UNIVERSITATEA DIN ORADEA
FACULTATEA DE GEOGRAFIE, TURISM ŞI SPORT
DEPARTAMENTUL DE EDUCAŢIE FIZICĂ, SPORT ŞI KINETOTERAPIE

REVISTA ROMÂNĂ DE KINETOTERAPIE

ROMANIAN JOURNAL OF PHYSICAL THERAPY

VOLUMUL 27 | NUMĂRUL 46 | 2021

EDITURA UNIVERSITĂȚII DIN ORADEA

Revistă indexată în următoarele Baze de Date Internaţionale (BDI) / Indexed by:

EBSCO Publishing, DOAJ, EuroPub database, Socolar, Index Copernicus International, Google Scholar

Adresa / Editorial Office:
Universitatea din Oradea
Facultatea de Geografie, Turism şi Sport - Departamentul de Educaţie Fizică, Sport şi Kinetoterapie
Str. Universităţii, nr.1, 410087, Oradea
Tel: 04-0259 -408148; 04-0259 -408164; 0722-384835/ Fax: 04-0259 -425921

ISSN 1224 - 6220 / ONLINE ISSN 2068 - 1712

CUPRINS / CONTENTS

REHABILITATION FOR A POST-TRAUMATIC PATELLA DISLOCATION IN A PATIENT WITH HIP DYSPLASIA – A CHALLENGING COMBINATION FOR A PHYSIOTHERAPIST

RECUPERAREA MEDICALĂ ÎN LUXAȚIA DE ROTULĂ POST-TRAUMATICĂ LA UN PACIENT CU DISPLAZIE DE ȘOLD – O COMBINAȚIE DIFICILĂ PENTRU UN FIZIOTERAPEUT

***Oana-Ruxandra STÎNCEL*[1]**

Abstract

Introduction: Hip dysplasia is a well-known cause of hip pain and dysfunction characterized by an increased mechanical load on the hip joint and soft tissues in this region. A common sign of atraumatic hip dysplasia is hyperlaxity caused by repetitive micro traumatic activities, genetic predisposition, or benign hypermobility syndrome. Patellar dislocation is a traumatic disruption of the patella from the femoral trochlear which can result in patellar instability, pain, recurrent dislocations, damage to the medial patellofemoral ligament, and patellofemoral osteoarthritis.

Case presentation: A 30-year-old male patient presents to our clinic with a history of patellar dislocation of the right knee after a traumatic event, a direct lateral blow by a car. After conducting a brief examination, we could observe that the patient revealed a painless dislocating hip issue on the right side, the peculiarity in the patient's medical history representing the justification of the study. The association between both pathologies limited exercise applicability of the rehabilitation protocol and, in order to follow the protocol's progressive stages, we adapted some of the weight-bearing exercises. The patient was asked to complete the Knee Injury and Osteoarthritis Outcome Score (KOOS) and the Hip disability and Osteoarthritis Outcome Score (HOOS) at the baseline of the first evaluation, and also after 1 and 2 months after beginning the rehabilitation program.

Results: After following The Gundersen Health System Rehabilitation Program and knee-hip targeted exercises to increase posterolateral hip musculature we obtained significant improvements in patient-reported outcomes (quality of life and pain) and functional performance (functionality, sports and recreational activities).

Conclusion: Our case highlights the importance of a thorough examination and proper rehabilitation program approach to ensure full recovery. Thus, we can appreciate that a rehabilitation program which addresses the patients' hip dysplasia could cause a considerable decrease in patella dislocation prevalence or recurrence. Using specific instruments as KOOS and HOOS questionnaires to assess patients' opinion about their social, physical, and

Acceptat pentru publicare în 21.05.2021; Publicat pentru prima dată online în 23.05.2021
Pentru citare: Stîncel, O.E. (2021). Rehabilitation for a post-traumatic patella dislocation in a patient with hip dysplasia – a challenging combination for a physiotherapist, *Revista Română de Kinetoterapie*, 27(46), 4-13
[1] West University of Timisoara (ROMANIA), Faculty of Physical Education and Sports; oana.stincel@e-uvt.ro

associated problems helps us provide a better and more concise approach to conducting the rehabilitation program.

Key words: *patella dislocation; hip dysplasia; hyperlaxity; knee injury; hip injury*

Rezumat

Introducere: Displazia de șold este o cauză cunoscută a durerii locale și a disfuncției caracterizate printr-o creștere a încărcării mecanice pe articulația șoldului și pe țesuturile moi din această regiune. Un semn comun în displazia non-traumatică a șoldului este reprezentată de hiperlaxitatea cauzată de activități repetitive microtraumatice, predispoziția genetică sau de sindromul benign de hipermobilitate. Dislocarea patelară reprezintă deplasarea traumatică a patelei din trohleea femurală ceea ce determină instabilitate patelară, durere, dislocări recurente, deteriorarea ligamentului patelofemural medial, și artroză patelofemurală.

Prezentarea cazului: Un pacient de sex masculin în vârstă de 30 de ani se prezintă în cadrul clinicii noastre cu un istoric clinic de dislocare a rotulei drepte în urma unui incident traumatic, o lovitură din lateral cauzată de un accident rutier. În urma unei evaluări succinte, am observat că pacientul prezenta și o dislocare nedureroasă a șoldului drept, particularitatea istoricului medical reprezentând motivația studiului. Asocierea dintre cele două patologii a limitat aplicabilitatea exercițiilor fizice din protocolul de recuperare și, pentru a urma etapele progresive ale protocolului, am adaptat unele dintre exercițiile cu încărcarea greutății corporale. Pacientul a fost rugat să completeze chestionarul Knee Injury and Osteoarthritis Outcome Score (KOOS) și Hip disability and Osteoarthritis Outcome Score (HOOS) la prima evaluare și de asemenea după 1 și 2 luni de la începerea programului de recuperare.

Rezultate: în urma aplicării programului de recuperare The Gundersen Health System și a exercițiilor specifice pentru dezvoltarea musculaturii posterolaterale a șoldului am obținut îmbunătățiri semnificative în rezultatele raportate de către pacient (cu privire la calitatea vieții și nivelul durerii) și performanța funcțională (funcționalitate, sporturi și activități recreative).

Concluzie: Acest caz evidențiază importanța unei examinări amănunțite și o abordare adecvată a unui program de recuperare pentru a asigura o recuperare completă. Astfel, putem aprecia că un program de recuperare care se adresează pacienților cu displazie de șold poate favoriza o scădere considerabilă a prevalenței și recurenței dislocării patelare. Folosind instrumente specifice precum chestionarele KOOS și HOOS pentru a evalua opinia pacienților cu referire la probleme lor sociale, fizice și asociate, ne poate oferi o abordare mai potrivită și mai concisă în elaborarea programului de recuperare.

