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ORIGINAL STUDY

# Leg power, pelvic movement and physical activity after periacetabular osteotomy. A prospective cohort study

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**To investigate changes in leg power, pelvic movement and patient-reported outcome in patients with hip dysplasia one year after periacetabular osteotomy.**

**Forty-one patients (7 males) with a mean age of 28.8 years scheduled for periacetabular osteotomy were tested before surgery, and 4 and 12 months after. Leg power, pelvic range of motion and the Hip and Groin Outcome Score (HAGOS) was collected.**

**One year after surgery, power in the operated leg had improved (p = 0.004) and there was no significant difference between power in the operated leg and contralateral leg (p = 0.22). In the frontal plane, pelvic range of motion decreased significant during stair-climbing and stepping down. The same pattern was seen in the sagittal plane but the changes were non-significant. All subscales on the HAGOS improved significantly over time (p < 0.001).**

**Leg power and pelvic range of motion in patients with symptomatic hip dysplasia improved 12 months after periacetabular.**

**Keywords** : periacetabular osteotomy ; hip dysplasia ; leg power ; pelvic movement ; physical activity.

## INTRODUCTION

The transsartorial periacetabular osteotomy (PAO) *(30)* is performed in young patients with hip dysplasia to relieve hip pain and increase hip-related physical function.*(12,13)* By applying this surgical procedure we hope to postpone or to prevent hip osteoarthritis (OA). PAO offers good pain relief in symptomatic hip dysplasia *(18,25,32)* and results in good surgeon and patient-reported physical function *(2,9,10,22,27)*. However, little is known about what level of objectively measured physical function the patients achieve after PAO. Persistent hip pain in patients with hip dysplasia probably leads to reduced muscle strength and power, *(8)* compensatory pelvic movement by leaning over the affected hip to unload the affected hip and ultimately reduced physical function and activity. Leg press power is highly correlated with physical function *(37)* and thus important to measure. Altered pelvic movement might increase the load on the contralateral hip joint and thereby affect function.

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Moreover, it is important to establish whether patients with hip dysplasia become more physically active and participate in high impact activities, such as running after PAO.

We hypothesized that one year after PAO 1) leg power in the affected leg will increase and reach the level of the contralateral leg, 2) pelvic range of motion during walking, stair-climbing and stepping will decrease, 3) physical activity and participation in high impact activities will increase and 4) patient-reported hip function, pain and quality of life will improve.

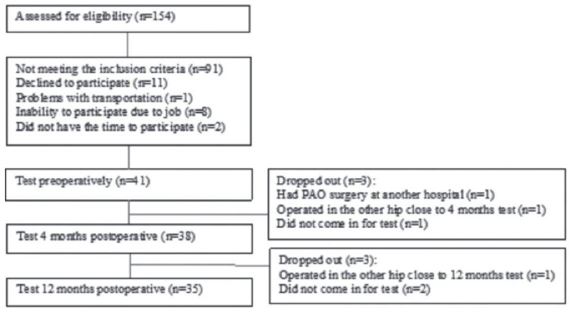


***Fig. 1.*** — 41 patients with hip dysplasia scheduled for periacetabular osteotomy were included from the Department of Orthopedics at Aarhus University Hospital in Denmark from October 23rd 2012 to February 2nd 2014.

## METHODS

The study is a prospective cohort study (level of evidence: II) conducted at Aarhus University Hospital. Forty-one patients (7 males) with a mean age of 28.8 years scheduled for PAO were included consecutively and operated on between November 2012 and January 2014 (Figure 1). Thirty-two of the patients had bilateral hip dysplasia. Written informed consent was obtained and ethical approval was obtained from the Central Denmark Region Committee on Biomedical Research Ethics (Journal Number: M-20100274). The study was registered at Clinical Trials.gov (NCT02015247). The inclusion criteria were: center-edge (CE) angle of Wiberg(35) 24∞ or less, OA degree 0 or 1 according to the classification of Tönnis,(31) spherical femoral heads, painful hip, minimum 110° flexion in the hip joint and living less than 70 km away from the hospital. Exclusion criteria were: Legg-Calvé-Perthe's disease, previous PAO or other hip surgery on the affected leg and age <18 years.

