S2). Of the analysed parameters, the transverse hip RoM during the step turn showed a moderate positive correlation with the HHS ($\rho = 0.36$; $p = 0.112$) while the peak hip extension angle during the spin turn showed a negative moderate correlation with the HHS ($\rho = -0.36$; $p = 0.106$). This means that larger hip transverse RoM during the step turn and larger hip extension angles during the spin turn are associated with better hip function based on the HHS.

3.3 Effects of hip bracing on hip and knee biomechanics

Results from the comparison of the HOA group under varying bracing conditions during the step and spin turn are presented in Tables 3 and 4, respectively.

For the step turn, forward-directed CoM velocity at initial contact was higher in both braced conditions compared to the baseline condition (short-term: MD = -0.07 m/s; $p = 0.013$; medium-term: MD = -0.13 m/s; $p = 0.004$) and also after medium-term bracing compared to short-term bracing (MD = -0.05 m/s; $p = 0.005$).

The FPA at foot-flat was less inwardly rotated with short-term bracing compared to the baseline condition (MD = -7.96°; $p = 0.03$). Compared to baseline, peak hip flexion decreased with short-term bracing (MD = 2.66°; $p = 0.046$); peak hip internal rotation decreased with medium-term bracing (MD = -5.44°; $p = 0.024$); and hip transverse RoM decreased in both braced conditions (short-term: MD = 3.89°; $p < 0.001$; medium-term: MD = 4.00°; $p < 0.001$). No effects of bracing on knee biomechanics during the 90° step turn were found.

For the spin turn, forward-directed CoM velocity at initial contact was higher in both braced conditions compared to the baseline condition (short-term: MD = -0.10 m/s; $p = 0.006$; medium-term: MD = -0.14 m/s; $p = 0.001$) and also after medium-term bracing compared to short-term bracing (MD = -0.04 m/s; $p = 0.046$). The FPA at foot-flat was less outwardly rotated with short-term bracing compared to the baseline condition (MD = 7.21°; $p = 0.009$). For the hip joint, decreased transverse RoM was found in both braced conditions compared to baseline (short-term: MD = 2.94°; $p = 0.014$; medium-term: MD = 2.90°; $p = 0.025$). For the knee joint, compared to baseline the peak knee adduction moment increased with short-term bracing (MD = -0.75 Nm/kg; $p = 0.015$), and peak internal rotation moment increased in both braced conditions (short-term: MD = -0.42 Nm/kg; $p = 0.021$; medium-term: MD = -0.43 Nm/kg; $p = 0.025$).

4 Discussion

4.1 Effects of hip osteoarthritis on hip and knee biomechanics

The first aim of this study was to quantify the effect of mild-to-moderate HOA on hip and knee biomechanics during 90° turns while walking. As hypothesized, HOA participants demonstrated reduced peak hip extension and reduced sagittal and transverse hip RoM in both turning conditions as well as reduced peak hip adduction resulting in a decreased frontal hip RoM during the spin turn. Additionally, increased knee flexion was found during the step turn in the HOA group compared to the CON group. Subsequent analyses showed that larger transverse hip ROM during the step turn and larger peak hip extension during the spin turn were moderately correlated with better hip function based on the HHS in persons with HOA.

The limitations observed in sagittal and transverse hip kinematics during turning are in line with those occurring during straight walking [7, 22-28] in persons with mild-to-moderate HOA. Thereby, the limitations in sagittal and transverse hip RoM mainly stem from reduced hip extension and internal rotation angles. Spin and step turning has been found to require substantially larger internal and external rotation at the knee joint [29] as well as larger external rotation angles at the hip joint [12] than straight walking. Compared to data from straight walking in the same cohort [7], we observed larger peak hip internal rotation angles during both turning conditions as well as larger hip external rotation during the spin turn. Thus, limitations in transverse plane hip mobility due to HOA are more likely to impose difficulties during 90° turning than during straight walking which was also shown by the correlation between hip function and transverse hip RoM during the step turn. Likewise, reduced hip adduction during the spin turn is in line with data from 45° turns in persons with severe HOA [13]; but was not present during straight walking in persons with mild-to-moderate HOA [27]. In contrast to our expectations, we did not find reduced peak hip abduction during the step turn. However, in the study of Tateuchi et al. [13], participants suffered from end-stage HOA so alterations in hip abduction angle during the step turn might depend on HOA severity. Therefore, including 90° spin and step turns in clinical gait analysis might be helpful to identify limitations in frontal and transverse plane hip mobility that might not be apparent in straight walking, and the hip transverse ROM could potentially differentiate between various degrees of HOA.

The increase in knee flexion during the step turn contradicts the results from 45° spin turns as well as straight walking [13] where a reduction of peak knee flexion was described. Increasing knee flexion might allow people to lower the CoM and thereby increase CoM stability during turning, at the cost of higher muscular demands for the quadriceps muscle. Furthermore, flexion of the knee joint allows greater knee external rotation due to the relaxation of the joint capsule and collateral ligaments [30]. Thus, flexion of the knee joint might be a mechanism to compensate for a lack of hip external rotation which is needed in more pronounced turning of 90° compared to 45° turns. Furthermore, in contrast to Tateuchi et al. [13], no differences in joint dynamics were found between the HOA and CON groups. However, as stated previously, the population in their study consisted of patients with severe HOA, which may have affected gait dynamics as these have been found to depend on HOA severity [31]. Thus, alterations in joint dynamics might not be present in people with mild-to-moderate HOA.

4.2 Effects of hip bracing on hip and knee biomechanics

The second aim of this study was to quantify the short- and medium-term effects of hip bracing on hip and knee biomechanics during 90° turns while walking. The main findings are that bracing led to an increase in initial movement velocity as well as a short-term adjustment of foot placement strategy in both turning conditions. In line with our hypothesis, transverse hip RoM was reduced in both braced conditions and during both turning movements. In contrast to our expectations, no differences in frontal hip biomechanics were found. However, hip bracing led to increases in knee adduction and internal rotation moments during the spin turn.