Cuvinte cheie: *luxație de rotulă; displazie de șold; hiperlaxitate; traumatism al genunchiului; traumatism al șoldului*

Introduction

Hip dysplasia, a well-known cause of hip pain and dysfunction is an orthopedic disorder characterized by an increased mechanical load on the hip joint and soft tissues in this region due to

a shallow coverage of the acetabulum [1, 2]. Hip dysplasia is more likely to occur during infancy, but it is also often discovered in adolescence or adulthood under the medical term "acetabular dysplasia" due to a shallow socket, the acetabulum, which does not support the ball, namely the femoral head. Poor congruency in the hip socket may increase stress on the labrum [3]. The acetabular labrum role in hip biomechanicsis to retain a layer of pressurized intra-articular fluid essential in load support, distribution, and stabilization against distractive forces in the hip joint and to better lubricate the joint [4, 5]. During hip dysplasia, the labrum is exposed to 10 times the normal load [5], which exposes it to increased stress and leads to labral hypertrophy [1], degeneration, and tearing [5]. Most common structures implicated in the appearance of hip pain in patients with hip dysplasia are associated with degeneration and hypertrophy of the labrum and the ligamentum teres, increased stress in the cartilaginous surfaces [6], and a decreased function of the muscles surrounding the hip joint which participate in load transfer and hip stability [7]. A common sign of atraumatic hip dysplasia is hyperlaxity caused by repetitive microtraumatic activities (in sports like ballet or gymnastics), genetic predisposition, or benign hypermobility syndrome [8].

Patellar dislocation is a traumatic disruption of the patella from the femoral trochlear, sometimes referred to as primary patellar dislocation, which can result in patellar instability, pain, recurrent dislocations [9, 10], damage to the medial patellofemoral ligament [11], and patellofemoral osteoarthritis. It is considered the second most seen cause of knee hemarthrosis [12, 13]. Primary and recurrent patellar dislocations can be caused by predisposing factors as hyperlaxity of the knee ligaments, increased femoral anteversion, vastus medialis muscle hypotrophy, or genu valgus.

Case study

A 30-year-old male patient presents to our clinic with a history of patellar dislocation of the right knee after a traumatic event, a direct lateral blow by a car. After the incident, the patient was taken to the emergency room at the County Hospital of Timisoara, where the doctors applied a long-leg cylinder cast with the recommendations to keep the cast for four weeks. The patient did not have a history of prior knee injury, surgery, or instability. After the removal of the cast, the patient continued to use a knee brace to help stabilize the kneecap. We conducted a brief physical examination and noticed that there was moderate effusion around the knee joint, tightness on the lateral retinaculum, tenderness along the iliotibial band, moderate atrophy of the quadriceps muscle, extension deficiency (knee blocked in flexion at about 10°) and passive knee flexion limited at 80°. During the adjoining joints' evaluation, we could observe that the patient revealed a painless dislocating hip issue on the right side when conducting passive knee and hip flexion (beyond 30-40°) in supine position. When assessing the patient from standing the lower limb posture presented overpronation at the feet level (more visible at the hind foot in the right leg than the left). Altered biomechanics have been observed during gait analysis showing a limping pattern with an external tibial torsion and overpronation more visible in the right leg as the patient was out-toeing during walking on a flat surface. The patient stated that he had increased pain with prolonged standing and difficulties when climbing/descending stairs.

An MRI conducted on the 9th of February 2021 stated that there was intra-articular hematic build-up as well as around the patellar bursae, a lateral subluxation of the patella, anosteochondral fracture on the medial condyle of the femur, osseous edema, a millimetric bone fragment

detachment, medial patellar retinaculum avulsion in the patellar insertion, and mild edema at the insertion of the patellar tendon. At the beginning of the rehabilitation program the patient was using crutches and a knee brace.

The peculiarity in the patient's medical history, which described a hip dysplasia on the same side as the affected knee, represented the justification of this study. The association between both pathologies limited exercise applicability of the rehabilitation protocol that we use for patellar dislocations; to follow the protocol's progressive stages, we adapted some of the weight-bearing (closed kinetic chain and open kinetic chain) exercises.

The patient signed an informed consent regarding his participation in this study.

The patient was asked to complete the Knee Injury and Osteoarthritis Outcome Score [14] and the Hip disability and Osteoarthritis Outcome Score [15]. The Knee injury and Osteoarthritis Outcome Score (KOOS) was developed in the 1990s to evaluate the patients' knee symptoms and functionality. KOOS questionnaire consists of 5 subscales regarding pain, other symptoms, functionality in daily living, sports and recreation, and knee related quality of life [14, 16]. The Hip disability and Osteoarthritis Outcome Score (HOOS) assesses patients' hip symptoms and functionality according to their opinion in cases with or without osteoarthritis and consists of 5 subscales, just like KOOS. Both questionnaires can be used on a weekly or even yearly basis; a normalized score (100 indicating no symptoms and 0 indicating extreme symptoms) is calculated for each subscale for both questionnaires. We also conducted a general hypermobility test using the 9-point Beighton score [17, 18] in which a maximum score for ligament laxity is 9 and a score of 0 is tight. Our patient scored 5 out of 9, which indicates a generalized hypermobility of the joints.

The treatment plan was conducted in a conservative manner following objectives such as resolution of pain, swelling and inflammation, recovery of joint motion and flexibility, recovery of muscle strength, improve proprioception, motor patterns and coordination, and eventually return to sport activity.

As rehabilitation protocol we followed The Gundersen Health System Rehabilitation Program [19], which is an evidence-based and soft tissue healing dependent program. Following clinical practice guidelines recommended by Willy et al. (2019) [20], we also focused on including combined hip-knee targeted exercises as increasing strength on the posterolateral hip musculature in order to improve patient-reported outcomes and functional performance.

Knee rehabilitation protocol (Table I) was described to the patient and structured on 6-8 weeks treatment plan. In the first 2 weeks, the primary objectives were to minimize knee joint effusion and to increase knee range of motion per tolerance. In this phase, the strength exercise program included quad sets, hip abduction with resistance from side-lying position to increase strength in the gluteal muscles, calf raises and balance exercises (standing on the affected leg) with wall/chair support. A significant aim of this phase was the normalization of gait pattern. In the second phase (weeks 2-4), the primary objectives were to return to full range of motion, and improve muscle strength, endurance and balance. The patient regained full weight-bearing normalized gait pattern by the 3rd week. In the last phase (4+ weeks),our major goals followed exercises which promoted muscle strength, endurance, balance activities, single leg stance progressions and cuing the patient to regain proper running pattern and reduce hip adduction while running.

