Impact of the exposure method in total hip arthroplasty on dinamic balancing ability, and on the variability of gait in the first six months of the postoperative period

Theses of PhD dissertation

Dr. Gergely Holnapy

Semmelweis University
Doctoral School of Clinical Medicine

PhD Supervisor: Dr. Rita M. Kiss DSc

Opponents: Dr. Ferenc Tölgyesi, PhD.
Dr. Krisztián Sisák, PhD.

Examination bord: Dr. László Tretter, DSc
Dr. Lajos Borbás, PhD
Dr. Gergely Pánics, PhD

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1. INTRODUCTION

International studies justify, that hip arthrosis is one of the most frequent cause of moving disability, in elderly population. In aged patients, the severity of hip arthrosis, necessitates hip arthroplasty in 3-5 %. After surgery, the pain mostly disappear, the previously weakned functions and motion function partially or totally restored. One of the main goal of the scientific field deal with motion analysis, is the effect of hip arthrosis to the gaitparameters. Using biomechanical methods, with well selected motion analysis systems, the status survey of patients can be more exact by quantified, and comparing numeral datas, the changes in motion can be examined numerical too.

Besides static measurments, the motion analysis systems are able to detect dynamic changes – during motion –, so the replicability of motion analysis is ensured. The degenerative orthopaedic and rheumatological changes affecting lower extremity recommended to be analyzed during walking, but at the same time it is not enough to analyse the gait patterns. The description of walking safety is needed, that is characterized by gait variabilty and dynamic balancing ability.

2. AIMS OF RESEARCH

The aim of this study is to characterize quantitatively the walking safety using ultrasound-based motion analysis method, influenced by the gait variability and dynamic balancing ability and detect the life quality, the functionality and the self-selected walking speed in patients who underwent total hip arthroplasty (THA) due to hip arthrosis, using different surgical approach. The internationally accepted motion analysis method of our research group elaborated earlier is able to investigate the variability of gait and dynamic balancing ability. The method was available for our studies. Beginning of the research the following questions were set:

1. What is the effect of different surgical approaches in THA on life quality and on functional tests praeoperatively and in the first six postoperative months.
2. What is the effect of different surgical approaches in THA on dynamic balancing ability measured by the ultrasound based sudden perturbation test praeoperatively and in the first six postoperative months.
3. What is the effect of different surgical approaches in THA on self-selected walking speed measured in walkway, praeoperatively and in the first six postoperative months.
4. What is the effect of different surgical approaches in THA on the variability of gait measured on treadmill during minimum of 400 gait cycle praeoperatively and in the first six postoperative months

3. METHOD

3.1. Subjects

Patients with severe hip osteoarthritis from an impact study of hip osteoarthritis were selected from patients at the Department of Orthopaedics at Semmelweis University. Patients between age 55-65 with unilateral hip arthrosis were selected to our study, but they were able to walk without helping tools, making them able to walk on treadmill with 1,2 m/s walking speed during 10 minutes. Two directional X-rays were taken of the subjects' hip joints; an expert radiologist ascertained that all the patients suffered from severe (grade 4) hip osteoarthritis according to Kellgren-Lawrence score. All patients excluded from the investigation, who had earlier degenertive or traumatological disease of the lower extremity or spine, or who had operative treatment in this regions.

72 patients involved in the investigation were divided into three groups according to the method of THA exposure. The 25 patients making up the first group were operated on by traditional direct-lateral (DL) exposure with the joint capsule removed; the 22 patients forming the second group were subjected to antero-lateral (AL) exposure, also with the joint capsule exstirpated; and the 25 patients making up the third group were operated on by posterior (P) exposure with the joint capsule preserved. 45 healthy elderly people were making up the control group involved in the impact study of hip osteoarthritis.

3.2. Measuring methods

3.2.1. The status of locomotor system, detected by the life quality and functional tests

Before all measurements orthopaedic physical examinations were performed, these contained: detection of functional status of the subjects with Harris Hip Score (HHS) focusing on hip joint, and also life quality status was detected with a 36 question short form life quality questionnary scale (SF-36), and the life quality of hip osteoarthritic patients was detected by a special Western Ontario and MacMaster University scale (WOMAC).

3.2.2. Modelling the dynamic balancing ability

The ability was characterised by ultrasound-based provocation tests. Unidirectional sudden perturbation was modelled by a PosturoMed© (Haider-Bioswing GmbH, Weiden, Germany) therapeutic device. These measurements were performed in the Gait Laboratory at the Department of Orthopaedics at Semmelweis University. *(Fig. 1.)* The double-support phase of the gait was modelled with standing on both legs, and the single-support phase was modelled with standing on single leg. After 2 seconds, as the locking element was released, the rigid plate was returned to its original position modelling a sudden perturbation. The subjects had to balance on the moving platform to regain their equilibrium in the given position. In this case, the WinPosture software detected the damped free oscillation of the rigid plate; the damping corresponded to the subject's balancing ability.

The Lehr's damping ratio were calculated from the motion of rigid plate. Lehr's damping ratio was expressed as the mean and SD, in all four examined groups. The data were analysed using a multi-variable ANOVA method, supplemented.

Fig. 1.

Measurement arrangement for the ultrasound-based tests with sudden perturbation

3.2.3. The measuring method of self-selected walking speed

The self-selected, comfortable walking speed was determined on 10m long flat area (walkway). The examined patients had to pass this whole distance three times and the time needed for passing was measured. The examined patient's personal, comfortable self-selected

Fig. 2.

Measurement apparatus. The measuring head of the Zebris CMS-HS system was positioned behind the individual being examined. Ultrasound-based triplets to record the motion of lower limbs were placed on the shins, thights, and over the pelvis. The measurement control software calculated the spatial coordinates of the sensors and the anatomical points designated on the segments were examined based on the propagation time of the ultrasound recorded by the measurement system walkig speed, were defined from the everage of three measurements. Data were analysed by single-variable ANOVA method with repeated measurements.