Increasing movement velocity at turn initiation could be interpreted as an increase in movement confidence, possibly explained by decreased pain during movement. Yet, as randomization of bracing conditions was not possible it might also result from habituation with the movement task.

Sato et al. [6] observed increased TUG velocity with unilateral bracing, but only if turning was conducted with the unbraced leg inside. This suggests that the increase in velocity stemmed from alterations in the turning movement and not during rising, walking or sitting down. It was speculated that the beneficial effect of bracing is more pronounced when the hip joint is abducted and externally rotated. In contrast to these findings, an increase in initial CoM velocity was present in both turning conditions in our study. However, the TUG requires a 180° change in direction which is likely executed with more than one step, and thus not directly comparable to the 90° turns conducted in our study. Additionally, it has to be noted that the increase in movement initiation velocity did not reduce stance phase duration. Higher movement velocities are linked to higher ground reaction forces, and subsequently higher joint moments [32, 33]. However, despite an increased CoM velocity at turn initiation, no changes in hip moments were found in either turning condition. During the step turn, greater knee adduction and internal rotation moments were observed, which might indicate additional loading to be compensated at the knee rather than the hip joint.

The passive resistance of the brace might explain the decrease in peak hip flexion during the step turn and reduction of the inward and outward rotation of the foot during the step and spin turns, respectively. Yet, all of these changes diminish after medium-term brace application due to habituation.

Data from the CON group show that larger hip internal rotation is needed during the step compared to the spin turn. However, similar peak hip internal rotation angles are found during both turning conditions in the HOA group. Thus, both turning conditions might require the entire available functional transverse hip RoM of the HOA participants. After medium-term bracing, decreased hip internal rotation during the step turn was observed. Thus, bracing might prevent RoM endpoints from being reached which might be associated with hip pain [34, 35]. Similar results have previously been found by Nérot and Nicholls [19] during walking. However, the brace in their study aimed to alter hip biomechanics by mechanically induced abduction and outward rotation of the femur, which is not the case for the brace applied in the current study, which aims to manipulate soft tissue around the hip joint and pelvis.

4.3 Limitations

We acknowledge several limitations in this study. First, during our study, the starting position of the participants in the lab was manipulated to provoke either a spin or a step turn on the force plate. Thus, no data exists on the self-selected turning strategy. In our subjective perception during data capture, participants tended to alter step length to complete the turn in a step-turn manner. Yet, this is speculative at best. Glaister et al. [8] stated that turning in most activities of daily living happens in a step-turn manner, and likewise, data from Dixon et al. [36] suggest that pre-planned turns on flat surfaces are mainly conducted in this manner. In contrast, Akram et al. [37] reported a high number of spin turns in healthy older adults. As no data exist on the preferred turning strategies in people with HOA, the turning preferences in this population are unknown. To estimate the impact of brace-induced modifications in step and spin turn biomechanics, the relevance of these movements for the daily loading profile of persons with HOA has to be clarified in the future. However, from a diagnostic perspective, spin turning in our study required more pronounced hip adduction and external rotation as well as larger transverse RoM of the hip and knee joints and can, therefore, serve as a valuable addition to straight walking in clinical gait analysis.

Secondly, interpretation of transverse plane hip and knee biomechanics should always happen with caution because multi-body modelling is prone to errors in this movement plane. Observed knee transverse angles in the present study are shifted towards external rotation compared to the literature. This offset is caused by differences in the definition of the tibia neutral position. Consequently, when comparing our data to other studies, individual model definitions should be considered. However, transverse plane joint movements are of high significance for executing rotational movements such as turning while walking and should therefore not be disregarded. Furthermore, the error is systematic and should not impact group comparison. The observed group differences in the transverse plane hip angle ranged between 6 and 10° and thus should not be dismissed.

5 Conclusion

While limitations in hip mobility have already been investigated during 45° turns in persons with end-stage HOA [13], the biomechanics during potentially more relevant [15] 90° turns, in persons with mild-to-moderate HOA, were unknown. In the present study, this population demonstrated limited hip mobility in all three movement planes during 90° spin turns. While partly not apparent during straight walking, mobility limitations of hip internal and external rotation, as well as hip adduction, become especially apparent during this movement task. Therefore, the inclusion of 90° spin turns in the portfolio of clinical movement analysis might allow a more comprehensive understanding of movement limitations at an earlier stage of HOA, and thus improve planning and evaluation of conservative treatment options. Hip bracing, as one conservative treatment option, led to higher movement velocity at turn initiation and reduced transverse hip RoM during 90° turns. While no increase in hip joint moments was observed, increases in knee joint loading warrant further investigation to avoid overloading of adjacent joints. Additionally, future studies should assess the rate of occurrence of 90° turns in the everyday life of persons with HOA as well as their elected coping strategy (spin vs. step turn) to further clarify the ecologic validity of this movement task.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of funding and role of funding source

Bauerfeind AG provided financial and material support for this study. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests

Stefan Sell reports a relationship with Bauerfeind AG that includes medical advisory. Hannah Steingrebe and Thorsten Stein declare that they have no conflict of interest.

CRediT authorship contribution statement

Hannah Steingrebe: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing - Original Draft, Project administration. **Stefan Sell:** Conceptualization, Methodology, Writing - Review & Editing, Supervision, Funding acquisition. **Thorsten Stein:** Conceptualization, Methodology, Writing - Review & Editing, Supervision, Funding acquisition.

Studies involving humans or animals

The study was approved by the ethical committee of the Karlsruhe Institute of Technology. All participants gave their written informed consent before study participation.