Table I. Rehabilitation program [19]

Rehabilitation phase	Goals	Exercises
0-2 weeks (acute phase)	- Normalize gait pattern; - Minimize joint effusion; - Increase ROM per tolerance; - Therapeutic exercises for strengthening, stretching and balance; - Improve and increase quadriceps function;	- Emphasis on return to full knee extension: prone hang exercise; - Restore quadriceps strength: single leg raises in all planes (with 1kg ankle weights, progressing to 1.5 kg by 2nd week); - Weight transfer exercises on single leg stance to challenge unilateral balance/proprioception and partial wall-squats bilateral and unilateral on the affected leg; - Flexibility and strengthening exercises for hamstrings (leg curls) and triceps surae muscle; - Multi-angle isometrics for quadriceps, hamstrings and iliopsoas (with resistance band); - Side-lying exercises to increase hip rotator muscles strength: clam shell exercises progressions and variations (with resistance band and/or ankle weights).
2-4 weeks (minimal protective phase)	- Regain full range of motion; - Increase muscle strength and endurance; - Improve single leg balance;	- Stretching exercises to promote full ROM using wall bars to support the affected leg; - Progression of strengthening exercises in closed kinetic chain: sumo squats (to avoid dislocating hip), partial lunges (with front leg supported on a stepper), hip thrusts (with resistance band above knees and hip externally rotated); - Balance and proprioception exercise: star excursion balance exercise using sliders, on flat surface and on balance board; - Standing glute exercises progressions and variations in closed and open kinetic chain (clam shells and fire hydrants with resistance band around ankles and/or above knees).
4-8 weeks (return to sport activity)	- Progression to improve muscle strength, endurance and balance;	- Closed and open kinetic chain exercises to increase single leg strengthening: multiple directions lunges (with resistance band above knees), from partial squats to sumo squats (with resistance band above knees), step-ups variations (on flat surface and on wobble board); - Running progression – acceleration and deceleration, controlled change of direction, and basic agility drills (figure eight, carioca and shuttle run); - Impact activities started by 6th week – plyometric exercises (double and single leg directional hops on flat, even surface, 90° to 180° jump, and series jumping from/on height) (patient presented >75% strength compared to the unaffected leg).

In the acute phase, the patient exercised without knee brace, but continued wearing it throughout the day and night. Gait pattern without crutches was encouraged under supervision with progression to use 1 crutch by the end of 1st week and no crutches by the end of 2nd week. During exercises which promoted knee flexion patient was advised to be aware of his hip dislocation.
In the second phase of the program the patient continued to use the knee brace for long distance walks or prolonged standing daily activities; during all exercises in standing (closed and open kinetic chain manner), the patient was advised to control hip flexion in order to avoid dislocating the hip.

After 4 weeks into the rehabilitation program we used kinesiotaping during impact exercises to stabilize the knee instead of the knee brace.

By the 8th week of the program we conducted a functional testing consisting of 5 items: balance, single hop in place, triple forward hop, jump/land, and single leg squat. The patient did not have any pain during testing and performed all movements with good control and balance (in all

planes of movement), no knee valgus in landing technique, and good trunk stability at contact with the floor. Only during single leg squat, when on the right leg, we did observe a painless mild dislocation of the hip at hip flexion past 60°.

Results

In order to assess and measure the outcomes of the individualized exercise protocol which we used with our patient, we analyzed the results of both KOOS and HOOS questionnaires. At the beginning of the rehabilitation program our patient presented a score of 15% after completing the KOOS questionnaire and a score of 89.4% after completing the HOOS questionnaire. After 1 month of individualized exercise protocol for the knee and hip, the patient presented significant improvement in both questionnaires scoring a high of 66% for the KOOS and 95% for the HOOS questionnaire; after 2 months both scores reached a high of 91.1%, respectively 98.1% (Figure 1).

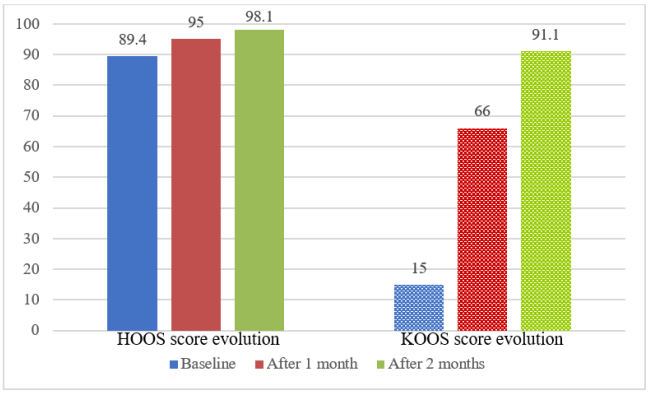

Figure 1. Evolution of KOOS and HOOS at baseline, after 1 month and 2 months of rehabilitation

Between February 22nd (at baseline) and after 2 months, significant improvements were noticed in the quality of life subscale and functionality, and sports and recreational activities subscale for the knee injury, both of them having improved by about 75%, respectively 85%. Pain and symptoms have subsided, and daily living activities improved significantly between baseline evaluation and the evaluation conducted after 2 months (Figure 2).

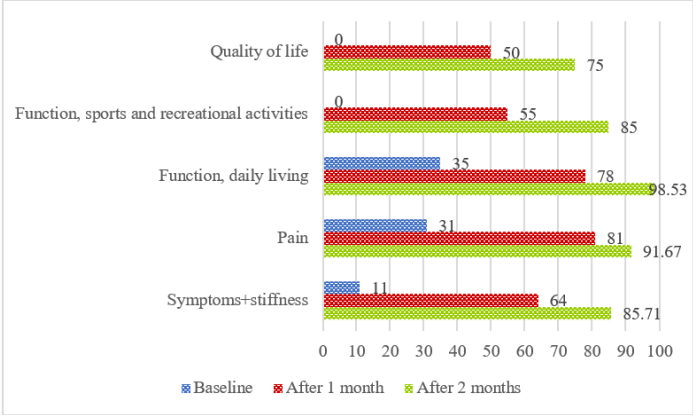

Figure 2. Subscales evolution for Knee injury and Osteoarthritis Outcome Score (KOOS)

Significant improvements were observed regarding the functionality, sports and recreational activities, and quality of life subscales between the first evaluation and after 2 months for the hip (Figure 3).

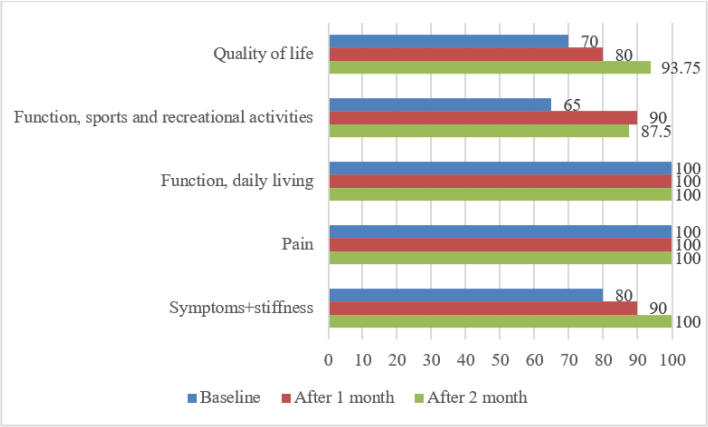

Figure 3. Subscales evolution for Hip disability and Osteoarthritis Outcome Score (HOOS)

Discussions

Li et al. (2013)[21] demonstrated in a study conducted on 75 patients with hip dysplasia that there are structural and biomechanical changes in their knees; it has been proven that the anterior femoral condylar angle of the femur and the groove angle was increased, and the trochlear groove was shallower in these patients. The lateral patella shift was also reduced, and the patellar tilt angle was increased in patients with dislocated hips compared with patients with normal hips. The authors observed that the extent of the mentioned changes differed with the degree of dislocation. Hu et al. (2019) [22] have also found patella alignment abnormality in 138 patients with developmental dysplasia of the hip; these patients' patellar instability was correlated with a more significant valgus angle of the lower limbs, a higher femoral neck torsion angle, quadriceps angle, and sulcus angle. In this context, even if the presented patient's patella dislocation was one of traumatic etiology, we must note that hip dysplasia may be a predisposing factor for such pathology of the knee.