3.2.4. Modelling the gait variability

Gait analysis for modeling the variability of gait was performed using a zebris CMS-HS (zebris, Medizintechnik GmbH, Germany), a computerized ultrasound-based motion analysis system, at the Biomechanical Laboratory of the Department of Applied Mechanics at the Budapest University of Technology and Economics *(Fig. 2.).*

4. RESULTS

4.1. Impact of the method of exposure in total hip arthroplasty on the result of life quality and functional tests

At the 6th postoperative week, the result of life quality questionnaries (WOMAC and SF-36) significantly increased ($p<0,02$) in all three examined groups, but according to SF-36 questionnary, in groups AL and P, there is a higher increase in life quality than in group DL. According to WOMAC questionnary, in group P there is a higher increase in life quality than in group DL and AL. The result of DL group at the 12th postoperative week, shows remarkable relapse compared to the results of 6th postoperative week *(Figs. 3. and 4.).*
At the 6th postoperative months, the result of life quality and functional questionnaries significantly increased, compared to the results of 12th postoperative week, in all three examined groups. The best result in SF-36 and WOMAC questionnaries was found in group P (88-90%), nevertheless even this group doesn't reach the result of control group (97-99%) *(Figs. 3. and 4.).*
The preoperative results of affected hips, doesn't reach the 50% of the value of non-affected side, according to Harris Hip Score (HHS) *(Figs. 5.a. and 5.b.).* At the 6th postoperative week, a significant increase is visible on affected side, in all three groups, but the best result given by group AL. The lilt of improvement slows, and the differences between groups disappear at the 12th week postoperatively. At the 6th postoperative month, a significant increase is visible in HHS values on affected side in all three groups and the AL- and P-groups reaches even 88%. The results in HHS on non-affected side, show just moderate changes during the 6 postoperative months *(Figs. 5.a. and 5.b.).*

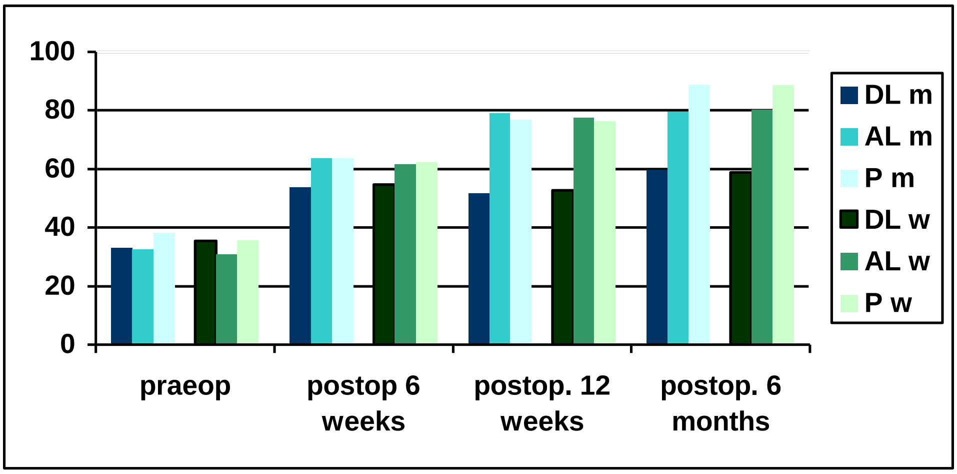

Fig. 3.
Changes in life quality according to SF-36 questionnary, in the first 6 postoperative months: the actual result in % visible on vertical axis, counting the maximal WOMAC score to 100% (m: man, w: woman)

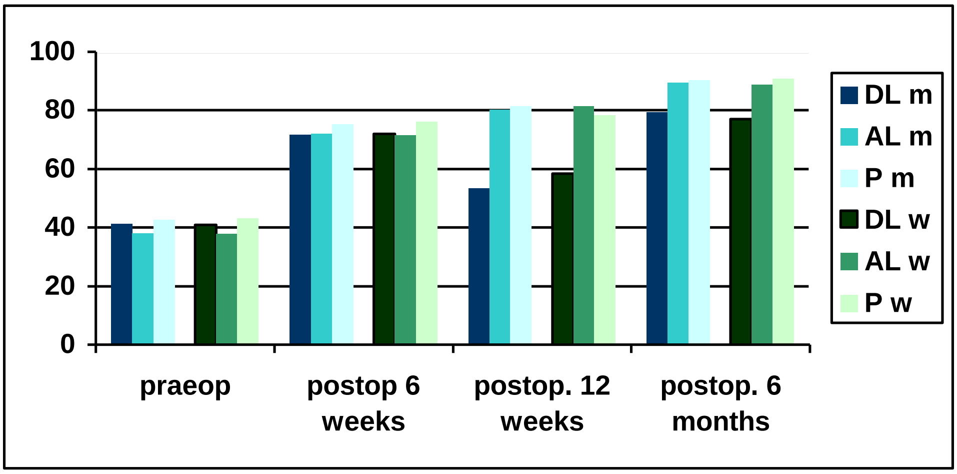

Fig. 4.
Changes in life quality according to WOMAC questionnary, in the first 6 postoperative months: the actual result in % visible on vertical axis, counting the maximal WOMAC score to 100% (m: man, w: woman)