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Figure captions

Fig. 1: CoxaTrain hip brace; ©Bauerfeind AG.

Fig. 2: Schematic representation of foot placement during 90° spin turn (left) and 90° step turn (right). Red feet represent affected limbs in HOA participants and matched limbs in healthy controls. Calculation of foot progression angle (FPA) between approach axis and longitudinal foot axis with (+) outward rotation and (-) inward rotation of the foot.

Tables

Table 1: Mean values and standard deviations (SD) of discrete hip and knee joint angle and moment parameters during the step turn for the hip osteoarthritis (HOA) group at baseline and control group (CON) with respective *P*-values as revealed by independent sample t-tests/Mann-Whitney-U tests (MWU) and effect sizes (|d|). Level of significance < 0.05; *marks a significant result; CoM = Centre of mass; IC = initial contact; TO = toe off.

		Variable	HOA Baseline	CON	Mean difference	t-test/MWU
			mean (SD)	mean (SD)	(95% CI)	*P* (|d|)
Sagittal plane	Hip joint	Minimum angle/peak extension [°]	-20.32 (5.73)	-25.13 (5.76)	-4.82 (-8.40 -1.24)	0.01* (0.84)
		Maximum angle/peak flexion [°]	8.18 (6.84)	9.64 (5.58)	1.46 (-2.44 5.35)	0.45 (0.23)
		Range of motion [°]	28.50 (8.01)	34.77 (5.58)	6.27 (1.97 10.58)	0.005* (0.91)
		Peak ext. extension moment [Nm/kg]	2.82 (2.80)	2.61 (2.74)	0.13 (-0.90 1.16)	0.75 (0.08)
		Peak ext. flexion moment [Nm/kg]	-2.77 (1.80)	-2.63 (1.48)	0.21 (-1.52 1.94)	0.80 (0.08)
	Knee joint	Minimum angle/peak extension [°]	11.05 (4.165)	8.88 (3.218)	-2.17 (-4.49 0.15)	0.07 (0.58)
		Maximum angle/peak flexion [°]	44.37 (4.74)	40.67 (4.71)	-3.70 (-6.64 -0.75)	0.02* (0.78)
		Range of motion [°]	33.32 (5.25)	31.79 (4.02)	-1.53 (-4.44 1.39)	0.30 (0.33)
		Peak ext. extension moment [Nm/kg]	-2.37 (1.59)	-2.21 (1.42)	0.17 (-0.78 1.11)	0.72 (0.11)
		Peak ext. flexion moment [Nm/kg]	0.72 (1.22)	0.75 (1.20)	0.03 (-0.72 0.79)	0.52 (0.03)
Frontal plane	Hip joint	Minimum angle/peak adduction [°]	-3.26 (2.53)	-2.61 (2.76)	0.65 (-1.00 2.30)	0.43 (0.24)
		Maximum angle/peak abduction [°]	5.47 (2.98)	6.71 (3.37)	1.24 (-0.75 3.22)	0.22 (0.39)
		Range of motion [°]	8.73 (2.39)	9.32 (2.41)	0.59 (-0.91 2.09)	0.43 (0.25)
		Peak ext. adduction moment [Nm/kg]	-1.25 (1.47)	-1.29 (1.75)	-0.04 (-1.05 0.97)	0.37 (0.03)
		Peak ext. abduction moment [Nm/kg]	3.50 (3.01)	3.89 (3.13)	0.40 (-1.52 2.31)	0.40 (0.13)
	Knee joint	Minimum angle/peak adduction [°]	-2.66 (3.66)	-3.62 (4.56)	-0.96 (-3.54 1.62)	0.86 (0.23)
		Maximum angle/peak abduction [°]	2.36 (4.18)	1.45 (4.27)	-0.92 (-3.55 1.71)	0.48 (0.22)
		Range of motion [°]	5.03 (2.51)	5.07 (2.41)	0.04 (-1.49 1.58)	0.92 (0.02)
		Peak ext. adduction moment [Nm/kg]	3.56 (3.59)	3.84 (3.77)	0.29 (-2.01 2.58)	0.58 (0.08)
		Peak ext. abduction moment [Nm/kg]	-1.81 (2.08)	-1.80 (2.18)	0.01 (-1.32 1.34)	0.71 (0.01)
Transverse plane	Hip joint	Minimum angle/peak int. rotation [°]	-13.82 (13.68)	-23.07 (16.03)	-9.26 (-18.55 0.03)	0.05 (0.62)
		Maximum angle/peak ext. rotation [°]	6.97 (11.45)	7.68 (14.33)	0.70 (-7.38 8.79)	0.86 (0.05)
		Range of motion [°]	20.79 (7.85)	30.75 (5.97)	9.96 (5.61 14.31)	<0.001* (1.43)
		Peak ext. internal rotation moment [Nm/kg]	-1.81 (0.81)	-2.21 (0.94)	-0.41 (-0.95 0.14)	0.14 (0.46)
		Peak ext. external rotation moment [Nm/kg]	0.58 (0.61)	0.46 (0.52)	-0.12 (-0.48 0.23)	0.33 (0.22)
	Knee joint	Minimum angle/peak int. rotation [°]	28.46 (11.62)	32.71 (13.69)	4.25 (-3.67 12.17)	0.28 (0.33)
		Maximum angle/peak ext. rotation [°]	42.57 (12.65)	45.49 (13.61)	2.93 (-5.27 11.12)	0.36 (0.22)
		Range of motion [°]	14.11 (3.97)	12.78 (2.87)	-1.32 (-3.49 0.84)	0.22 (0.38)
		Peak ext. internal rotation moment [Nm/kg]	0.95 (0.49)	0.76 (0.37)	0.76 (-0.46 0.08)	0.16 (0.44)
		Peak ext. external rotation moment [Nm/kg]	-1.30 (0.84)	-1.47 (0.99)	-0.18 (-0.75 0.39)	0.49 (0.19)
Temporal-spatial		Stance phase duration [s]	0.73 (0.10)	0.70 (0.08)	-0.03 (-0.08 0.02)	0.23 (0.34)
		Forward CoM velocity [m/s] at IC	0.94 (0.14)	0.97 (0.12)	0.03 (-0.05 0.11)	0.43 (0.25)
		Forward CoM velocity [m/s] at TO	0.94 (0.16)	0.98 (0.15)	0.04 (-0.06 0.14)	0.40 (0.26)
		Foot progression angle at foot-flat	-37.05 (15.88)	-34.68 (18.83)	2.37 (-8.49 13.24)	0.66 (0.14)

