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Medial and lateral osteoarthritis of the knee is related to variations of hip and pelvic anatomy

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Summary

Objective: We evaluated if increased risk of combined hip and lateral knee osteoarthritis (OA) could be attributed to anatomical reasons in the hip region resulting in increased abductor moment over the knee.

Methods: We measured pelvic width, femoral offset, femoral neck length and angle in 29 women with lateral knee OA (13 unilateral, 16 bilateral) and 27 women with bilateral medial OA. Twenty-one of these patients with normal hips (lateral/medial OA of the knee = 12/9) and 35 with associated hip OA (lateral/medial OA of the knee = 17/18) were evaluated separately. Radiographic examinations in 14 women planned for hip prosthesis because of failures after hip fracture acted as controls.

Results: Patients with lateral OA of the knee had wider pelvis than controls (13.7 mm increased distance between the medial borders of the acetabulum, $P = 0.001$). Patients with medial OA had 11.4 mm longer distance from the centre of the femoral head to the centre of the proximal part of the femoral shaft ($P = 0.005$), corresponding to a higher offset.
The pelvic and hip anatomy also differed between patients with medial and lateral OA of the knee. In the groups without hip OA, presence of lateral knee OA was associated with a wider pelvis ($P = 0.009$), shorter femoral neck ($P = 0.02$) and Head-Shaft distance ($P = 0.04$). In the groups with OA of the hip associated lateral OA of the knee also implied increased Neck Shaft angle (coxa valga, $P = 0.008$), but there was no difference in pelvic width ($P = 0.15$). We found a shorter lever arm over the hip in lateral knee OA compared to medial knee OA ($P = 0.02$), but not when compared to controls.

Conclusion: Our findings suggest that occurrence of medial or lateral OA has a biomechanical background originating from pelvis and hip anatomy.

Key words: OA, Knee, Hip, Biomechanics, Radiographic measurements.

Introduction

Several factors such as overweight during adolescence, female gender and certain types of heavy work have been associated with the development of osteoarthritis (OA)[1–8]. Some authors have postulated that different risk factors are involved in the development of tibiofemoral and patellofemoral OA of the knee[9–13], but only a few tried to distinguish between the aetiology of medial and lateral OA[14,15].

Our aim was to evaluate if increased risk of combined hip and lateral knee OA could be attributed to coxa valga and reduced lever arm in the hip resulting in increased abductor moment over the knee. Increased abductor moment over the knee would imply increased compressive forces in the lateral compartment and could with time be expected to induce a valgus position of the knee and facilitate development of lateral OA. We performed measurements on conventional radiographs of the pelvis and the hip in patients with lateral or medial OA of the knee and in a control group. We measured parameters (pelvic width, femoral offset, femoral neck length and angle) which reflected the size of the skeleton and could be used to calculate a theoretical lever arm in the hip (Fig. 1)

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In a patient population operated with knee arthroplasty at Halmstad Hospital during a 10 years period, we observed that patients with bilateral disease more often had their right knee operated. We therefore evaluated if there were any side related differences of the anatomy.

Material and methods

In 546 patients operated with knee prosthesis replacement at the Halmstad hospital during the period 1985–1994, the case records and the reports from the radiologist were used to collect information about operated side or sequence of operations (left/right) and presence of unilateral/bilateral and medial/lateral OA. Presence of OA was defined as joint space narrowing exceeding 50% (Ahlbäck Grade I[16] or higher, Ahlbäck 1968). Bilateral OA was defined as presence of at least Grade I OA on both sides.

To become included in this study reports from the radiologist should clearly state presence or not of Grade I OA or more on both sides. If not, complete radiographic examinations of both knees should be available for review.