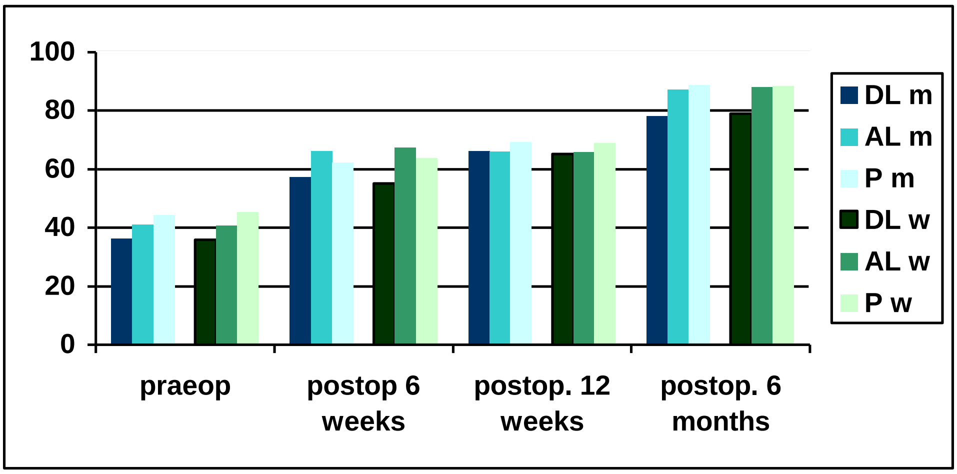

Fig. 5.a.
Changes in hip function on affected side according to Harris Hip Score: the actual result in % visible on vertical axis, counting the maximal HHS score to 100% (m: man, w: woman)

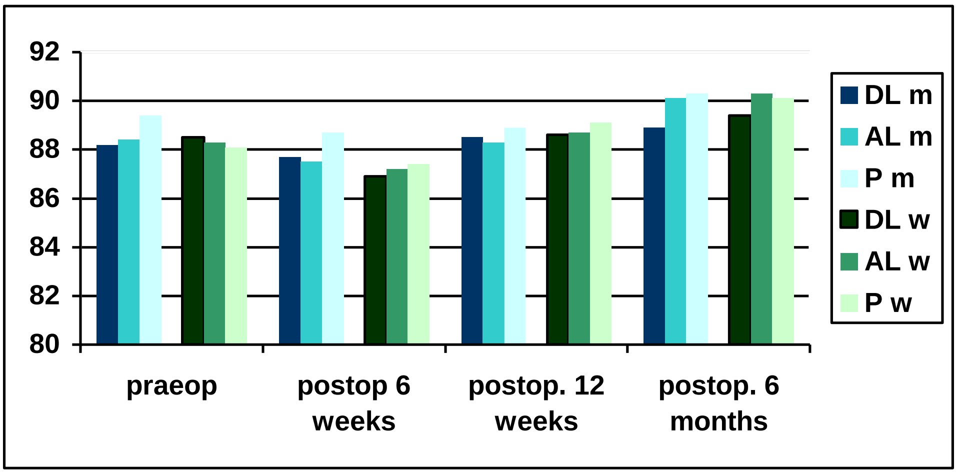

Fig. 5.b.
Changes in hip function on non-affected side, according to Harris Hip Score: the actual result in % is indicated on vertical axis, counting the maximal HHS score to 100% (m: man, w: woman)

4.2. Impact of the method of exposure in total hip arthroplasty on balancing ability

At controls, the Lehr's damping ratio is lower, while standing on non-dominant side, than the Lehr's damping ratio calculated in standing on dominant- or on both limbs, so the dynamic balancing ability is influenced by the limb dominance. The values of Lehr's damping ratio at women were significantly higher in all three standing position, than its of men *(Fig. 6.)*.

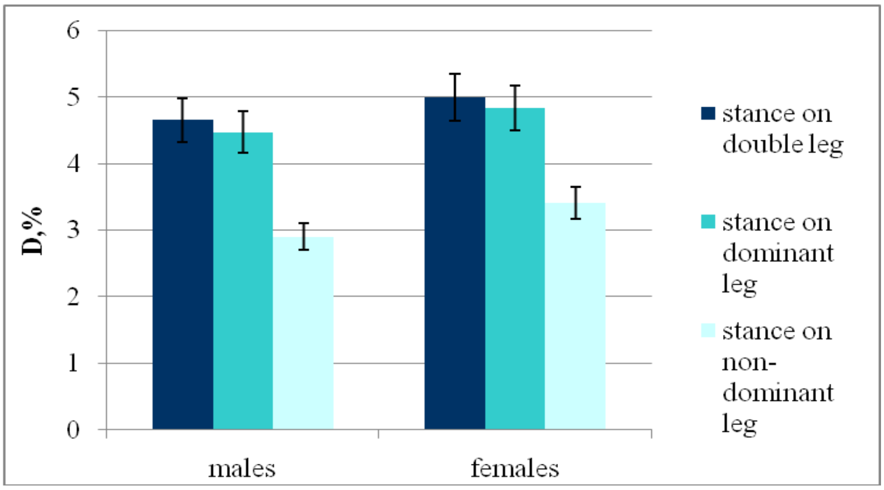

Fig. 6.
Lehr's damping ratio (D, %) of the control group calculated from data collected through ultrasound-based tests with sudden perturbation

No significant difference could be found between *patients suffering from severe hip arthrosis* in the three examined group before operation *(Fig. 7.)*. The Lehr's damping ratio calculated while standing on dominant side is significantly lower, than the Lehr's damping ratio calculated while standing on non-dominant- or on both limbs.