All PAO procedures were performed by a single surgeon (KS) using the transsartorial approach *(30)*. The incision is made from the anterior superior iliac spine descending 7 cm along the sartorius muscle. The lateral femoral cutaneous nerve is located and isolated, and the inguinal ligament is cut at the attachment to the anterior superior iliac spine. In the direction of the fibers, the sartorius muscle is split and the deep fascia of the muscle is cut. The iliopsoas muscle and the medial part of the sartorius muscle are retracted medially to allow room for performing of the osteotomies. First the pubic bone is cut and then under fluoroscopic control the ischial osteotomies and the posterior iliac osteotomy are performed. For the latter, an oblique view is used to ensure that the cut is extra-articular and to avoid penetration of the posterior column of the acetabulum. After the iliac bone is osteotomised, the acetabular fragment is reoriented; first adduction and then extension to optimise lateral and anterior coverage of the femoral head. Care is taken not to overcorrect the position of the acetabulum which may result in impingement(23). Intraoperative fluoroscopy is applied to evaluate the lateral and anterior coverage of the femoral head, the version of the acetabulum and the fixation of the two cortical screws inserted in the iliac crest into the medial aspect of the acetabulum. Patients were discharged to their home 2-4 days after surgery. During admission, the patients were mobilised on the day of surgery and seen daily by a physiotherapist for active hip range of motion exercises. Four weeks after discharge, a standardized rehabilitation program was initiated and offered twice a week consisting of an aerobic and strength program followed by a 30-minute program of mobility and gait training. From the eighth postoperative week, the patients were allowed to fully weight-bear.

### Outcome measures

Two physiotherapists (PBJ, KS) collected all data (tests and questionnaires) at the hospital. These physiotherapists underwent special training before study initiation. All outcome measurements were performed at baseline, typically 1-2 weeks prior to PAO, at 4 months and at 12 months follow-up. Before testing, the patients rated pain at rest on a 10 cm VAS scale, and immediately after testing they rated pain during activity.

*Leg extension power*

We measured leg extension power to capture changes in muscle performance relevant for physical function. The Nottingham Power Rig (University of Nottingham Mechanical Engineering Unit, UK) was used to measure leg extension power expressed as the product of force and velocity in a single-leg simultaneous hip and knee extension *(3,4)*. Subjects seated in the rig with arms folded gave maximal push against a footplate attached to a flywheel. Power output was derived from the acceleration of the flywheel and was recorded in Watts. This measurement has previously been used to assess muscle power in hip OA patients *(34)* and after total hip replacement *(5,20)*. The test was repeated with 20 seconds rest between trials until a plateau was reached, defined as two successive measurements below the highest. Three submaximal practice trials were allowed in order to minimize learning effect. Then a minimum of three trials to and a maximum of 10 trials were obtained and the highest measurement in watt was normalized for body weight in kg and used as the data point. The inter-tester reliability of this measurement is acceptable with ICC of 0.91 (95% CI: 0.83;0.99) and measurement error (SEM) of 10% *(21)*.

*Intertia measurement unit based functional tests*

With an inertial measurement unit (IMU) mounted on the pelvis, the patients performed three functional tests; 10 m walk test, stair climbing and a stepping test. We used the IMU to capture changes in compensatory pelvic movements during the functional tests.

*Walking test*

Range of motion parameters were measured during a 10-m walk test. Patients were instructed to walk 10 meters between two marked lines in an undisturbed hallway with a concrete floor. Subjects were instructed to walk at their "usual, self-selected walking speed". A static starting procedure was applied, where the subjects started at the zero line and were asked to walk until the 10 meter mark, pass it and stop. The tester measured the distance from the 10-meter mark to the front foot with a non-elastic tape measure. The test was performed twice separated by a break of at least 30 seconds.