Information was incomplete in 47 cases and 35 (23 men, 12 women) did not fulfil the inclusion criteria because the joint space narrowing turned out to be less than 50% (Ahlbäck Grade 0). Thirteen patients (5 men and 8 women) had medial OA on one side and lateral OA on the other one leaving

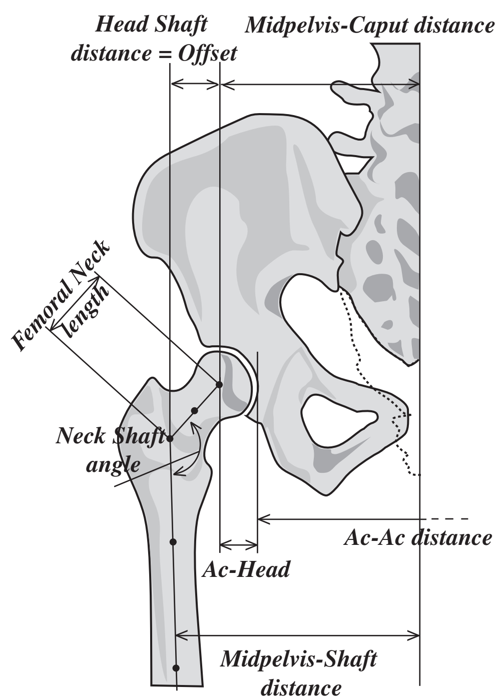


Fig. 1. Reconstruction of angles and distances reconstructed in the pelvic and hip regions.

451 patients to be studied. Lateral OA on both sides was only found in women. Therefore, not to be biased by anatomical gender differences, we restricted our study to female gender ($n = 242$).

THE STUDY GROUPS

There were 25 women with *lateral OA* (11 unilateral, 14 bilateral). Further 14 consecutive women operated during 1995–2000 with lateral OA (6 unilateral and 8 bilateral) were included to increase the number of observations.

Pelvic views were available in 29 of these 39 patients resulting in 12 cases without and 17 with simultaneous hip and knee OA to be studied (Table I).

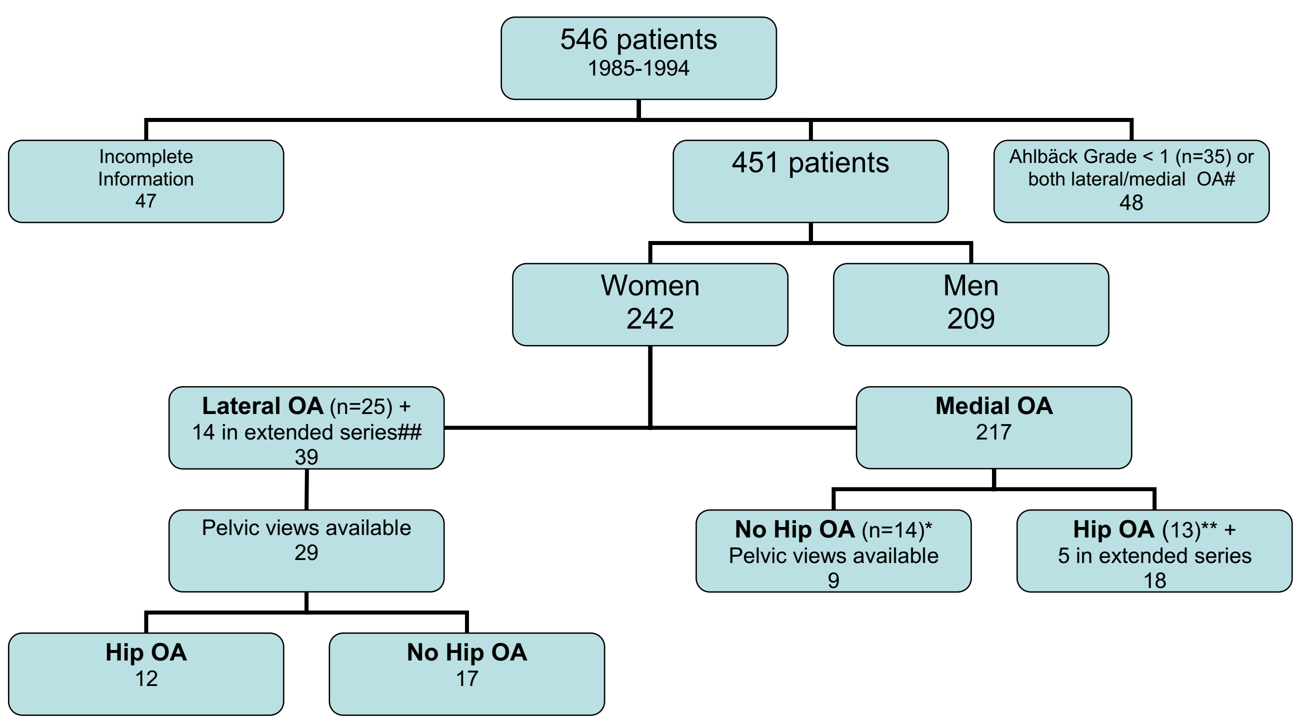
Nine of 14 women with *medial OA* age-matched with the bilateral cases in the series with lateral OA accepted to undergo a radiographic investigation of the pelvis. In the primary material we identified further 13 women with medial OA, who also had been operated because of OA of the hip. Further five consecutive patients with hip OA and medial OA of the knee from the period 1995 to 2000 were added to increase sample size resulting in a total of 27 cases to be studied (nine without and 18 with simultaneous hip and knee OA). In both series some measurements on the radiographs had to be discarded because of poor film quality or absence of solitary radiographs (Table II).