Table 2: Mean values and standard deviations (SD) of discrete hip and knee joint angle and moment parameters during the spin turn for the hip osteoarthritis (HOA) group at baseline and control group (CON) with respective *P*-values as revealed by independent sample t-tests/Mann-Whitney-U tests (MWU) and effect sizes (|d|). Level of significance < 0.05; *marks a significant result; CoM = Centre of mass; IC = initial contact; TO = toe off.

		Variable	HOA Baseline mean (SD)	CON mean (SD)	Mean difference (95% CI)	t-test/MWU *P* (|d|)
Sagittal plane	Hip joint	Minimum angle/peak extension [°]	-20.08 (5.82)	-24.715 (5.25)	-4.64 (-8.09 -1.18)	0.01* (0.84)
		Maximum angle/peak flexion [°]	12.49 (5.82)	12.95 (5.55)	0.46 (-3.08 4.01)	0.79 (0.08)
		Range of motion [°]	32.57 (6.49)	37.66 (5.25)	5.10 (1.42 8.78)	0.008* (0.86)
		Peak ext. extension moment [Nm/kg]	2.45 (2.46)	2.50 (2.58)	0.27 (-0.39 0.93)	0.44 (0.02)
		Peak ext. flexion moment [Nm/kg]	-2.89 (1.06)	-2.62 (1.06)	0.05 (-1.53 1.62)	0.41 (0.26)
	Knee joint	Minimum angle/peak extension [°]	11.90 (3.64)	10.06 (2.58)	-1.84 (-3.80 0.13)	0.07 (0.58)
		Maximum angle/peak flexion [°]	46.74 (5.15)	45.05 (5.24)	-1.68 (-4.92 1.56)	0.30 (0.32)
		Range of motion [°]	34.84 (4.23)	34.99 (5.99)	0.15 (-3.08 3.39)	0.92 (0.03)
		Peak ext. knee extension moment [Nm/kg]	-1.75 (1.80)	-1.80 (1.77)	-0.05 (-1.17 1.06)	0.90 (0.03)
		Peak ext. knee flexion moment [Nm/kg]	3.06 (3.35)	3.45 (3.78)	0.38 (-1.84 2.61)	0.34 (0.11)
Frontal plane	Hip joint	Minimum angle/peak adduction [°]	-9.26 (3.12)	-11.25 (2.03)	-1.99 (-3.63 -0.35)	0.02* (0.75)
		Maximum angle/peak abduction [°]	1.95 (2.38)	1.71 (2.92)	-0.23 (-1.89 1.43)	0.78 (0.09)
		Range of motion [°]	11.21 (3.00)	12.97 (1.81)	1.76 (0.21 3.30)	0.03* (0.71)
		Peak ext. adduction moment [Nm/kg]	-3.78 (3.63)	-4.28 (4.10)	-0.50 (-2.91 1.92)	0.55 (0.13)
		Peak ext. abduction moment [Nm/kg]	1.09 (1.35)	1.33 (1.62)	0.25 (-0.68 1.18)	0.82 (0.17)
	Knee joint	Minimum angle/peak adduction [°]	-2.98 (3.65)	-4.63 (5.02)	-1.65 (-4.39 1.09)	0.23 (0.38)
		Maximum angle/peak abduction [°]	2.20 (4.56)	1.17 (4.33)	-1.02 (-3.79 1.75)	0.46 (0.23)
		Range of motion [°]	5.17 (2.02)	5.80 (2.73)	0.63 (-0.87 2.13)	0.60 (0.26)

		Peak ext. adduction moment [Nm/kg]	0.69 (1.08)	1.12 (1.33)	0.43 (-0.33 1.18)	0.49 (0.35)	0.69 (1.08)	1.12 (1.33)	0.43 (-0.33 1.18)	0.49 (0.35)
		Peak ext. abduction moment [Nm/kg]					-2.63 (1.97)	-2.42 (2.08)	0.21 (-1.05 1.48)	0.50 (0.11)
Transverse plane	Hip joint	Minimum angle/peak int. rotation [°]					-13.20 (12.19)	-19.62 (13.94)	-6.42 (-14.59 1.74)	0.12 (0.49)
		Maximum angle/peak ext. rotation [°]					15.82 (11.05)	15.41 (15.01)	-0.41 (-8.63 7.81)	0.92 (0.03)
		Range of motion [°]					29.02 (8.72)	35.03 (8.45)	6.01 (0.66 11.36)	0.03* (0.70)
		Peak ext. internal rotation moment [Nm/kg]					-0.69 (0.83)	-0.71 (0.69)	-0.02 (-0.50 0.45)	0.77 (0.03)
		Peak ext. external rotation moment [Nm/kg]					1.37 (1.06)	1.74 (1.22)	0.37 (-0.34 1.08)	0.18 (0.32)
	Knee joint	Minimum angle/peak int. rotation [°]					24.49 (11.28)	29.29 (13.55)	4.80 (-2.98 12.57)	0.22 (0.38)
		Maximum angle/peak ext. rotation [°]					49.65 (13.33)	46.66 (12.13)	2.98 (-4.97 10.93)	0.45 (0.23)
		Range of motion [°]					22.17 (6.70)	20.36 (3.81)	-1.81 (-5.21 1.59)	0.29 (0.33)
		Peak ext. internal rotation moment [Nm/kg]					1.03 (0.60)	1.33 (0.71)	0.30 (-0.11 0.71)	0.08 (0.46)
		Peak ext. external rotation moment [Nm/kg]					-0.71 (0.33)	-0.71 (0.48)	0.01 (-0.25 0.26)	0.97 (0.01)
Temporal-spatial		Stance phase duration [s]					0.78 (0.14)	0.74 (0.08)	-0.04 (-0.11 0.03)	0.25 (0.36)
		Forward CoM velocity [m/s] at IC					0.92 (0.19)	0.96 (0.12)	0.04 (-0.06 0.14)	0.40 (0.26)
		Forward CoM velocity [m/s] at TO					0.93 (0.12)	0.97 (0.11)	0.04 (-0.03 0.11)	0.30 (0.32)
		Foot progression angle at foot-flat					45.26 (14.39)	50.78 (14.23)	5.51 (-3.41 14.44)	0.22 (0.39)