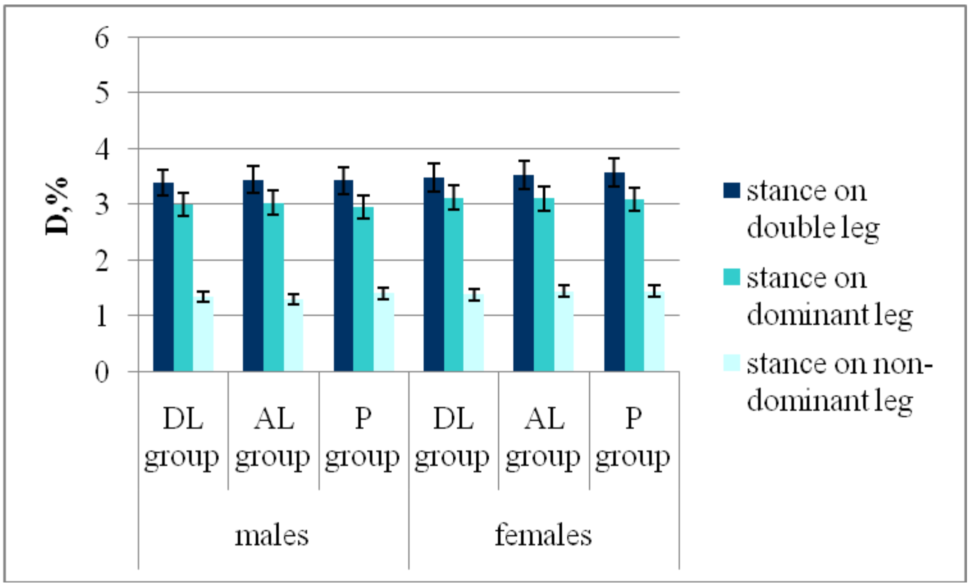

Fig. 7.

Lehr's damping ratio (D, %) of patients operated on using different methods of exposure, calculated from measurement collected during ultrasound-based tests with sudden perturbation prior to THA

The Lehr's damping ratio, calculated in all three methods (standing on both limbs, standing on affected- and non-affected side) in 6th postoperative week is significantly decreased in case of *patients with DL- and AL- exposures (Fig. 8. and 9.).*

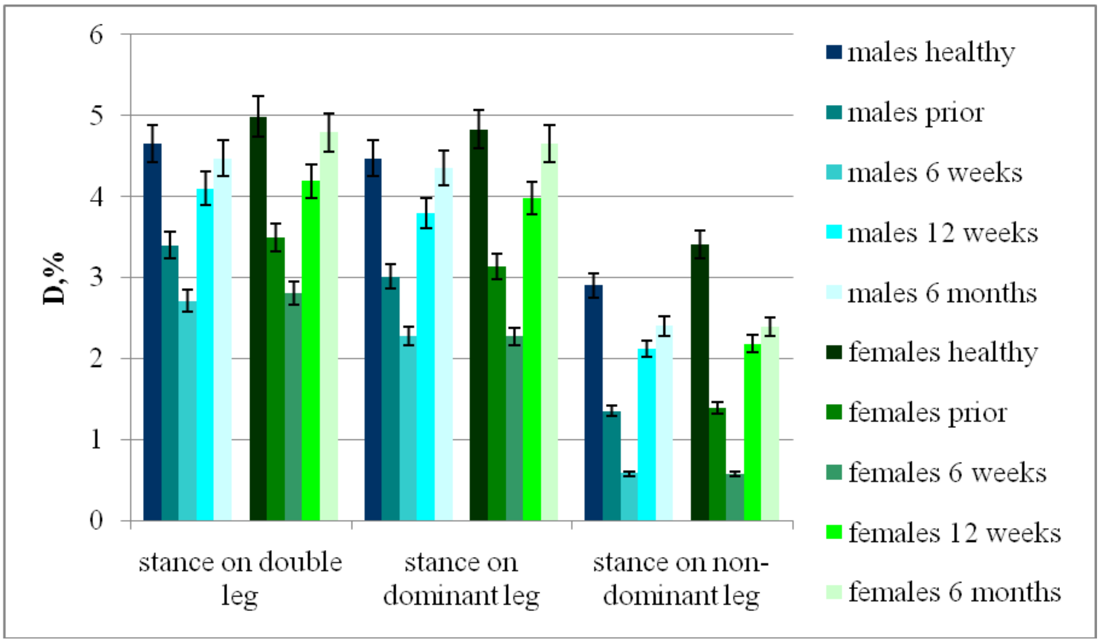

Fig. 8.

Lehr's damping ratio (D, %) for the control group and for patients operated on using a direct-lateral (DL) method of exposure, calculated from data collected during ultrasound-based tests with sudden perturbation in the first 6 months of the postoperative period