Pelvic radiographs of 14 women admitted during 2000–2001, because of failed femoral neck *fracture* on the left side, were used as controls in the measurement of hip and pelvis distances and hip angles on the right (non-fractured) side.

RADIOGRAPHIC MEASUREMENTS

All pelvic views were exposed with fixed patient-film distance resulting in a standardised magnification of about 20%. The patient was supine. A small pillow was placed beneath the knees to obtain a standardised position of the pelvis as possible. At the radiographic evaluation we did not correct for magnification since only relative lengths and

Table I



#Lateral OA on one side and medial OA on the opposite side. ##Cases recruited from period 1995 to 2000 to increase sample size. *Selected to age-match corresponding cases with lateral OA. **Known hip OA (operated).

Table II
Distribution between medial and lateral OA of the knee and absence or presence of hip OA. Patients with/without *pelvic view available have been separated*

	Presence of hip OA	
	No	Yes
Location of knee OA		
Medial	9/14 (9 bilat.)	18/18 (15 bi-, 3 unilat.)
Lateral	12/17 (6 bi-,6 unilat.)	17/22 (10 bi-, 7 unilat.)

angles were measured. All measurements were made using templates, pencil, set square and a ruler.

Hip angles

Two lines were reconstructed, one in the centre of the femoral neck and one in the centre of the femoral shaft. These lines were used to reconstruct the *Neck Shaft angle*. The distance between the centre of the femoral head and the point where these two lines intersected represented Femoral Neck length (*Femoral Neck length*). The horizontal distance between the femoral head centre and the line through the centre of the femoral canal represented ''offset'' (*Head-Shaft distance*) (Fig. 1).

Pelvis distances

Three distances are presented: the first is between the medial border of the right and left acetabulum (*Ac–Ac distance*). The two other distances is the sum of half of the distance between the medial borders of the right and left acetabulum and the distance between the medial border of the acetabulum and the femoral shaft (*Midpelvis-Shaft distance*) and centre of the caput (*Midpelvis-Caput distance*) (Fig. 1).

Biomechanical evaluation (i.e., the Lever Arm)

We measured the distance between the medial borders of the acetabulum to the centre of the femoral head (*Midpelvis-Caput distance*). This length was related to the distance between the femoral head centre and a central line in the proximal femur (*Offset*) (Fig. 2).