*Stair-climbing test*

Stair-climb performance has been suggested and used when measuring functional performance in hip OA patients *(1,26)* A stair-case (height: 16.5 cm, depth: 34 cm) was used to assess movement strategies during stair-climbing. The use of handrails was not allowed. At self-selected speed, subjects ascended and descended five steps on a step-over-step manner twice.

*Block step test*

The block step test consisted of ascending and backward descending a 40 cm block step at self-selected speed. Three repetitions stepping up and down with one leg was followed by three repetitions stepping up and down with the other leg. *(7)*. Subjects had to be able to complete at least three steps with each leg before the test was included for further analysis.

*Intertia-based measurement unit and the corresponding algorithms*

An IMU can be applied to assess pelvic range of motion parameters and provides valid data of trunk movements *(36)*. An IMU (Inertia-Link, MicroStrain, USA) was mounted on the patient's pelvis at the level of S1 with double adhesive tape. The IMU measures with a precision of +/- 0.005 g for acceleration and +/- 0.2° at 300°/s for rotation. Values of x, y and z- acceleration and rotation were sampled at a frequency of 100 Hz and the unit transmitted digital data via Bluetooth to a laptop with appropriate software (Inertia Link 1.4.2., MicroStrain, USA).

The IMU-derived range of motion were calculated by algorithms developed by AHORSE Foundation (Atrium Medical Center, NL), based on algorithms of Zijlstra *(36)*. At the walking test a peak-detection algorithm was used. The algorithm detected heel contacts and displayed anterior-posterior and vertical acceleration peaks, allowing the analyser to mark undetected peaks and delete incorrect peaks. The average estimate of pelvic range of motion over two trials was used for further analysis. At the stair-climbing test, pelvic range of motion in the sagittal and frontal planes was derived with an algorithm based on detection of start and completion of the test. The average estimate of range of motion over two trials of five steps was used for further analysis. At the stepping test, pelvic range of motion in the sagittal and frontal planes was derived with an algorithm based on detection of initiation and completion of each step and average estimates of three steps were calculated.

*Physical activity*

Type of and duration of activity was monitored with accelerometers to obtain objective data on changes in physical activity after PAO. A commercially available 3D accelerometer (GCdataconcepts, USA) was taped to the right lateral thigh using hypo-allergic double sided tape (3M, US). Fourteen bit data (range ± 8 g) was collected at a sampling rate of 50 Hz and stored on an on-board micro-SD card. Patients were instructed to wear the accelerometer for five continuous days during waking hours, except during bathing and swimming, and recharge it at night. Patients with less than three days of measurements were excluded from the analyses and likewise were days with less than 8 hours of data. After five days of wear, the patients returned the accelerometer in a postage-paid mailing package. Data was processed and analysed as described by van Rooij et al *(33)*.

*Patient-reported outcome*

We used the Hip And Groin Outcome Score (HAGOS) to measure patient reported outcome in the following subscales: Symptoms, Pain, Function in daily living (ADL), Function in sport and recreation (Sports/Rec), Participation in Physical Activities (PA) and hip and/or groin-related Quality of Life (QOL). HAGOS has been validated to measure the status of health in young to middle aged physically active patients with longstanding hip and/or groin pain *(29)*. HAGOS has been found to have good test-retest reliability with a smallest detectable change (SDC) between 2.7 point and 5.2 point out of 100 point at the group level *(29)*. The patients completed HAGOS at the end of the test sessions.

**Sample size**

The sample size calculation was based on earlier obtained leg extension power data from patients before PAO (mean ± SD: 1.85 ±0.70 Watt/kg). The expected difference in power between preoperative and one year postoperative was defined as 20% as suggested by Cochrane Musculoskeletal Group *(19)*. With a significance level of 0.05 and a power of 80%, the required sample size was 31. To allow for drop outs, 41 patients were included.