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Table 3: Mean values and standard deviations (SD) of discrete hip and knee joint angle and moment parameters during the step turn for the hip osteoarthritis group at baseline (B), short-term (S) and medium-term (M) brace application with respective p-values and effect sizes (η_p^2) as revealed by one-way repeated measures ANOVAs/Friedman tests. Mean differences (mean diff.) with 95% confidence intervals (95% CI) and Holm-Bonferroni corrected *P*-values for pairwise comparisons. Level of significance < 0.05; *marks a significant result; CoM = Centre of mass; IC = initial contact; TO = toe off.

		Variable	Baseline	Short-term	Medium-term	ANOVA/ Friedman	B vs. S		B vs. M		S vs. M	
			mean (SD)	mean (SD)	mean (SD)	*P* (η_p^2)	*mean diff. (95% CI)*	*P*	*mean diff. (95% CI)*	*P*	*mean diff. (95% CI)*	*P*
Sagittal plane	Hip joint	Minimum angle/peak extension [°]	-20.32 (5.73)	-21.30 (5.98)	-21.96 (5.19)	0.34 (0.05)	0.98 (-0.74 2.71)		1.64 (-0.79 4.07)		0.66 (-2.00 3.31)	
		Maximum angle/peak flexion [°]	8.18 (6.84)	5.52 (5.46)	5.95 (7.57)	0.03* (0.16)	2.66 (0.57 4.75)	0.046*	2.23 (0.00 4.47)	0.101	-0.42 (-2.58 1.73)	0.687
		Range of motion [°]	28.50 (8.01)	26.82 (7.50)	27.90 (9.02)	0.22 (0.07)	1.67 (-0.06 3.41)		0.59 (-1.77 2.96)		-1.08 (-2.87 0.71)	
		Peak ext. extension moment [Nm/kg]	2.61 (2.74)	2.80 (3.12)	3.08 (3.27)	0.17 (0.11)	-0.11 (-0.69 0.46)		-0.17 (-0.65 0.30)		-0.06 (-0.50 0.38)	
		Peak ext. flexion moment [Nm/kg]	-2.77 (1.80)	-2.65 (1.52)	-2.59 (1.77)	0.77 (0.01)	-0.19 (-0.69 0.31)		-0.47 (-0.96 0.01)		-0.28 (-0.61 0.04)	
	Knee joint	Minimum angle/peak extension [°]	11.05(4.17)	9.16 (4.13)	8.85 (4.72)	0.10 (0.12)	1.89 (0.74 3.04)		2.20 (-0.35 4.76)		0.31 (-2.07 2.70)	
		Maximum angle/peak flexion [°]	44.37 (4.74)	44.19 (4.72)	42.62 (6.76)	0.26 (0.06)	0.17 (-1.55 1.90)		1.75 (-0.78 4.27)		1.57 (-1.30 4.45)	
		Range of motion [°]	33.32 (5.25)	35.03 (5.09)	33.77 (5.86)	0.19 (0.08)	-1.71 (-3.20 -0.23)		-0.45 (-2.83 1.93)		1.26 (-0.62 3.14)	
		Peak ext. knee extension moment [Nm/kg]	-2.37 (1.59)	-1.88 (1.22)	-1.88 (1.42)	0.08 (0.26)	-0.50 (-1.24 0.25)		-0.50 (-1.16 0.16)		0.00 (-0.52 0.52)	
		Peak ext. knee flexion moment [Nm/kg]	0.72 (1.22)	1.08 (1.49)	1.44 (1.95)	0.65 (0.17)	-0.36 (-0.90 0.18)		-0.72 (-1.36 -0.08)		-0.36 (-0.74 0.02)	
Frontal plane	Hip joint	Minimum angle/peak adduction [°]	-3.26 (2.53)	-2.97 (2.86)	-3.18 (3.21)	0.80 (0.01)	-0.29 (-1.22 0.64)		-0.08 (-0.95 0.78)		0.20 (-0.81 1.22)	
		Maximum angle/peak abduction [°]	5.47 (2.98)	6.12 (2.53)	6.03 (3.58)	0.33 (0.06)	-0.65 (-1.54 0.23)		-0.55 (-1.60 0.49)		0.10 (-0.86 1.05)	
		Range of motion [°]	8.73 (2.39)	9.09 (2.92)	9.20 (3.90)	0.65 (0.02)	-0.36 (-1.35 0.63)		-0.47 (-1.68 0.74)		-0.11 (-1.21 0.99)	
		Peak ext. adduction moment [Nm/kg]	-1.25 (1.47)	-1.63 (2.04)	-1.60 (2.21)	0.72 (0.09)	0.38 (0.01 0.76)		0.35 (-0.17 0.86)		-0.04 (-0.45 0.38)	
		Peak ext. abduction moment [Nm/kg]	3.50 (3.01)	3.39 (3.18)	3.68 (3.25)	0.05 (0.06)	0.11 (-0.28 0.49)		-0.19 (-0.57 0.20)		-0.29 (-0.68 0.10)	
	Knee joint	Minimum angle/peak adduction [°]	-2.66 (3.66)	-2.53 (4.91)	-1.63 (4.11)	0.42 (0.04)	-0.14 (-1.95 1.68)		-1.03 (-2.50 0.44)		-0.89 (-2.82 1.03)	
		Maximum angle/peak abduction [°]	2.36 (4.18)	2.37 (4.39)	3.28 (4.50)	0.30 (0.05)	0.00 (-1.54 1.54)		-0.91 (-2.40 0.57)		-0.91 (-2.66 0.84)	