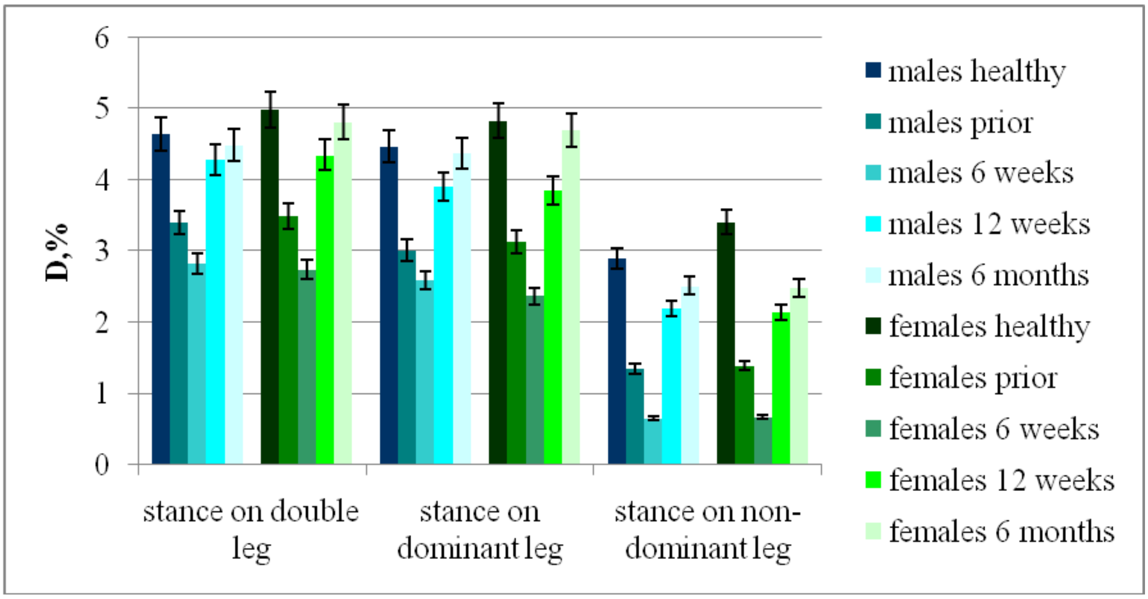

Fig. 9.

Lehr's damping ratio (D, %) for the control group and for patients operated on using an antero-lateral (AL) method of exposure, calculated from measurements collected during ultrasound-based tests with sudden perturbation in the first 6 months of the postoperative period

The Lehr's damping ratio, calculated from values of *group P, operated with capsule preserving technique*, is significantly increased comparing with the preoperative result, and shows higher rate than that of the two other groups *(Fig. 10.).*

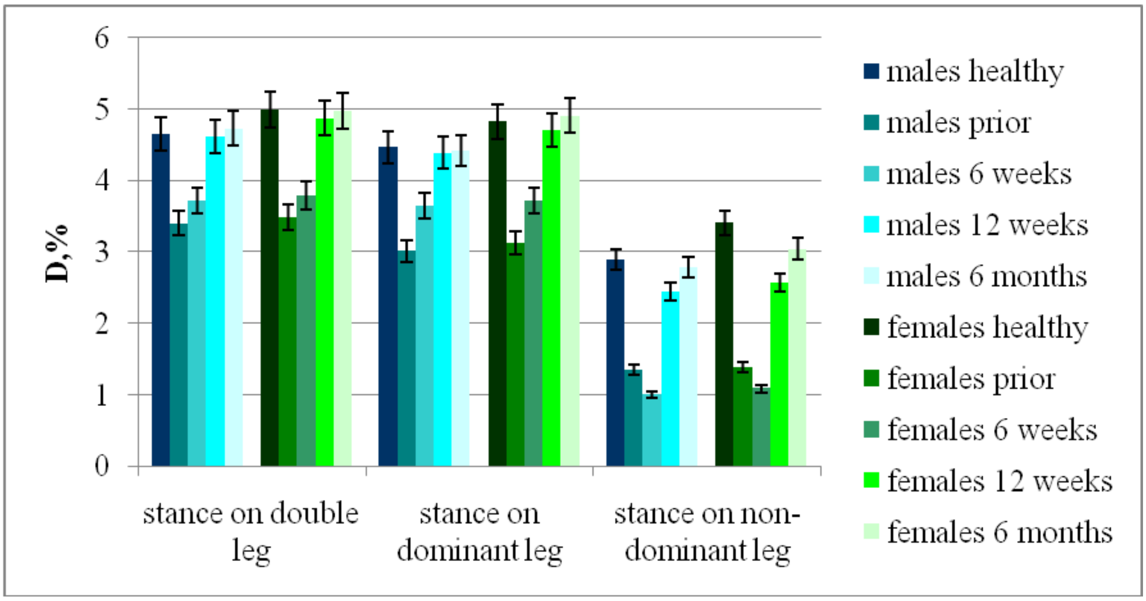

Fig. 10.

Lehr's damping ratio (D, %) for the control group and for patients operated on using a posterior (P) method of exposure, calculated from measurements collected during ultrasound-based tests with sudden perturbation in the first 6 months of the postoperative period

Summarizing: we can conclude, that in the first six postoperative months patients operated on by DL- and AL- approaches the dynamic balancing ability continously increases, but the affected side's dynamic balancing ability differ from the result of controll group. The increase of dynamic balancing ability is faster, in group with P-exposure capsule preserving technique, comparing to other two groups and it doesn't differ significantly from balancing ability of the controll group at the 6th postoperative months.

4.3. Impact of the method of exposure in total hip arthroplasty on self selected walking speed

Investigations on walkway demonstrated, that chosen, controlled walking speeds are match with self-selected comfortable walking speeds of each groups. The 0.8 m/s walking speed, seen in patients with severe hip OA, 3 months after hip arthroplasty, was similar to the walking speed of patients with AL- and DL-exposures. The 1.0 m/s walking speed which is seen in patients with P-exposure 3 months after hip arthroplasty, was similar to the walking speed of patients with AL- and DL-exposures, 6 months after surgery. The 1.2 m/s walking speed which is seen in control group, was similar to the walking speed of patients with P-exposure 6 months after surgery.

The self-selected walking speed in patients with severe hip OA was slower, than self-selected walking speed in control group. After surgery, in the postoperative period the self-selected walkig speed increased at the hip arthroplasty patients; but at patients who was operated on by DL- or AL-exposure, this speed was lower even 6th postoperative month, that is the control group. The reason of it, that the slower walk gives greater stability. At patients with P-exposure 6 months after surgery the self-selected walking speed was similar to that of the control group.