We consider that a noticeable fact that made the rehabilitation easier and functionality improve for the patient was the hypermobility score that the patient presents, but at the same time, looking at the findings by Enix et al. (2015) [11], a predisposing factor in patients with a higher risk of patellar dislocations occurrence is hypermobility, especially in the knee region, as well as a mal-positioning of the patella.

Depending on the MRI findings and the evaluation of the supporting structures of the knee, after a displaced patella is reduced, a period of immobilization is preferred in a cast. A study conducted by Mäenpää and Lehto (1997) [23] suggested that by limiting the period of immobilization to three weeks, they could avoid and reduce muscle atrophy, knee joint restrictions, and retro-patellar crepitation. Although our patient was immobilized for four weeks in a long-leg cylinder cast and presented moderate muscle atrophy, especially on the quadriceps muscle (a difference of 2.5 cm between both thighs at the baseline evaluation), after two months from the baseline evaluation when measuring the thigh at the proximal third, we observed only a 1.5 cm difference between limbs. Several studies conducted by Powers et al. (2003) [24], Sillanpää and Mäenpää (2012) [25], and Van Gemert et al. (2012) [26] that followed patients with patellar

dislocations cases, show return to full activity 8-12 weeks from the time of injury. When assessing the patient after eight weeks from the baseline evaluation, the KOOS score improved significantly, especially regarding function and daily activities subscale (from 35% to 98.53%) and functionality, sports and recreational activities (from 0 to 85%).

Conclusions

Our case highlights the importance of conducting a brief examination in order to elaborate the rehabilitation program approach and to ensure full recovery and a secondary prevention program.

Conducting a thorough clinical examination and discussing the patient's medical history is essential in creating an individualized exercise protocol. We followed clinical practice guidelines recommended for the pathology and diagnosis accordingly, but clinical outcomes as per the examination required minor modifications and variations of the protocol exercises. Thus, we can appreciate that a rehabilitation program which addresses the patients' hip dysplasia could cause a considerable decrease in patella dislocation prevalence or recurrence.

Using specific instruments as KOOS and HOOS questionnaires to assess patients' opinion about their social, physical, and associated problems helps us provide a better and more concise approach to conduct the rehabilitation program.

References

[1] Lewis, C. L., Khuu, A., & Marinko, L. N. (2015). Postural correction reduces hip pain in adult with acetabular dysplasia: A case report. *Manual Therapy*, *20*(3), 508–512.

[2] Mortensen, L., Schultz, J., Elsner, A., Jakobsen, S. S., Søballe, K., Jacobsen, J. S., Kierkegaard, S., Dalgas, U., & Mechlenburg, I. (2018). Progressive resistance training in patients with hip dysplasia: A feasibility study. *Journal of Rehabilitation Medicine*, *50*(8), 751–758

[3] Jacobsen, J. S., Bolvig, L., Hölmich, P., Thorborg, K., Jakobsen, S. S., Søballe, K., & Mechlenburg, I. (2018). Muscle–tendon-related abnormalities detected by ultrasonography are common in symptomatic hip dysplasia. *Archives of Orthopaedic and Trauma Surgery*, *138*(8), 1059–1067

[4] Bsat, S., Frei, H., & Beaulé, P. E. (2016). The acetabular labrum: A review of its function. *Bone and Joint Journal*, *98-B*(6), 730–735

[5] Garabekyan, T., Ashwell, Z., Chadayammuri, V., Jesse, M. K., Pascual-Garrido, C., Petersen, B., & Mei-Dan, O. (2016). Lateral acetabular coverage predicts the size of the hip labrum. *American Journal of Sports Medicine*, *44*(6), 1582–1589

[6] Ross, J. R., Zaltz, I., Nepple, J. J., Schoenecker, P. L., & Clohisy, J. C. (2011). Arthroscopic Disease Classification and Interventions as an Adjunct in the Treatment of Acetabular Dysplasia. *American Journal of Sports Medicine*, *39*(1_suppl), 72S-78S

[7] Dumont, G. D. (2016). Hip Instability: Current Concepts and Treatment Options. *Clinics in Sports Medicine*, *35*(3), 435–447

[8] Johannsen, A. M., Behn, A. W., Shibata, K., Ejnisman, L., Thio, T., & Safran, M. R. (2019). The Role of Anterior Capsular Laxity in Hip Microinstability: A Novel Biomechanical Model. *American Journal of Sports Medicine*, *47*(5), 1151–1158

[9] Smith, T. O., Chester, R., Cross, J., Hunt, N., Clark, A., & Donell, S. T. (2015). Rehabilitation following first-time patellar dislocation: A randomised controlled trial of purported vastus medialis obliquus muscle versus general quadriceps strengthening exercises. *Knee*, *22*(4), 313–320

[10] Stefancin, J. J., & Parker, R. D. (2007). First-time traumatic patellar dislocation: A systematic review. *Clinical Orthopaedics and Related Research*, *455*, 93–101

[11] Enix, D. E., Sudkamp, K., Scali, F., Keating, R., & Welk, A. (2015). Management of Acute Patellar Dislocation: A Case Report. *Journal of Chiropractic Medicine*, *14*(3), 212–219

[12] Buchner, M., Baudendistel, B., Sabo, D., & Schmitt, H. (2005). Acute Traumatic Primary Patellar Dislocation Long-Term Results Comparing Conservative and Surgical Treatment Conclusions: Even with a focus on acute traumatic etiology and. *Clin J Sport Med*, *15*(2), 62–66

[13] Tsai, C. H., Hsu, C. J., Hung, C. H., & Hsu, H. C. (2012). Primary traumatic patellar dislocation. *Journal of Orthopaedic Surgery and Research*, *7*(1), 1–6

[14] Roos, E. M., & Lohmander, L. S. (2003). Health and Quality of Life Outcomes The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis The Knee injury and Osteoarthritis Outcome Score (KOOS). *Health and Quality of Life Outcomes*, *1*(64), 1–8

[15] Klassbo, M., Larsson, E., & Mannevik, E. (2008). Hip disability and osteoarthritis outcome score. *BMC Musculoskeletal Disorders*, *May*, 1–7.