Comparisons between the left and right sides

We compared the hip angles and distances on the right and left sides in the study patients with medial and lateral knee OA. No data were available on controls as the left hip was fractured.

Demographic data

Data of actual length and weight at the time of surgery were collected from the case records.

Intra- and interobserver variability

Seventeen radiographic examinations of the pelvis were used to evaluate both intra- and interobserver variability. When the same observer measured the radiographs with an interval of 6 months the SD of the *Neck Shaft angle* was 1.7°. The corresponding errors for the *Femoral Neck length* and *Head-Shaft distance* were 4.2 and 3.1 mm. The interobserver error (mean $\pm$ 1 SD) for *Neck Shaft angle*, *Femoral Neck length* and *Head-Shaft distance* was $-0.29 \pm 2.4°$, 1.1 ± 4.5 mm and 1.6 ± 2.2 mm, respectively.

The intraobserver variability for *Ac–Ac distance* and *Midpelvis-Shaft distance* was 1.8 and 3.2 mm. The interobserver error (mean $\pm$ 1 SD) for the same distances was -1.0 ± 6.6 and -0.2 ± 3.5 mm.

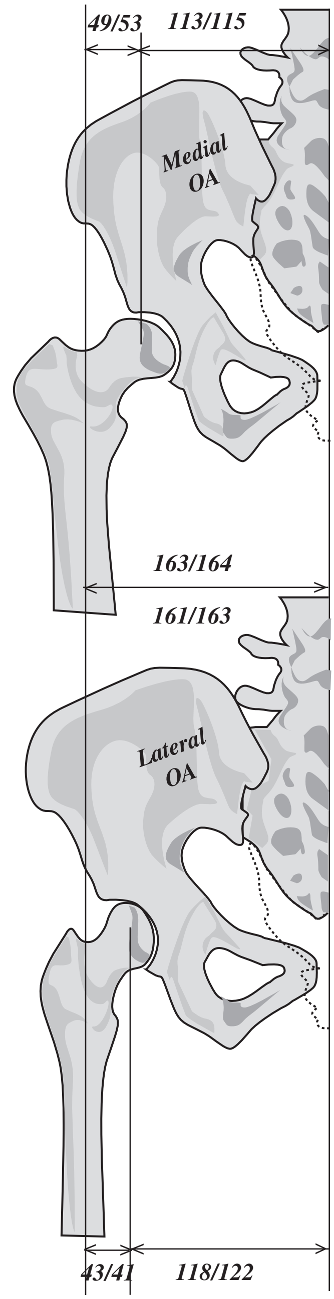


Fig. 2. Schematic view of results presented as median values *without/with* hip OA. Observations at the hip region in patients with medial (top) and lateral (bottom) OA of the knee. In this example the Midpelvis-Shaft distances are the same. At the top the pelvis is more narrow, which has been compensated for by higher femoral offset. At the bottom the patient has a wide pelvis, but coxa valga resulting in a smaller femoral offset.

Table III
Anatomic hip angles and distances. Comparison between right and left side

	N	Right side		Left side		*P*-value*
		Median	Range	Median	Range	
Medial OA of the knee						
Neck Shaft angle	10	130	117.5–142	133	119–136.5	0.41
Femoral Neck length	10	62.5	59–72	61	57–66	0.07
Head-Shaft distance	10	46	40–63	45	39–57	0.03
Lateral OA of the knee						
Neck Shaft angle	7	134.5	127–143	134.5	127–144	0.60
Femoral Neck length	7	61	58–65	57	52–61	0.03
Head-Shaft distance	7	44	37–51	41	36–47	0.03

*Wilcoxon signed rank test.

Statistics

When comparing the values between left and right sides, Wilcoxon signed ranks test was used, and for demographic data Mann–Whitney *U* test was used. The values are presented as median and range. For all other statistics *t* test and Fisher's Exact test were used and values are presented as mean and SD.