**Statistical analysis**

Data were tested for normality by the Shapiro-Wilk test and Q-Q plots. Normally distributed data were described by mean and standard deviation (SD), and data not normally distributed were described by median and interquartile range. Data for the outcome measures were compared from before surgery to one year after and tested by a paired t-test or by a Wilcoxon signed-rank test. The comparison of data for physical activity was between 4 and 12 months after surgery since we did not collect preoperative activity data. The statistical analyses were performed using STATA 13.0 (StataCorp, College Station, TX) software package. The significance level was set at 0.05.

## RESULTS

154 patients were assessed for eligibility and out of those 41 patients were included and tested before PAO. Baseline characteristics are shown in Table I. At the 4 months follow up, 3 patients dropped out and at 12 months follow up, another 3 dropped out. Thirty-five patients completed the 12 months

Table I. — Baseline descriptive data for 41 patients with hip dysplasia scheduled for periacetabular osteotomy

| Gender female/male (%) | Age mean (SD) | BMI mean (SD) | Affected hip side Right/left | Hip brace in childhood yes/no (%) | Duration of pain months mean (SD) | Resting pain VAS mean (SD) | Pain after test VAS mean (SD) | Use of analgesics due to HD yes/no (%) |
|---|---|---|---|---|---|---|---|---|
| 34/7 (83/17) | 28.8 (9.3) | 23.1 (5.3) | 22/19 | 1/40 (2/98) | 50.4 (55.5) | 2.0 (2.3) | 2.9 (2.1) | 11/30 (27/73) |

SD: standard deviation, VAS: Visual analog scale, HD: hip dysplasia

follow up. Apart from physical activity, all outcome measures were compared from before surgery to one year after.

Preoperatively, leg power in the operated leg/contralateral leg was mean ± SD 2.31 ± 0.75/2.45 ± 0.57 W/kg, at 4 months follow up 2.07 ± 0.71/2.35 ± 0.81 W/kg and at 12 months follow up 2.53 ± 0.81/2.62 ± 0.77 W/kg (Figure 2). One year after surgery, power in the operated leg had improved (p = 0.004) and there was no significant differences between power in the operated leg and contralateral leg (p = 0.22).

Pelvic range of motion in the frontal plane (Figure 3) decreased significantly during stair-climbing in both ascending (p=0.0001) and descending (p = 0.001) and at stepping down (p = 0.002). The same pattern was seen in the sagittal plane (Figure 4) but the changes were non-significant. For walking there were no differences in pelvic range of motion over time in either the frontal or the sagittal plane.

All subscales of HAGOS improved significantly over time (p < 0.001) and the changes were evident already at 4 months after surgery (Figure 5).

Physical activity was monitored at 4 and 12 months and we had complete data on 23 patients (Table 2). There was no significant change in percentage of the measurement time spent sitting (p=0.89), standing (p=0.57), walking (p=0.09), running (p=0.95), number of sit-to-stand transfers (p=0.55) or cadence (p= 0.85). But at 12 months after PAO, patients cycled significantly less than at 4 months (p=0.04).

VAS scores at rest and after test were mean±SD 2.0±2.3/2.9±2.1 at baseline, 1.1±1.7/1.6±1.7 cm at 4 months follow up and 1.1 ± 1.8/1.2 ± 1.7 cm at 12 months follow up.