		Range of motion [°]	5.03 (2.51)	4.89 (2.04)	4.91 (2.20)	0.65 (0.00)	0.14 (-1.19 1.46)		0.12 (-1.07 1.31)		-0.02 (-1.25 1.22)	
		Peak ext. adduction moment [Nm/kg]	3.56 (3.59)	3.75 (3.78)	3.87 (3.88)	0.13 (0.10)	-0.19 (-0.53 0.15)		-0.32 (-0.64 0.01)		-0.13 (-0.43 0.18)	
		Peak ext. abduction moment [Nm/kg]	-1.81 (2.08)	-2.07 (2.35)	-1.95 (2.21)	0.40 (0.04)	0.26 (-0.15 0.66)		0.14 (-0.30 0.59)		-0.11 (-0.56 0.33)	
Transverse plane	Hip joint	Minimum angle/peak int. rotation [°]	-13.82 (13.68)	-10.45 (10.84)	-8.38 (10.99)	0.02* (0.18)	-3.37 (-7.41 0.67)	0.195	-5.44 (-9.28 -1.59)	0.024*	-2.07 (-5.66 1.52)	0.243
		Maximum angle/peak ext. rotation [°]	6.97 (11.45)	6.45 (10.46)	8.41 (10.84)	0.51 (0.03)	0.53 (-2.96 4.01)		-1.44 (-5.11 2.23)		-1.97 (-5.77 1.84)	
		Range of motion [°]	20.79 (7.85)	16.89 (6.65)	16.79 (7.01)	<0.001* (0.51)	3.89 (2.31 5.47)	<0.001*	4.00 (2.48 5.51)	<0.001*	0.10 (-1.26 1.46)	0.878
		Peak ext. internal rotation moment [Nm/kg]	-1.81 (0.81)	-2.02 (0.98)	-1.96 (0.92)	0.17 (0.04)	0.21 (-0.19 0.60)		0.15 (-0.22 0.53)		-0.06 (-0.28 0.17)	
		Peak ext. external rotation moment [Nm/kg]	0.58 (0.61)	0.62 (0.61)	0.66 (0.73)	0.95 (0.02)	-0.04 (-0.19 0.11)		-0.08 (-0.26 0.10)		-0.04 (-0.22 0.13)	
	Knee joint	Minimum angle/peak int. rotation [°]	28.46 (11.62)	28.27 (9.45)	29.73 (11.20)	0.79 (0.01	0.19 (-4.52 4.91)		-1.27 (-6.73 4.19)		-1.47 (-5.79 2.86)	
		Maximum angle/peak ext. rotation [°]	42.57 (12.65)	43.32 (8.82)	43.39 (11.43)	0.17 (0.00)	-0.76 (-5.87 4.35)		-0.82 (-6.71 5.07)		-0.06 (-3.96 3.83)	
		Range of motion [°]	14.11 (3.97)	15.06 (2.77)	13.66 (3.56)	0.23 (0.07	-0.95 (-2.75 0.84)		0.45 (-1.50 2.40)		1.40 (0.07 2.73)	
		Peak ext. internal rotation moment [Nm/kg]	0.95 (0.49)	0.90 (0.46)	0.81 (0.43)	0.30 (0.06)	0.05 (-0.07 0.17)		0.14 (-0.10 0.39)		0.09 (-0.11 0.29)	
		Peak ext. external rotation moment [Nm/kg]	-1.30 (0.84)	-1.49 (1.09)	-1.49 (1.13)	0.40 (0.07)	0.19 (-0.03 0.42)		0.19 (-0.08 0.46)		0.00 (-0.29 0.29)	
Temporal-spatial		Stance phase duration [s]	0.73 (0.10)	0.74 (0.12)	0.71 (0.12)	0.03* (0.06)	-0.01 (-0.03 0.02)	0.708	0.02 (-0.03 0.08)	0.222	0.03 (-0.02 0.09)	0.096
		Forward CoM velocity [m/s] at IC	0.94 (0.14)	1.01 (0.19)	1.07 (0.21)	0.003* (0.31)	-0.07 (-0.14 -0.01)	0.013*	-0.13 (-0.20 -0.05)	0.004*	-0.05 (-0.09 -0.01)	0.005*
		Forward CoM velocity [m/s] at TO	0.94 (0.16)	0.91 (0.14)	0.97 (0.14)	0.10 (0.12)	0.02 (-0.01 0.06)		-0.04 (-0.11 0.03)		-0.06 (-0.12 -0.01)	
		Foot progression angle at foot-flat	-37.05 (15.88)	-29.09 (15.22)	-31.39 (16.16)	0.04* (0.15)	-7.96 (-15.21 -0.70)	0.030*	-5.66 (-12.94 1.61)	0.119	2.29 (-2.56 7.14)	0.320

Table 4: Mean values and standard deviations (SD) of discrete hip and knee joint angle and moment parameters during the spin turn for the hip osteoarthritis group at baseline (B), short-term (S) and medium-term (M) brace application with respective p-values and effect sizes (η_p^2) as revealed by one-way repeated measures ANOVAs/Friedman tests. Mean differences (mean diff.) with 95% confidence intervals (95% CI) and Holm-Bonferroni corrected *P*-values for pairwise comparisons. Level of significance < 0.05; *marks a significant result; CoM = Centre of mass; IC = initial contact; TO = toe off.