Results

LEFT VS RIGHT SIDE

The *Femoral Neck length* and the *Head-Shaft distance* were 4 and 3 mm longer on the right side in patients with lateral OA ($P = 0.03$ and $P = 0.03$). In cases with medial OA, a difference was only found for the latter parameter (median increase of *Neck Shaft angle* on the right side of 1.5°; $P = 0.07$; increase of Head-Shaft distance: 1 mm; $P = 0.03$, Table III). Because of significant differences between the two sides further comparisons between patients with medial and lateral OA were restricted to the right side.

OA OF THE HIP

In the first series of patients operated during 1985–1994, those with lateral OA more often had been operated with hip arthroplasty (13 of 25) than those with medial OA (13 of 217) ($P < 0.0005$).

HIP ANGLES AND DISTANCES

In patients with *medial knee OA* without hip OA there were no difference in the width of the pelvis when measured as *Ac–Ac distance* (+1.5 mm, $P = 0.7$) compared to controls but the offset were 11.4 mm greater ($P = 0.005$). There were a tendency to coxa vara (*Neck Shaft angle* 5.8° less than normal, $P = 0.08$). There were a longer *Femoral Neck* than observed in the controls (64 vs 53 mm; $P = 0.001$) (Table IV).

Patients with *lateral knee OA* without hip OA also had longer femoral neck than normal (59 vs 53 mm, $P = 0.02$) but less compared to the group with medial OA (−5 mm, $P = 0.02$).

The *Ac–Ac distance* was 13.7 mm longer compared to controls ($P = 0.001$) but the offset did not differ (+4.7 mm, $P = 0.11$).

The wider pelvis in lateral OA was "compensated for" by shorter "offset" on the AP radiographs resulting in about equal shaft-to-shaft distances (*Midpelvis-Shaft distance*) in the two groups (lateral vs medial OA of the knee: −1.6 mm, $P = 0.7$).

The influence of hip OA

Coincidence of hip OA in medial knee OA decreased the femoral neck angle with 2.2° and increased it with 1.2° in lateral knee OA. When compared with those two groups the difference was 7.8° ($P = 0.008$).

Coincidence of hip OA decreased the difference in pelvic width (*Ac–Ac distance*) between the groups with medial (+3.9 mm) and lateral OA (−2.0 mm) with 6.3 mm ($P = 0.15$). The difference in offset did, however, increase to 12.2 mm ($P = 0.01$).

The Lever Arm

The calculated Lever Arm (*Offset* / *Midpelvis-Caput distance*) was 19% smaller in patient without and 30% smaller in patients with OA of the hip and simultaneous lateral knee OA when compared to those with medial knee OA ($P = 0.02$ and 0.02). No differences were found compared to controls ($P > 0.28$).

Demographic data

Patients with medial OA were 2 cm shorter ($P = 0.03$) and 6 kg heavier ($P = 0.04$) than those with lateral OA. No age differences were found ($P = 0.2$). The body length did not differ between controls and OA cases ($P = 0.5$) (Table V).

Discussion

In patients with OA knee alignment is associated with progression of cartilage loss[17]. The influence of tibiofemoral alignment on the incidence of knee OA in the population has however not been completely mapped out. In two large cohort studies[18] higher frequency of lateral OA was observed in a Beijing compared to a Framingham population. The authors speculated that this difference could be caused by an increased prevalence of valgus angulation in the Chinese population without OA, but they could only demonstrate such a difference in males and not in females.