[16] Roos, E. M., & Toksvig-Larsen, S. (2003). *KOOS validation WOMAC TKRA-BMC-03.pdf*. *10*, 1–10.

[17] Cooper, D. J., Scammell, B. E., Batt, M. E., & Palmer, D. (2018). Development and validation of self-reported line drawings of the modified Beighton score for the assessment of generalised joint hypermobility. *BMC Medical Research Methodology*, *18*(1), 1–8

[18] Naal, F. D., Hatzung, G., Müller, A., Impellizzeri, F., & Leunig, M. (2014). Validation of a self-reported Beighton score to assess hypermobility in patients with femoroacetabular impingement. *International Orthopaedics*, *38*(11), 2245–2250

[19] Gundersen Health System (2021, March 22). *Patellofemoral Dislocation Rehabilitation Program – Accelerated.* https://www.gundersenhealth.org/app/files/public/e72f2a70-b6c7-4aa0-81d1-478532d17d2d/Sports-Medicine-Protocol-Patellofemoral-Dislocation-Accelerated.pdf

[20] Willy, R. W., Hoglund, L. T., Barton, C. J., Bolgla, L. A., Scalzitti, D. A., Logerstedt, D. S., Lynch, A. D., Snyder-Mackler, L., & McDonough, C. M. (2019). Patellofemoral pain clinical practice guidelines linked to the international classification of functioning, disability and health from the academy of orthopaedic physical therapy of the American physical therapy association. *Journal of Orthopaedic and Sports Physical Therapy*, *49*(9), CPG1–CPG95

[21] Li, H., Qu, X., Wang, Y., Dai, K., & Zhu, Z. (2013). Morphological analysis of the knee joint in patients with hip dysplasia. *Knee Surgery, Sports Traumatology, Arthroscopy*, *21*(9), 2081–2088

[22] Hu, B., Sang, L., Gao, D., Wu, Y., Zhang, H., & Luo, D. (2019). Patella alignment abnormality in patients with developmental dysplasia of the hip. *Journal of Orthopaedic Surgery*, *27*(2), 1–7

[23] Mäenpää, H., & Lehto, M. U. K. (1997). Patellar dislocation. The long-term results of nonoperative management in 100 patients. *American Journal of Sports Medicine*, *25*(2), 213–217

[24] Powers, C. M., Ward, S. R., Fredericson, M., Guillet, M., & Shellock, F. G. (2003). Patellofemoral Kinematics during Weight-Bearing and Non-Weight-Bearing Knee Extension in Persons with Lateral Subluxation of the Patella: A Preliminary Study. *Journal of Orthopaedic and Sports Physical Therapy*, *33*(11), 677–685

[25] Sillanpää, P. J., & Mäenpää, H. M. (2012). First-time patellar dislocation: Surgery or conservative treatment? *Sports Medicine and Arthroscopy Review*, *20*(3), 128–135

[26] Van Gemert, J. P., De Vree, L. M., Hessels, R. A. P. A., & Gaakeer, M. I. (2012). Patellar dislocation: Cylinder cast, splint or brace? An evidence-based review of the literature. *International Journal of Emergency Medicine*, *5*(1)

A PSHYCHOMOTRIC APPROACH FOR THE CORRECTION OF CHILDREN'S GAIT – THE ADAPTED MOVEMENT SCORE METHOD

CORECTAREA MERSULUI LA COPII PRIN ABORDAREA PSIHOMOTRICĂ - METODA PARTITURII MIȘCĂRII ADAPTATĂ

Camelia MOLDOVAN[1], Ion Dănuț MOLDOVAN[2], Dorina IANC[3]

Abstract

Walking is a complex process which requires full control throughout its entire duration, from walking inception up to locomotion ending, imposing continuous adjustments regarding speed, step length and width, direction and posture in response to internal and external stimuli. The general objective of this paper was highlighting the effectiveness of using the "Movement score" psychometric approach to improve the quality of walking in children with feet deficiencies. Human walking is a standard, repeatable and rhythmic locomotor act, having biomechanical patterns that are common for all healthy subjects. The human brain plays a very important role in the act of walking with cultural, cognitive and psychological factors that can affect how we walk. Psychomotric education is the starting point for the learning process of children. The movement score, also called "The Hungarian movement method" provides an efficient and plan-based tool that enables educators to playfully develop the physical, cognitive, affective and behavioural functions by adapting to the physical and psychological characteristics of early childhood. In order to create a gait motor engram which is as correct and precise as possible, the "Movement score" method can be use to obtain the conditions for the correct walking parameters. The introduction of an adapted "Movement score" method in the usual physiotherapy program can improve the kinesthetic image of walking.

Key words: *motor engram, score papers, walking re-education*

Rezumat

Mersul este un act complex care necesită control pe tot parcursul desfășurării lui de la inițierea mersului până la finalul locomoției, cu ajustări continue ale vitezei, lungimii și lățimii pasului, a direcției și posturii în mers ca răspuns la stimuli interni și externi. Obiectivul general al acestei lucrări a fost evidențierea eficacității utilizării metodei psihomotrice „Partitura mișcării", pentru îmbunătățirea calitativă a mersului la copiii cu deficiențe ale piciorului. Mersul uman este un act locomotor standard, repetabil, ritmic, cu

Acceptat pentru publicare în 30.05.2021; Publicat pentru prima dată online în 01.06.2021
Pentru citare: Moldovan, C., Moldovan, I.-D., Ianc, D. (2021). A pshychomotric approach for the correction of children's gait – the adapted Movement score method, *Revista Română de Kinetoterapie*, 27(46), 14-19
[1] Centrul Școlar de Educație Incluzivă Nr. 3, Reghin
[2] Școala Gimnazială „Florea Bogdan", Reghin
[3] Autor corespondent, Universitatea din Oradea, Departamentul de Educație Fizică, Sport și Kinetoterapie; dianc@uoradea.ro

modele biomecanice raportate ca fiind comune la toți subiecții sănătoși. Creierul uman are un rol foarte important în timpul mersului, cu factori psihologici, cognitive și culturali care pot afecta modul de a merge. Educația psihomotorie este „punctul de plecare" al procesului de învățare a copiilor. Partitura mișcării numită și „Metoda de mișcare ungară" oferă un instrument planificat și eficient pentru educatori să dezvolte în mod ludic funcțiile fizice, cognitive, afective și comportamentale ale copilului prin adaptarea la caracteristicile fizice și psihologice ale copilăriei timpurii. Pentru crearea unor engrame motorii cât mai corecte ale mersului se poate adapta metoda „Partitura mișcării" pentru obținerea condițiilor pentru parametrii unui mers corect. Introducerea metodei "Partitura mișcării" în programul kinetic cu adaptările adecvate, poate îmbunătăți imaginea kinestezică a mersului.

Cuvinte cheie: *engramă motorie, foi de partitură, reeducarea mersului*

Introduction

Schools and teachers have always played, ever since the beginning years, an important part in the development process of children. Regarding physical activity, professionals can use recreational games that stimulate different areas of child development: socially, cognitively, affectively and motor development [1].