		Variable	Baseline	Short-term	Medium-term	ANOVA/ Friedman	B vs. S		B vs. M		S vs. M	
			mean (SD)	mean (SD)	mean (SD)	$P\ (\eta_p^2)$	*mean diff. (95% CI)*	*P*	*mean diff. (95% CI)*	*P*	*mean diff. (95% CI)*	*P*
Sagittal plane	Hip joint	Minimum angle/peak extension [°]	-20.08 (5.82)	-21.87 (5.48)	-21.54 (5.15)	0.15 (0.09)	1.79 (0.05 3.53)		1.46 (-0.70 3.61)		-0.33 (-2.36 1.70)	
		Maximum angle/peak flexion [°]	12.49 (5.82)	11.00 (6.13)	11.32 (6.63)	0.28 (0.06)	1.49 (-0.32 3.30)		1.17 (-0.98 3.32)		-0.32 (-2.38 1.74)	
		Range of motion [°]	32.57 (6.49)	32.87 (7.17)	32.86 (6.47)	0.87 (0.01)	-0.30 (-1.86 1.26)		-0.29 (-1.46 0.88)		0.01 (-1.31 1.34)	
		Peak ext. extension moment [Nm/kg]	2.45 (2.46)	2.67 (2.73)	2.33 (2.49)	0.83 (0.06)	-0.26 (-0.71 0.20)		0.05 (-0.70 0.81)		0.31 (-0.28 0.90)	
		Peak ext. flexion moment [Nm/kg]	-2.89 (1.06)	-2.63 (0.76)	-2.94 (1.54)	0.54 (0.03)	-0.23 (-0.67 0.22)		0.12 (-0.30 0.54)		0.34 (-0.16 0.85)	
	Knee joint	Minimum angle/peak extension [°]	11.90 (3.64)	10.02 (2.73)	9.53 (4.49)	0.09 (0.13)	1.88 (0.59 3.17)		2.37 (-0.40 5.15)		0.49 (-1.49 2.48)	
		Maximum angle/peak flexion [°]	46.74 (5.15)	45.75 (4.94)	45.75 (6.22)	0.55 (0.02)	0.99 (-0.31 2.28)		0.99 (-1.88 3.85)		0.00 (-2.77 2.77)	
		Range of motion [°]	34.84 (4.23)	35.73 (5.35)	36.22 (6.06)	0.35 (0.05)	-0.89 (-2.25 0.47)		-1.39 (-3.89 1.12)		-0.49 (-2.60 1.61)	
		Peak ext. knee extension moment [Nm/kg]	-1.75 (1.80)	-1.89 (1.93)	-1.99 (2.23)	0.87 (0.03)	0.15 (-0.19 0.49)		0.25 (-0.41 0.90)		0.10 (-0.39 0.59)	
		Peak ext. knee flexion moment [Nm/kg]	3.06 (3.35)	3.37 (3.74)	3.19 (3.50)	0.37 (0.08)	-0.30 (-0.71 0.10)		-0.13 (-0.31 0.06)		0.17 (-0.23 0.58)	
Frontal plane	Hip joint	Minimum angle/peak adduction [°]	-9.26 (3.12)	-8.26 (3.20)	-8.94 (3.14)	0.04* (0.15)	-1.00 (-1.81 -0.19)	0.053	-0.33 (-1.11 0.45)	0.388	0.67 (-0.12 1.47)	0.186
		Maximum angle/peak abduction [°]	1.95 (2.38)	2.91 (2.84)	2.72 (3.24)	0.16 (0.09)	-0.96 (-2.01 0.09)		-0.78 (-2.04 0.48)		0.18 (-0.74 1.10)	
		Range of motion [°]	11.21 (3.00)	11.17 (3.28)	11.66 (3.97)	0.95 (0.02)	0.04 (-1.12 1.21)		-0.45 (-1.86 0.96)		-0.49 (-1.31 0.34)	
		Peak ext. adduction moment [Nm/kg]	-3.78 (3.63)	-3.72 (3.88)	-3.95 (4.01)	0.13 (0.03)	-0.06 (-0.50 0.38)		0.16 (-0.33 0.65)		0.22 (-0.08 0.53)	
		Peak ext. abduction moment [Nm/kg]	1.09 (1.35)	1.56 (1.82)	1.52 (1.89)	0.40 (0.10)	-0.47 (-1.04 0.09)		-0.44 (-1.11 0.24)		0.03 (-0.17 0.24)	
	Knee joint	Minimum angle/peak adduction [°]	-2.98 (3.65)	-3.30 (5.22)	-2.65 (4.86)	0.75 (0.01)	0.32 (-1.41 2.05)		-0.33 (-2.00 1.34)		-0.65 (-2.55 1.26)	
		Maximum angle/peak abduction [°]	2.20 (4.56)	1.56 (4.15)	2.82 (4.66)	0.47 (0.07)	0.64 (-0.89 2.17)		-0.63 (-2.07 0.81)		-1.27 (-2.79 0.26)	
		Range of motion [°]	5.17 (2.02)	4.86 (1.92)	5.47 (1.97)	0.23 (0.03)	0.32 (-1.04 1.68)		-0.30 (-1.50 0.90)		-0.62 (-1.61 0.37)	