In 1983, Cooke[19] pointed out "the coexistence of knee disease in cases with hip osteoarthritis (10/24) compared to the low incidences of hip changes in those with knee involvement (3/27)". He found that almost half of those with hip OA also had knee involvement, but when he studied a group with knee OA only 1/10 had hip involvement. He

Table IV
Pelvis and hip distances and angles. Lateral and medial arthrosis of the knee with *and* without *coxarthrosis vs controls. Hip values on the right side. (Missing observations are due to discarded radiographs)*

	Lateral arthrosis				Medial arthrosis				Controls		Comparison against controls				Lateral vs medial arthrosis	
	No coxarthrosis (LNC)		With coxarthrosis (LWC)		No coxarthrosis (MNC)		With coxarthrosis (MWC)				LNC	LWC	MNC	MWC	NC	WC
	N	Mean (SD)	*N*	Mean (SD)	*N*	Mean (SD)	*N*	Mean (SD)	*N*	Mean (SD)	*t* test					
Ac–Ac distance	12	166 (10.3)	17	164 (6.8)	9	153.8 (8.2)	18	157.7 (12.5)	14	152.3 (8.7)	0.001	0.009	0.68	0.18	0.009	0.15
Neck Shaft angle	11	133.3 (4.4)	13	134.5 (6.8)	9	128.9 (7.8)	10	126.7 (5.8)	14	134.7 (6.8)	0.53	0.93	0.07	0.007	0.14	0.008
Head-Shaft distance	10	42.7 (4.6)	8	40.9 (8.1)	9	49.4 (7.7)	10	53.1 (10.3)	14	38 (9.0)	0.14	0.46	0.005	0.001	0.04	0.01
Femoral Neck length	10	59 (4.1)	8	57 (7.9)	9	64.0 (4.2)	10	64.8 (8.0)	14	53 (7.7)	0.04	0.26	0.001	0.001	0.02	0.055
Midpelvis-Caput distance	9	118 (5.0)	7	122.5 (8.9)	9	113.3 (6.0)	8	114.6 (2.8)	14	113.4 (5.7)	0.06	0.036	0.98	0.58	0.10	0.03
Midpelvis-Shaft distance	9	161.3 (7.8)	7	162.8 (8.3)	9	162.8 (9.4)	8	164.4 (6.1)	14	151.4 (10.0)	0.02	0.18	0.01	0.003	0.73	0.68
Lever arm	9	0.37 (0.03)	7	0.33 (0.09)	9	0.44 (0.07)	8	0.43 (0.05)	14	0.34 (0.08)	0.28	0.92	0.006	0.002	0.02	0.02

There were no significant differences between coxarthrosis or not, within medial and lateral arthrosis.

suggested a causal relationship. We found a coexistence of hip disease in cases with lateral knee OA (13/25) and a much low incidence of hip changes in those with medial knee OA (13/217). This finding might raise the hypothesis that the development of lateral knee OA is facilitated by certain anatomical abnormalities in the hip region.

The width of the pelvis in terms of the distance between the medial borders of the acetabulum was more than 1 cm larger in cases with lateral OA notwithstanding presence of OA of the hip or not. This difference could not be explained by the fact that patients with medial OA were 2 cm shorter than those with lateral OA. In medial OA a wide pelvis was observed only in cases, which also had hip OA. Based on the observed numerical values of pelvic width it seems as the location of the OA of the knee could be influenced by pelvic width. Women, who have short functional femoral neck, may have difficulties to maintain sufficient hip abductor strength due to a short lever arm. During gait the pelvic tilt might increase resulting in hip adduction and increased external abduction moment at the knee. This gait pattern might also predispose to development of hip OA resulting in further contracture of the hip adductors. Prospective longitudinal studies and information about pelvic width in cases with hip OA but without the corresponding disease of the knee is necessary to clarify this issue.

Yoshioka *et al.*[20] studied the anteversion in 32 normal cadaveric femora. In women the mean value was 8° but with a considerable individual variation (−10.8–22.1°). Our hypothesis was that cases with lateral OA had coxa valga with higher abduction moment over the hip and the knee resulting in OA also of the hip. Our measurements of *Neck Shaft angle* showed equal values in lateral OA and controls contradicting this theory. Instead, we found a tendency to coxa vara in medial OA, which reached significance only in the group with OA of the hip. On AP radiographs this variation might partly be hidden due to different rotational positions of the femur when the radiograph is exposed. Measurements of the Neck Shaft angle are subjected to methodological errors. A higher anteversion in lateral OA could result in false steeper *Neck Shaft angle* on conventional radiographs suggesting that the *Neck Shaft angle* only reflects differences in femoral rotation. Further studies based on computerized tomography are necessary to elucidate this issue.