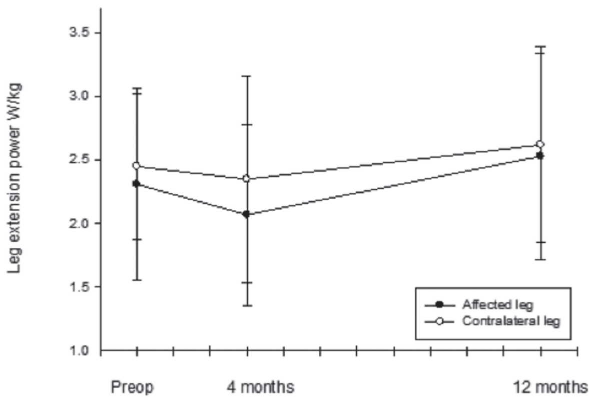


*Fig. 2.* — Leg power in the operated leg and the contralateral leg determined before surgery and at 4 and 12 months after surgery. Mean and standard deviation are presented. Leg power in the operated leg increased significantly between preoperative and at 12 months postoperative

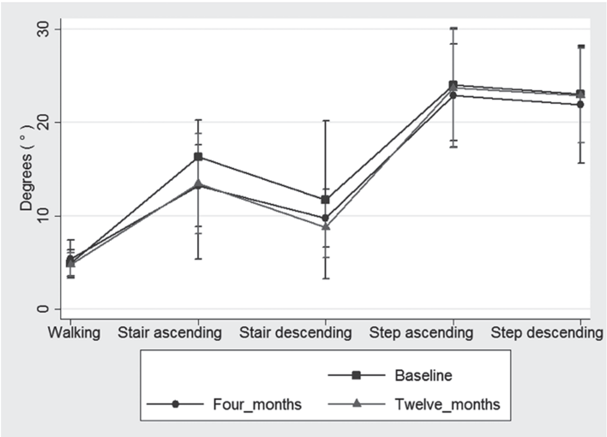


*Fig. 3.* — Pelvic range of motion in the frontal plane determined before surgery (baseline), at 4 and at 12 months after surgery. Mean and standard deviation values are given. ◊Significant differences between values at baseline and at 12 months follow up

Table 2. — Mean percentage of performed activities, number of transfers and cadence per day for 23 patients measured over 3-5 days at 4 and 12 months after periacetabular osteotomy.

| | | Total time per day (min) | Sitting % | Standing % | Walking % | Cycling % | Running % | Number of transfers (sit-stand-sit) | Cadence (steps/min) |
|---|---|---|---|---|---|---|---|---|---|
| 4 months follow up | Mean | 514.99 | 61.06 | 28.16 | 9.67 | 1.04 | 0.06 | 51.95 | 98.93 |
| | SD | 45.44 | 8.87 | 6.91 | 3.89 | 1.09 | 0.16 | 14.55 | 6.50 |
| | 95% CI | 495.38 - 534.64 | 57.22 - 64.89 | 25.17 - 31.14 | 7.99 - 11.36 | 0.57 - 1.51 | 0.01 - 0.12 | 45.66 - 58.24 | 96.12 - 101.74 |
| 12 months follow up | Mean | 502.88 | 61.33 | 27.21 | 10.77 | 0.61 | 0.06 | 50.54 | 98.61 |
| | SD | 57.08 | 11.00 | 9.05 | 3.20 | 0.83 | 0.16 | 14.61 | 6.89 |
| | 95% CI | 478.20 - 527.57 | 56.57 - 66.09 | 23.29 - 31.13 | 9.38 - 12.15 | 0.25 - 0.97 | 0.01 - 0.13 | 44.23 - 56.86 | 95.63 - 101.59 |