		Peak ext. adduction moment [Nm/kg]	0.69 (1.08)	1.44 (1.71)	1.29 (1.87)	0.01* (0.20)	-0.75 (-1.30 -0.20)	0.015*	-0.60 (-1.26 0.06)	0.053	0.15 (-0.15 0.45)	0.243
		Peak ext. abduction moment [Nm/kg]	-2.63 (1.97)	-2.42 (2.37)	-2.62 (2.52)	0.23 0.02)	-0.21 (-0.80 0.39)		-0.01 (-0.68 0.66)		0.20 (-0.32 0.71)	
Transverse plane	Hip joint	Minimum angle/peak int. rotation [°]	-13.20 (12.19)	-11.92 (11.26)	-9.75 (12.06)	0.18 (0.08)	-1.28 (-5.38 2.83)		-3.44 (-7.31 0.42)		-2.17 (-5.66 1.33)	
		Maximum angle/peak ext. rotation [°]	15.82 (11.05)	14.16 (8.86)	16.37 (10.67)	0.37 (0.05)	1.66 (-1.37 4.70)		-0.55 (-4.01 2.91)		-2.21 (-5.75 1.33)	
		Range of motion [°]	29.02 (8.72)	26.08 (8.87)	26.12 (10.38)	0.01* (0.23)	2.94 (1.02 4.87)	0.014*	2.90 (0.70 5.10)	0.025*	-0.05 (-2.08 1.98)	0.962
		Peak ext. internal rotation moment [Nm/kg]	-0.69 (0.83)	-0.69 (0.75)	-0.69 (0.75)	0.54 (0.00)	0.01 (-0.18 0.19)		0.01 (-0.20 0.22)		0.00 (-0.12 0.13)	
		Peak ext. external rotation moment [Nm/kg]	1.37 (1.06)	1.67 (1.27)	1.76 (1.33)	0.08 (0.24)	-0.30 (-0.55 -0.06)		-0.40 (-0.66 -0.13)		-0.09 (-0.31 0.12)	
	Knee joint	Minimum angle/peak int. rotation [°]	24.49 (11.28)	23.28 (9.98)	25.64 (12.61)	0.59 (0.03)	1.21 (-3.30 5.73)		-1.14 (-6.46 4.17)		-2.36 (-6.68 1.97)	
		Maximum angle/peak ext. rotation [°]	46.66 (12.13)	46.02 (9.64)	46.72 (11.57)	0.95 (0.00)	0.65 (-4.70 5.99)		-0.06 (-6.22 6.10)		-0.71 (-4.85 3.43)	
		Range of motion [°]	22.17 (6.70)	22.74 (4.15	21.09 (4.60)	0.21 (0.08)	-0.56 (-2.83 1.70)		1.08 (-0.84 3.01)		1.65 (0.06 3.24)	
		Peak ext. internal rotation moment [Nm/kg]	1.03 (0.60)	1.45 (0.83)	1.47 (0.93)	0.01* (0.24)	-0.42 (-0.74 -0.10)	0.021*	-0.43 (-0.80 -0.07)	0.025*	-0.02 (-0.14 0.11)	0.919
		Peak ext. external rotation moment [Nm/kg]	-0.71 (0.33)	-0.57 (0.48)	-0.75 (0.69)	0.40 (0.05)	-0.14 (-0.38 0.09)		0.04 (-0.30 0.37)		0.18 (-0.02 0.38)	
Temporal-spatial		Stance phase duration [s]	0.78 (0.14)	0.82 (0.16)	0.77 (0.16)	0.08 (0.08)	-0.04 (-0.09 0.00)		0.01 (-0.06 0.09)		0.05 (-0.01 0.12)	
		Forward CoM velocity [m/s] at IC	0.92 (0.19)	1.02 (0.20)	1.05 (0.22)	<0.001* (0.36)	-0.10 (-0.16 -0.03)	0.006*	-0.14 (-0.22 -0.06)	0.001*	-0.04 (-0.07 0.00)	0.046*
		Forward CoM velocity [m/s] at TO	0.93 (0.12)	0.89 (0.13)	0.91 (0.15)	0.32 (0.05)	0.04 (0.00 0.08)		0.02 (-0.05 0.08)		-0.02 (-0.07 0.02)	
		Foot progression angle at foot-flat	45.26 (14.39)	38.05 (12.15)	38.47 (15.22)	0.04* (0.18)	7.21 (2.75 11.68)	0.009*	6.80 (-0.77 14.37)	0.152	-0.42 (-4.86 4.03)	0.847

Highlights

- Mild-to-moderate hip osteoarthritis alters hip kinematics during 90° turns
- Hip dynamics during turning are not affected by mild-to-moderate hip osteoarthritis
- Hip bracing increases movement velocity and reduces transverse hip range of motion
- 90° turns are useful to assess frontal and transverse hip mobility

Figure 1

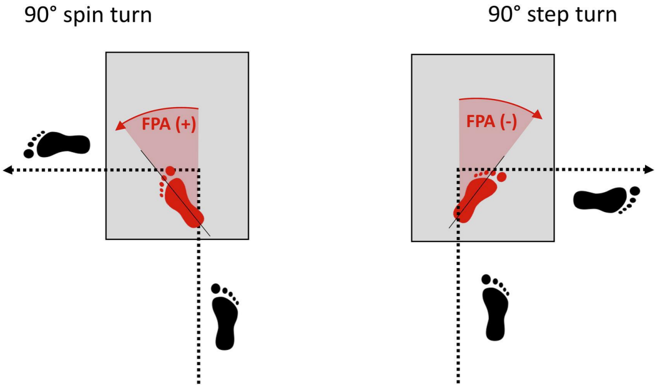

Figure 2