4.4. Impact of the method of exposure in total hip arthroplasty on the variability of gait

Comparing with the preoperative results; 6 months after the hip prosthesis implantation at the DL-group, the coefficient of variance (CV) of spacial- and temporal parameters decreased *(Fig. 11.)*, and the mean coefficient of variance (MeanCV) of angular parameters of knee and hip motions and pelvis at the non-affected side are decreased too, and the MeanCV of joint motions at the affected side are also decreased. These values did not reach the results of controll group at slower walking speed: 0,8 m/s, and 1,0 m/s see *Figs. 11. and 12.* At 1,2 m/s walkig speed the coefficient of variance of spacial- and temporal parameters *(Fig. 11.)*, and the MeanCV of angular parameters *(Fig. 11.)*, doesn't differ significantly from the preoperativ results. This results indicate that in patients in DL-group the lower limb-coordinated movements from stride to stride are worsened.

At the AL-group 6 months after the hip prosthesis implantation, the coefficient of variance of spacial- and temporal parameters at slower walking speed (0,8 m/s, and 1,0 m/s) doesn’t differ significantly from the results of controll group *(Fig. 11.)*; but the MeanCV of motions of affected joint remained lower; comparing to the controll group *(Fig. 12.)* the MeanCV of hip- and knee motions and pelvis rotation were significantly higher.

It is presumable, that the regularity of gait similar to control group is ensured by the increased gait variability of joints of non-affected side and pelvis rotation. Despite the decreased adaptability of the joints of affected side, the gait is coordinated.

This confirms, that the joints of non-affcted side and the pelvis rotation play an important role in compensation mechanism. The decreased hip motion of affected side, and increased variability parameters of hip- and knee motions and pelvis rotation of non-affected side verify the inaccuracy of reproducibility-, and the decreased stability of gait, leading to a higher risk of fall.

In case of all three walking speeds six months after surgery, in patients operated on by P exposure, the variability of spatial-temporal and angular parameters – except the rotation of pelvis – was similar to that of controls, see *Figs. 11. and 12.* These results indicate that patients in group wuth P exposure reproduced comparable lower limb-coordinated movements, and articular flexibility was sufficient to adapt limb movements from stride to stride in order to reproduce comparable limb-coordinated movements with slight deviations at each step, and their role in correction is similar to that of the control group. On the basis of our results, it can be assumed that gait stability six months after hip arthroplasty with posterior exposure and with the joint capsule preserved is similar to that of the control group.

Results shows, that patients operated on using capsule extirpation, by DL- and AL-exposure, the rigidity of joint on affected side decreases the joint flexibility, the imb-coordinated movements with slight deviations at each step and the adaptability to external conditions, so the gait stability is worse even in 6th postoperative months.

In contrast with patients operated on using capsule preserving technique, with P exposure, the variability of spatial-temporal and angular parameters are almost similar to that of the control group at the six postoperative months. It means, that the adaptability to external conditions and the stability of gait are close to normal values.

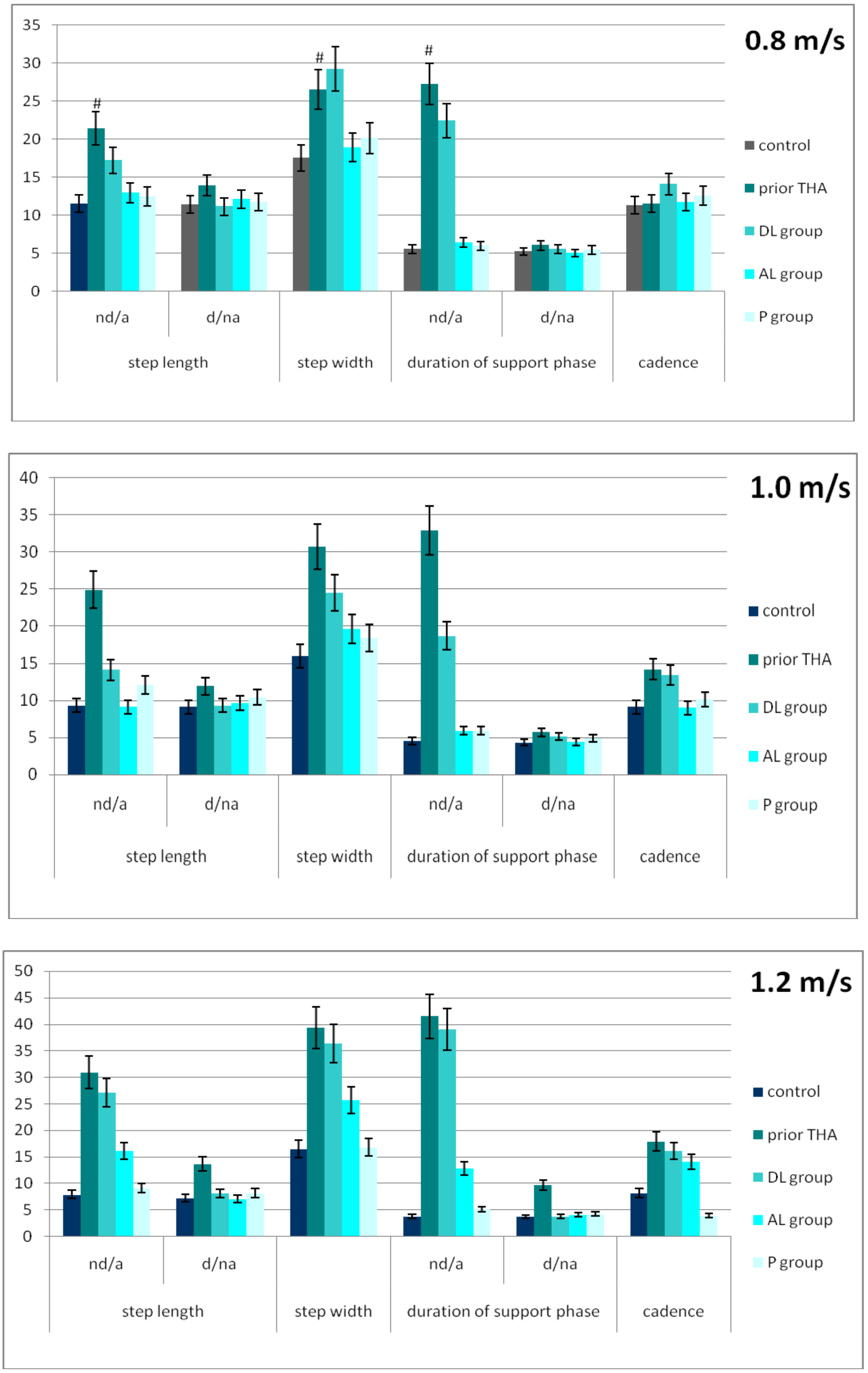

Fig. 11.