Through games, a child gets involved and feels the need to collaborate with all other participants. Playing will develop essential abilities for the future essential traits of the child, such as attention span, affection, ability to focus and other psychomotor perceptive abilities. "A playful lesson doesn't necessarily have to include games or toys. The playful attitude of the teacher and, subsequently, of children is what brings playfulness in a classroom" [2]. Psychomotor education with children must provide an essential starting point in the motor, emotional and psychological development of the child by creating opportunities for playing games. Taking part in such activities, the child develops the perceptive abilities by means of adjusting his psychomotric development [3].

The purpose of this paper has been the perfectioning of the process of re-educating the way children with foot deficiencies walk using the „Movement score" method. This method contains the tools for creating a correct walking pattern.

The general objective of this paper has been to highlight the efficiency of using the psychomotor method „Movement score" for significantly improving the quality of how children with foot deficiencies walk.

Walking

Human walking is a standard, repeatable and rhythmic locomotor act, having biomechanical patterns that are common for all healthy subjects [4]. Walking inception is related to signals coming from the volitional processing of the cerebral cortex or from the emotional processing coming from the limbic system. After its inception, walking becomes an automatically controlled movement [5]. Although walking is based on an automatic mechanism rooted in the similarities of worldwide walking models, there are some psycho-sociocultural characteristics that can influence the walking parameters [6]. The human brain plays a very important part during walking because of psychological, cognitive and cultural factors that can affect it.

Psychomotor education is the starting point for the educational process of children.

Mastering the body is the first condition for mastering the behaviour. Therefore, the relationship between the psychological and motor aspect is mandatory for the subject to successfully adapt to the surrounding environment.

The Movement score

One recently-developed approach for developing the psychomotor abilities is called the „Movement score". This method mainly focuses on physical activities, but it can also be used in the absence of a gym. Overall, it provides an opportunity for physical exercise to become a defining day-to-day experience. This method was developed by Gábor Magyar, a psychologist and special education teacher, resident in Szeged, Hungary and its team. The Movement score, also known as „The Hungarian movement method" offers teachers a plan-based and efficient instrument for playfully developing the physical, cognitive, affective and behavioural functions of the child by adapting the physical and psychological characteristics of early childhood.

The method uses small carpets or plates with different shapes, numbers and colors that are placed one after the other, each with its own purpose (Fig. 1).

Figure 1. The plates for Movement score

The „artistic" name of this method is given by the plates which have different plant or animal-based shapes and can be placed in several different ways, depending on the objectives, just as musical score sheets can be placed in various ways as building blocks of a song. Therefore, this method requires creativity and emphasizes the mastery of a teacher.

The colors and shapes on the score sheets and the way they are combined in different ways helps with the development of a mental image of movement. Complex movement is decomposed into simple, elementary units of movement.

For creating the motor engrams as correctly as possible, the method can be adapted for obtaining the parameters for a correct movement process.

The spatial and temporal characteristics of movement are represented through symbols that relate to the fantasies of young children: squirrels, bunnies, eagles, footprints, etc. These symbols are structured with an algorithmic approach, similar to a musical score, so that the child can successfully perform the traced task.

The score sheets direct the movement. Everything is explicit through the use of symbols:

- positioning the foot on the ground, the distance between steps, sole orientation, the movement direction: they are all guided by the plantar shape of the marks on the score sheets
- laterality is developed by assigning the blue color for the right side and the red color for the left side
- the flowers represent rotating on one leg and the rotation direction
- the pictures which contain animals show the spatial position of the arms (the eagle with open wings represents the position with laterally-straightened upper limbs, the squirrel represents the position with front-straightened upper limbs, the bunny represents the position with both hands up etc)
- the dots on the score sheets represent the number of to-be-performed movements, the duration of one movement or they simply regulate the movement succession

The accessories of the Movement score are:

- the domino pouches which have the same symbol as the scores
- a mirror that ensures the correction and self-correction of movement
- hoops and canes
- musical instruments
- balls

Several benefits of the usage of the Movement score have been noticed, such aș:

- it develops the general motricity, especially the fundamental movements (walking, jumping, running, rotating)
- it develops the basic natural-born physical abilities (strength, velocity, knack)
- it develops the psychomotricity
- it develops the motor color and shape structures, aș well aș combining them în different ways for creating a mental image of movement
- it provides the success feeling, which fuel the motivation of the subjects
- creating and developing of basic skills and knowledge
- the affective, cognitive and behavioural regulation of activity.

In order to re-educate the movement, the score sheets can be placed such that a correction, or even hypercorrection can be obtained, depending on the degree of deficiency of the foot. What's more, the sheets can be positioned at variable distances based on the step length. Some other ways of achieving the goals are:

- in order to correctly move by obeying the movement phases – for the heel attack, the contour of the heel is emphasized with a different colour than the rest of the heel
- in order to avoid the pulling of the foot on the ground, several obstacles can be used
- in order to obtain a match between the right (left) foot and the given footprint, scarves are used for tying the legs
- the length of the track can be altered to meet the number of score sheets

Conclusions

Walking is a complex process which requires full control throughout its entire duration, from walking inception up to locomotion ending, imposing continuous adjustments regarding speed, step length and width, direction and posture in response to internal and external stimuli. The knowledge of the subject regarding his/her own way of stepping and, implicitly, moving, have been referred to, in the specialty literature, as "motor knowledge" [8] or conscious monitoring of motor actions. Taking into account the relationship between the legs, feet and the central nervous system which results in the postural response, and also given that the abnormal walking pattern can be influenced and revised, the kinetic program "Movement score" can be used. Following this program can result in a correct walking pattern by adjusting some parameters of the plantar diagram.

One aspect of walking that can easily be improved by using the Movement score is the heel attack, because, in order to obtain this reflex for correctly placing the foot on the ground in an attacking position, the heel area can be emphasized on the score sheet. After a series of repetitions, a correct movement engram can be obtained.

In conclusion, introducing the "Movement score" method with the appropriate adaptations in the kinetic program can significantly improve the kinaesthetic image of movement.

Playful activities must be understood and applied as practices that promote learning and develop different motor, psychological, social and affective aspects of the human being. Games must be promoted by means of the psychomotric activities in an enjoyable and motivating manner. The teacher must prioritize activities which develop the human mind and body, thus the human being as a whole, especially during physical exercise and physiotherapy program. Playing provides a direct channel of communication, thus the child can express his/her feelings and wishes easily. This makes playing a very valuable instrument in both physical exercise classes and physiotherapy program.