In a motion analysis of patients with OA[21] of the knee we found 8° increased outward rotation of the hip in cases with lateral compared to those with medial OA and controls and lesser inward rotation moment. This outward rotation will place the femur closer to the pelvis and will result in reduction of the total width at the pelvic region (here labelled *Midpelvis-Shaft distance*). Increased outward rotation, anteversion or both may result. One explanation for higher risk among those with lateral OA to develop hip OA is perhaps a rotation of the femur that will change the pressure distribution in the acetabulum[22].

Our measurements could reflect differences in functional anatomy, which should have the same theoretical implications. The lever arm over the hip could be a function of the distance from the centre of the pelvis, independent of the rotation of the femur, like we look at the body in two-dimensions. Therefore, we compute the correlation of the distance from the centre of the caput to femoral line (*Offset*) and the distance from centre of the pelvis to the centre of the caput femoris (*Midpelvis-Caput distance*). One limitation of the study is even if the tip of the greater trochanter was not used. This has been more appropriate but this was not used because it is more difficult to identify and more sensitive to changes of the position of the hip.

Table V
Demographic data

	Lateral OA		*P*-value* (medial vs lateral OA)	Medial OA		*P*-value* (controls vs cases)	Controls	
	N	Median (range)		*N*	Median (range)		*N*	Median (range)
Weight	35	72 (50–124)	0.04	22	78 (54–123)	0.004	7	56 (42–80)
Length	35	162 (152–178)	0.03	22	160 (151–168)	0.51	7	160 (157–168)
BMI	35	27.5 (17.6–39.1)	0.004	22	31.6 (21.9–52.5)	0.002	7	21.9 (16.0–28.3)
Age	39	74 (62–89)	0.21	22	72.5 (59–81)	0.000	14	80.5 (75–87)

*Mann–Whitney *U* test.

We found that the calculated *Lever Arm* was 19% smaller in patient without OA of the hip and simultaneous lateral knee OA when compared to those with medial knee OA ($P = 0.02$). This is in line with a gait analysis study of patients with medial and lateral OA of the knee[21], in which we found that the maximum abduction moment over the hip was reduced with 22% in lateral and with 8% in medial OA compared to a healthy control group. The small lever arm at the hip will explain this observation. Reduced abductor moment at the hip will promote in hip adduction and secondary change of knee alignment into valgus. It might also be that any increase of the activity of the hip abductors trying to compensate the small lever arm at the hip also will involve the tensor fascia lata. Since this muscle also passes through the lateral side of the knee, it will play a role in the development of forces in its lateral compartment.

Another limitation of our study is that the normal material consisted of patients with a contralateral femoral neck fracture. Based on previous observations[23–26] it could be expected that these patients have a longer femoral neck than normal. Nonetheless in both patients with medial and lateral OA of the knee the femoral neck was still longer than in our "normal" hips. It is however uncertain if patients with unilateral femoral neck fracture have a longer neck on both sides even if this seems probable.

Our data suggest that a relatively narrower pelvis in medial OA is compensated for by larger "offset" resulting in equal width between the pelvic and femoral shaft centres in these two conditions. The reason why both patients with medial and lateral OA have a longer shaft-to-shaft distance than our controls, remains unclear. Lateral OA of the knee was more frequently associated with OA of the hip than observed in cases with medial OA of the knee. We speculate that this at least partly can be explained by a wide pelvis and normal Neck Shaft angle. Presence of coxa vara may be one reason for development of medial OA, but the relationship between these two conditions might be weaker.

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