The coefficient of variance (CV) of spatial and temporal parameters at different gait speeds in controls and in patients before and 6 months after THA

a/nd: affected side in patients and non-dominant side in healthy subjects; na/d: unaffected side in patients and dominant side in healthy subjects; Group I: patients operated on by traditional direct-lateral (DL) exposure with the joint capsule removed; Group II: patients operated on by antero-lateral (AL) exposure with the joint capsule extirpated; and Group III: patients operated on by posterior (P) exposure with the joint capsule preserved.

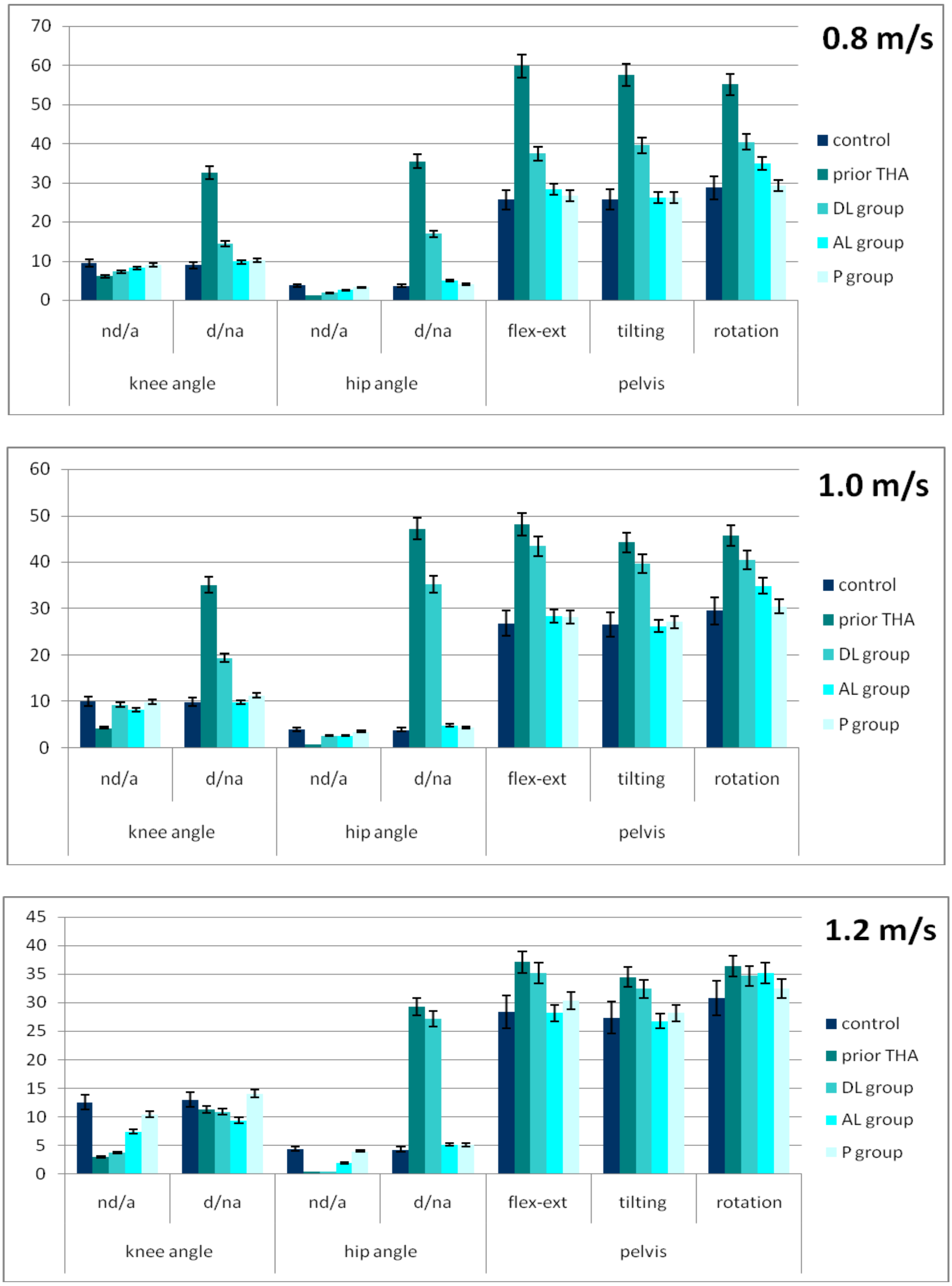

Fig. 12.
The mean coefficient of variance (MeanCV) of angular parameters at different gait speeds in controls and in patients before and 6 months after THA.
a/nd: affected side in patients and non-dominant side in healthy subjects; na/d: unaffected side in patients and dominant side in healthy subjects; Group I: patients operated on by traditional direct-lateral (DL) exposure with the joint capsule removed; Group II: patients operated on by antero-lateral (AL) exposure with the joint capsule extirpated; and Group III: patients operated on by posterior (P) exposure with the joint capsule preserved.