Bibliography

[1] Silva D.A. (2013). The importance of psychomotricity in children education. Work of conclusion of course (graduation in physical education*). College of education and health sciences*. Centro Universitário de Brasília. Brasília, p. 23

[2] https://www.cdof.com.br/recrea22.htm, accessed in 15.09.2020

[3] Rossi A. (2012). Considerations about the psychomotricity in children's Education. *Valley Voices Magazine*: *academic publications*, UFVJM, no 1, year 1, p. 18

[4] Iosa M. et al. (2013). The golden ratio of gait harmony: repetitive proportions of repetitive gait phases. *BioMed Research International.* 2013: 918642.
[5] Takakusaki K. (2013). Neurophysiology of Gait: From the Spinal Cord to the Frontal Lobe. *Movement Disorders.* 2013: 1483-1491.
[6] Ebersbach G. et al. (2000). Sociocultural differences in gait. *Movement Disorders*. 2000: 1145-1147.
[7] http://www.mozgaskotta.hu/bemutatkozas.html, accessed in 10.09.2020
[8] Nielsen, T. (1978) Acts. Analysis and synthesis of human acting, concerning the subject and from the standpoint of the subject. Copenhagen: *Dansk Psykologisk Forlag*.

THE EFFECTS OF A COMPLEX RECOVERY PROGRAM ON PAIN REDUCTION AND IMPROVEMENT OF LUMBAR SPINE MOBILITY IN PATIENTS WITH L4-L5 LUMBAR DISC HERNIATION

EFECTELE UNUI PROGRAM DE RECUPERARE COMPLEX ASUPRA REDUCERII DURERII ȘI ÎMBUNĂTĂȚIRII MOBILITĂȚII COLOANEI VERTEBRALE LOMBARE LA PACIENȚII CU HERNIE DE DISC LOMBARĂ L4-L5

Emilian TARCĂU[1], Ioan Cosmin BOCA[2], Anca OLTEAN[1], Andrei COTRĂU[1], Mihai Ionel ILLE[1]

Abstract

Hypothesis: In our study we started from the hypothesis that, by using a complex program, which uses as means of rehabilitation massage, electrotherapy, hydrotherapy and physical therapy in patients with lumbar disc herniation, a decrease in pain and an improvement in spine mobility are to be expected.

Material and methods: The study was performed on a number of 23 patients who were diagnosed with hernia of the L4-L5 intervertebral disc. They followed a recovery program which included a 15 minute massage session, 10 minutes of electrotherapy with diadynamic currents, 20 minutes of hydrokinetotherapy in the thermal water of Băile Felix Spa Town with its specific properties, at a water temperature of 37°C and 40 minutes of individual physiotherapy. Pain was assessed by using the Numerical Pain Rating Scale (NPRS), and spinal mobility by using fingertip-to-floor test (FTF), inverted Schober and Schober test, left and right lateral trunk tilt.

Results: The pain decreased in intensity in all 3 situations considered. Thus, in the morning it improved by 2.61 ± 1.75 deck of intensity, after the physiotherapy session by 1.57 ± 1.34 points, and in the evening by 2.43 ± 1.56 points.

Spine mobility increased for all movements analyzed, so that flexion had a positive evolution in both the fingertip-to-floor test (5.63 ± 4.76 cm gain) and the Schober test (0.61 ± 0.50 cm) extension gained 0.57 ± 0.47 cm on the average of sample, the right lateral trunk tilt 1.16 ± 1.37 cm, and the left lateral trunk tilt 0.80 ± 1.12 cm.

Conclusions: The conclusion reached was that the application of a complex recovery program, which uses massage, electrotherapy, hydrotherapy and physical therapy in patients with lumbar disc herniation at L4-L5, reduces the intensity of pain and improves spine mobility.

Acceptat pentru publicare în 14.06.2021; Publicat pentru prima dată online în 15.06.2021
Pentru citare: Tarcău, E., Boca, I.C., Oltean, A., Cotrău, A., Ille, M.I. (2021). The effects of a complex recovery program on pain reduction and improvement of lumbar spine mobility in patients with L4-L5 lumbar disc herniation, *Revista Română de Kinetoterapie*, 27(46), 20-26

[1] Universitatea din Oradea, Departamentul de Educație Fizică, Sport și Kinetoterapie
[2] Autor corespondent, Universitatea din Oradea, Departamentul de Educație Fizică, Sport și Kinetoterapie; icboca@yahoo.com

Keywords: *lumbar spine, pain, joint mobility, rehabilitation*

Rezumat

Ipoteza: În studiul nostru s-a plecat de la ipoteza conform căreia, prin utilizarea unui program complex, ce utilizează ca și mijloace de recuperare masajul, electroterapia, hidroterapia și kinetoterapia la pacienții hernie discală lombară, se așteaptă să se reducă durerea și să se îmbunătățească mobilitatea coloanei vertebrale.

Material și metode: Studiul s-a realizat pe un număr de 23 de pacienți care au prezentat diagnosticul de herniela nivelul discului intervertebral L4-L5. Ei au urmat un program de recuperare ce a cuprins masaj cu o durată de 15 minute, electroterapie cu curenți diadinamici timp de 10 minute, hidrokinetoterapie cu apă termală cu proprietățile specifice Stațiunii Băile Felix, timp de 20 de minute, la o temperatură a apei de 37°C și kinetoterapie individuală, timp de 40 de minute. Au fost evaluate durerea cu ajutorul scalei Numerical Pain Rating Scale (NPRS), și mobilitatea coloanei vertebrale (testul indice-sol, testul Schober și Schober inversat, inflexiunea laterală stânga și dreapta).

Rezultate: Durerea a scăzut în intensitate în toate cele 3 situații luate în considerare. Astfel dimineața s-a îmbunătățit cu 2,61 ± 1,75 punte de intensitate, după ședința de kinetoterapie cu 1,57 ± 1,34 puncte, iar seara cu 2,43 ± 1,56 puncte.

Mobilitatea coloanei vertebrale a crescut pentru toate mișcările analizate, astfel că flexia a avut o evoluție pozitivă atât la testul indice-sol (5,63 ± 4,76 cm), cât și la testul Schober (0,61 ± 0,50 cm). Extensia a câștigat 0,57 ± 0,47 cm pe media lotului, inflexiunea laterală dreapta 1,16 ± 1,37 cm, iar inflexiunea laterală stânga 0,80 ± 1,12 cm.

Concluzii: Concluzia la care s-a ajuns a fost aceea că, aplicarea unui program complex de recuperare, ce utilizează ca și mijloace masajul, electroterapia, hidroterapia și kinetoterapia la pacienții hernie discală lombară la nivel L4-L5, duce la reducerea intensității durerii și se îmbunătățește mobilitatea coloanei vertebrale.

Cuvinte cheie: *coloana vertebrală lombară, durere, mobilitate articulară, recuperare*

Introduction

Lumbar disk herniation accompanied by an increase in pain intensity at this level and a stiffening of the spine, is nowadays one of the most frequent pathologies addressing rehabilitation services. Thus, Papageorgiou, says that the monthly prevalence of back pain is estimated at 43% of the population [1], so that back pain is the second cause of general practitioner consultations after the ordinary cold [2]. The main causes of disc herniation in the lumbar area are, apart from the lack of movement, postural changes (mostly determined by long-held positions and associated with certain professions) and lifting weights repeatedly.