SD: standard deviation, CI: Confidence interval

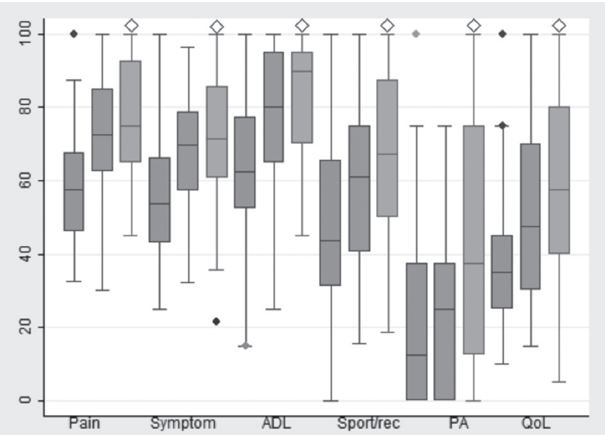


***Fig. 4.*** — Patient reported outcome in the 6 subscales of HAGOS: Symptoms, Pain, Function in daily living (ADL), Function in sport and recreation (Sports/Rec), Participation in Physical Activities (PA) and hip and/or groin-related Quality of Life (QOL) measured before surgery (blue), at 4 months follow up (purple) and at 12 months follow up (green). The horizontal line in the middle of each box indicates the median, the top and bottom borders of the box mark the interquartile range (75th and 25th percentiles), the whiskers mark the 90th and 10th percentiles and the dots indicate outliers. ◊Significant differences between values at baseline and at 12 months follow up.

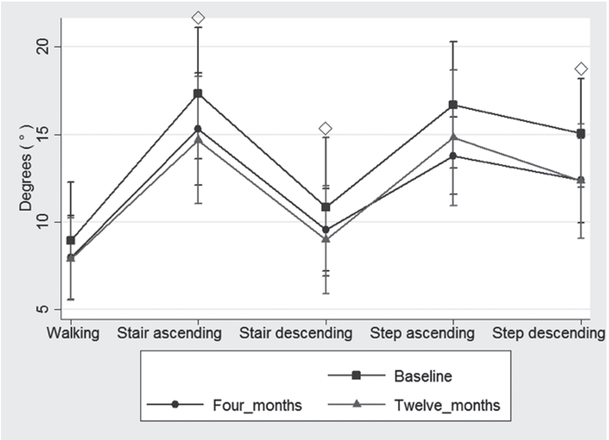


***Fig. 5.*** — Pelvic range of motion in the sagittal plane determined before surgery (baseline), at 4 and at 12 months after surgery. Mean and standard deviation values are given. There were no significant differences between values at baseline and at 12 months follow up

## DISCUSSION

To obtain clinically relevant data on the outcome that patients with symptomatic hip dysplasia can expect if they undergo PAO, we investigated changes in objectively measured physical function one year after PAO.

As we had hypothesized, muscle power in the affected leg increased significantly and reached the level of the contralateral leg one year after PAO.

Ezoe et al. *(8)* measured isokinetic muscle strength one year after curved PAO and found significantly increased hip muscles strength of all hip muscle groups. Sucato et al. *(28)* measured isokinetic muscle strength 6 and 12 months after PAO. They found the same pattern as seen in this study; a decrease in muscle strength at 6 months and an increase at 12 months compared to preoperative values. Although leg extension power as measured in our study is a single-leg simultaneous hip and knee extension and thus not directly comparable to isokinetic hip muscle strength, our results are in line with the existing knowledge of improved hip muscle strength after PAO.

We hypothesized that pelvic range of motion during walking, stair-climbing and stepping would decrease. We found that pelvic range of motion decreased significantly in the frontal plane during the demanding functional tasks of stair-climbing and stepping down from a 40 cm block. Although not statistically significant, all measurements in both planes, except for walking in the sagittal plane, pelvic range of motion was greatest at baseline and lower at 4 and 12 months follow up. The reduced pelvic range of motion in the frontal plane indicates improved medio-lateral stability of the hip joint during function. Patients with hip dysplasia may exhibit pelvic drop during stair-climbing and stepping down due to pain or weakness of the hip muscles and this compensatory movement is reduced one year after surgery. The increased pelvic range of motion in the frontal plane may be associated with reduced hip abductor muscle strength, *(8,16)* reduced length of the gluteus medius muscle and decreased hip abductor moment arm *(17)* found in patients with hip dysplasia.