5. CONCLUSIONS

The recently elaborated and internationally accepted motion analysis method of our research group, which is able to investigate the variability of gait and dynamic balancing ability, was used for our measurements. The aim of this study was to characterize how the life quality, the functionality, the self-selected walking speed, the variability of gait and dynamic balancing ability is influenced by the different method (direkt-lateral ─DL, antero-lateral ─AL, posterior capsule preserving ─P) of exposure. The adequate range of joint motion, appropriate accuracy and the balance recovery of walking patient is necessary for secure and harmonic gait. After statistical processing of results of performed motion analysis, the next scientific achievement can concluded:

1. *The different surgical approaches in THA has significant effect on results of life quality (SF-36 and WOMAC), and on functional (HHS) tests in patients involved to our study.*

   Before operation the three patients groups results on life quality and on functional tests did not differ significantly from each other, the initial values of three examined groups were homogeneous.

   The SF-36, WOMAC- and HHS values are continously higher in postoperative period in patients operated on by AL-exposure using capsule extirpation and in patients operated on by P exposure with capsule preserving method and after the 6th postoperative week the results are significantly higher than the results of patients with DL exposure with capsule extirpation *(Figs*. 3. and 4.). The reason of it, that the gait character, the muscles activity of patients operated on by AL- and P-exposure in 6th postoperative months is similar to that of controls. In conclusion, the AL exposure which proceeded in anatomical gap, and the P-exposure using capsule preserving gives better and faster rehabilitation possibilities, than the DL-exposure with musculus gluteus medius detachment and capsule extirpation.

2. *In patients involved to our study the different surgical approaches in THA have significant effect on dynamic balancing ability,* measured *by ultrasound-based sudden perturbation test. The dynamic balancing ability continously increases in patients group operated on by P- exposure with capsule preserving technique and it reaches the values of controls in the 6th postoperative months.*

   The Lehr's damping ratio, calculated in all three methods (standing on both limbs, standing on affected- and non-affected limb) in 6th postoperative week after THA is significantly decreased in case of patients operated on by DL- and AL- exposures *(Figs. 7. and 8. and 9.),* compared to that of the praeoperative result. After that, the dynamic balancing ability continously increases: in postoperative 6th month, standing on both limbs, and on non-affected limb are equal to the values of controls, it means similar to the balancing ability of controls. But standing on the affected limb, the dynamic balancing ability differ from the controls.

In case of P-exposure with capsule preserving, the increase of dynamic balancing ability is faster, comparing to the values of patients operated on using other two exposure methods. This shows us that, the Lehr's damping ratio is significantly higher at the postoperative 6th week, than before the operation and did not differ significantly from the values of the control group at the 6th postoperative month. At the 6th postoperative months, there is a significant difference between the values of males and females, that certify, that the method of balancing is similar to the controls.

3. *In patients involved to our study the self-selected walking speed detected on walkway before THA is significant slower, than the values of control group. After THA, different surgical approaches have significant effect on self-selected walking speed. Just the result of patient group operated on by P exposure, using capsule preserving technique, reaches the values of controls in the 6th postoperative month.*

   In patients with unilateral hip arthrosis before the THA, the self-selected walking speed (0,8 m/s) is significantly lower than that of the control group (1,2 m/s). The self-selected walking speed increases after surgery –independently from exposure method–: The walking speed (1,0 m/s) of patients with DL- and AL-exposure (so with capsule extirpation) does not exceed the control group's values even in the 6th postoperative month. The self-selected walking speed in patients with P-exposure (with capsule preserving method) does not differ significantly from values of control group at the 6th postoperative month. The slower walking gives a better stability so that way, the detected slower walking speed in postoperative period in patients operated on using capsule extirpation method is presumable, that can be tracted from missing of proprioceptive receptor in posterior part of hip joint capsule.

4. *The different surgical approaches in THA have significant effect on the variability of gait, characterized by CVs for spatial-temporal parameters and by the MeanCVs for hip and knee motion. The variability of gait of patients operated on by P-exposure with capsule preserving method is similar to that of the control group, at the end of 6th postoperative months.*

In patients operated on by DL- and AL-, so using a capsule extirpation exposure, the CVs for spatial-temporal parameters are significantly higher, and the MeanCVs for hip and knee motion on affected side are significantly lower than that of the control group in the whole postoperative period (*Figs. 11. and 12.*). It verifies, that the reproduced comparable lower limb-coordinated movements from stride to stride are worsened, and articular flexibility and the role in continous correction of affected side decreased. The CVs for spatial-temporal parameters of non-affected joints and the pelvis rotation significantly increased, compared to the control group. It verifies that, this motion plays important role in compensation mechanism and in formation of stable gait. The CVs for spatial-temporal parameters and the MeanCVs for hip and knee motion, characterizing the variability of gait (*Fig. 11.),* are approached the control group values in the 6th postoperative month at patients group operated on by P exposure using a capsule preserving method, so the regularity of gait returned to normal.

In conclusion we can say, that different surgical approaches in THA have significant effect on result of functional and life quality tests, on self-selected walking speed, and on the two characterizing factor of gait stability: on the dynamic balancing ability and on the variability of gait. In patients operated on by DL- and AL exposure using capsule extirpation, none of the examined parameters reached the values of the control group at the postoperative 6th month, but in patient group operated on by P exposure using capsule preservation the parameters reached that of the control values. During rehabilitation after surgery particular attention must be taken to enhancement of gait stability and balancing ability. The conservative therapy for patients after THA must include special exercises to increase the flexibility of the joint and muscle force on the affected side and to increase muscle strength around the joints on the unaffected side and pelvis and to increase proprioception. It should be taken into account when compiling rehabilitation protocols. Differences related to the method of exposure should be considered when abandoning therapeutic aids.

6. LIST OF PUBLICATIONS

6.1. Publications directly related to the dissertation topic:

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