Physical activity and participation in high impact activities did not increase from 4 to 12 months after surgery as hypothesized. In fact, cycling decreased significantly, however the patients did not spend much time cycling at either 4 or 12 months after surgery and this result may be a random result. Unfortunately, we did not collect activity data before surgery and hence we can only measure changes from 4 to 12 months after PAO. Although leg power, pelvic range of motion and patient-reported outcomes clearly improved from 4 to 12 months, we did not see an increase in the amount of time the patients spent engaging in physical activity. The included patients were instructed to wear the accelerometer for five continuous days during waking hours but 18 patients did not wear the sensor for five days or did not wear it for at least eight hours and thus we had to exclude their data from the analysis. Some studies have shown increased physical activity one year *(24)* and two years *(32)* after PAO with patient-reported activity whereas another study *(15)* found that at 9.5 months after PAO pedometer-based data showed an 8.75% decrease in average steps taken daily compared to before surgery, underlining that it is not clear whether PAO results in improved physical activity. Harris-Hayes et al. **(11)** measured total daily strides over 7 days with accelerometers in patients with hip dysplasia and in healthy controls and found that the patients with hip dysplasia took similar number of strides as the controls. An explanation for the inconsistency in the results from the studies on physical activity after PAO may be that patients with hip dysplasia are as active in daily life activities as healthy controls but they cannot perform sports activities to the degree they would like to. Moreover, patient-reported activity has low correlation with objectively measured activity *(11)* which may also explain the conflicting results.

As hypothesized patient-reported hip function, pain and quality of life measured with HAGOS improved significantly over time. In all subscales of HAGOS, the patients had clinically meaningful improvements at both 4 and 12 months follow up compared to baseline, but the score for physical activity remained low one year after PAO. Physical activity in the questionnaire is represented by two questions: “Are you able to participate in your preferred physical activities for as long as you would like” and “are you able to participate in your preferred physical activities at your normal performance level”. Hence, the low level of physical activity measured by HAGOS in this study reflects that the patients are not satisfied with the level and the duration of their preferred physical activities one year after PAO. The accelerometer-based measurements of this study show that totally less than 1 percentage of performed activities over

3-5 days is cycling and high impact activities which supports the low level physical activity measured by HAGOS. The patients in this study scored lower on physical function than in a previous study from our institution on the same patient population *(14)* but on all other subscales, the scores were comparable. Birch et al. *(6)* also reported similarly low scores of the physical components of the Short Form-36 in patients with hip dysplasia 2–13 years after PAO, indicating that the physical health may not improve significantly with a longer follow up period after PAO.

We acknowledge limitations to our study. Only 41 patients out of possible 154 patients were included in the study. Ninety-one of the assessed patients did not fulfill the inclusion criteria but nearly all these patients were excluded because they lived more than 70 km away from the hospital. The reason for this inclusion criteria was that if the patients should travel a long distance for tests at baseline, 4 and 12 months, they were more likely to drop out of the study. We do not think that the patients excluded due to living further than 70 km away from the hospital were different from the patients living closer to the hospital and thus we consider our results generalizable to patients with hip dysplasia operated with PAO, despite the numerous excluded patients. We have no control group in this study and hence we cannot conclude whether leg power and the pelvic range of motion is normalised. Furthermore, we did not measure physical activity before PAO and consequently, we can only show changes from 4 to 12 months postoperatively.

In conclusion, leg power, pelvic range of motion and patient-reported outcome in patients with symptomatic hip dysplasia improved 12 months after PAO but physical activity from 4 to 12 months did not increase. Patients may increase their functional capacity after PAO without becoming more physically active. The presented results may be useful to counsel the patients with symptomatic hip dysplasia about the improvement in physical function and activity to be expected after PAO.

*Ethical Board Review statement: Ethical approval was obtained from the Central Denmark Region Committee on Biomedical Research Ethics (Journal Number: M-20100274)*

*All authors contributed to the design, acquisition and analysis of the data and/or drafting and revising the manuscript and approved the final manuscript.*

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