Repetitive physical activities that overload the lumbar spine in flexion can eventually cause the destruction of the posterior fibrous ring [3]. In this context, a study of 177 patients shows that certain types of lifts are associated with an increased risk of herniation of the intervertebral disc. In particular, lifting objects weighing 25 kg or more, with extended knees and bent torso, increases the risk by almost 4 times, and it multiplies up to 7 times if the movement is performed more than 25 times a day. [4]

Depending on the duration of lumbar pain, Șchiopu, says that lumbar pain is classified as acute pain, lasting less than 6 weeks; subacute pain with a development between 6 and 12 weeks and chronic pain whose evolution exceeds 12 weeks or has frequent recurrences [5]. Regarding the type of pain (acute, subacute, chronic), the patient is under stress which creates discomfort primarily physically, affecting functional status. With the persistence of this pain, when the pathology becomes chronic, the physical discomfort is gradually transferred to the mental level, patients being often emotionally affected, experiencing depressive states and anxiety [6]. All these considerations draw attention to an early and complex intervention in the treatment of lumbar disc herniation.

Study hypothesis

By using a complex program that uses massage, electrotherapy, hydrotherapy and physical therapy in lumbar disc herniation patients as a means of rehabilitation, a decrease in pain and an improvement in spine mobility are expected.

Material and methods

For the study were selected 23 people, who presented the diagnosis of hernia at the level of the intervertebral disc L4-L5 at the treatment base of Thermal Hotel in Băile Felix. Patients were evaluated at the beginning of the recovery program as well as at the end. They each participated to 10 rehabilitation sessions.

Pain was assessed on the basis of the Numerical Pain Rating Scale (NPRS). This scale, like the visual analog scale (VAS), is used by the patient to describe the degree of pain felt. The scale has ratings from 0 to 10 (11 items) [7] and the patient will describe the pain he or she has felt in the last 24 hours [8]. This scale has been chosen because it can be used both in written and verbal communication [9]. For the validity of the scale, it has been demonstrated that NPRS is correlated with VAS in patients with rheumatic diseases and other chronic conditions of their pain, correlations values between 0.86 and 0.95. [10]

For spinal mobility, the index-ground and Schober tests for flexion, the Inverted Schober test for extension, and lateral trunk tilt were used. The patient in orthostatism, with his back against the wall, will be asked to keep his arms close to his thighs. The index-ground test consists of the anterior flexion of the torso, with the knees extended in an attempt to reach the tip of the toes with the hands. To determine the score, mark with "-" (the number of centimeters needed until the support surface is reached) and the sign "+" (the number of centimeters that have exceeded the level of the support surface or the tiptoes). [11]

For the Schober test, the patient is in orthostatism and the examiner draws a horizontal line that marks the spinous process S1. The next horizontal line is marked 10 cm above the first line and the patient will be instructed to perform the flexion of the torso (with the knees extended) in an attempt to touch his feet. The examiner measures the new distance between the two lines. The difference between the initial and the final measurement indicates the amount of lumbar flexion. The test is positive when the increase is no more than 5 cm.

The Inverted Schober test is the opposite of the Schober test. The patient in orthostatism will be asked to extend the spine as much as possible. The result is obtained by the difference between the initial measurement (10 cm) and the final measurement.

For lateral trunk tilt assessment, the patient is in orthostatism, with his back against the wall, the examiner will mark with a horizontal line, on the side of the thigh, the point where the dactilion (tip of the medius finger) is. The patient is asked to tilt the trunk on a side without detaching the back from the wall. Another horizontal line will mark the new landmark of the dactilion and the difference between the 2 landmarks on both sides will be measured.

The objectives based on initial assessments and on the expectations at the end of the rehabilitation period were:

- Reducing pain intensity;
- Regaining the amplitude of movement on the movements of flexion, extension and lateral trunk tilt;
- Increasing the strength of the abdominal and gluteal muscles;
- Maintaining an optimal balance of strength between the abdominal muscles and lumbar extensors, between the piriformis muscle and small and medium glutes, toning in condition of shortening of the abdominal muscles, toning in conditions of elongation of the paravertebral muscles;
- Pelvic rebalancing and delordosis / lordosis;
- Maintaining a proper body alignment between the pelvis and lumbar spine.

The rehabilitation program included a 15 minute massage session, 10 minutes of electrotherapy with diadynamic currents, 20 minutes of hydrokinetotherapy with thermal water with the specific properties of Băile Felix Spa Town, at a water temperature of 37°C and 40 minutes of physiotherapy individually designed.

Results

Pain indicates initially the higher intensity in the morning, group average was 3.65 ± 2.01, and the lowest, after the physiotherapy session, mean 1.96 ± 1.74. After 10 sessions of rehabilitation pain intensity decreased to 0.39 ± 0.58, after the physiotherapy session with an average to low effect size (0.332) and 1.00 ± 0.85 in the morning, the effect size being average (0.458). (Table 1)

Table 1. Results of pain intensity assessment

How pain intensity was perceived	Initial	Final	Difference	Effect size
Morning	3.65 ± 2.01	1.00 ± 0.85	2.61 ± 1.75	0.458
After the physical therapy session	1.96 ± 1.74	0 , 39 ± 0 , 58	1.57 ± 1.34	0.332
In the evening	3.00 ± 1.68	0.57 ± 0.79	2.43 ± 1.56	0.940

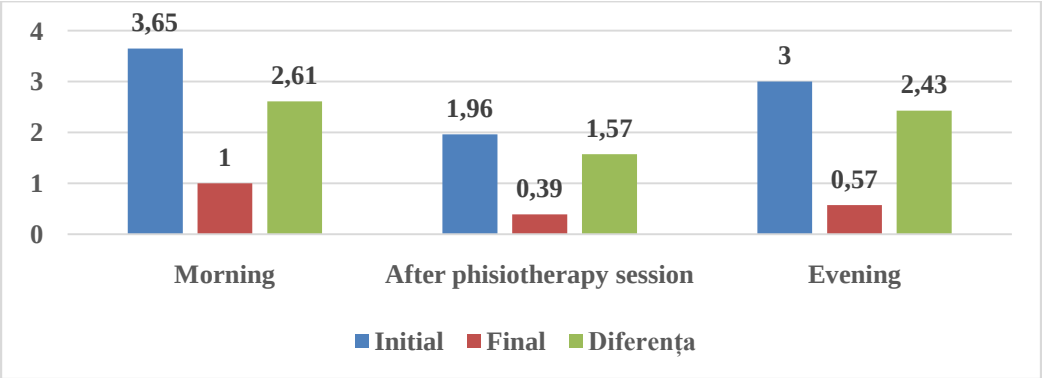

Figure 1. Pain analysis - group average

In the evening, the pain intensity values were between the other two measurements of the day, in both the initial evaluation with an average of 3.00 ± 1.68 and the final evaluation with an average of 0.57 ± 0.79, the effect size being high (0.940). (Figure 1)

The mobility of the spine was analyzed in flexion, extension and lateral tilt movements, the flexion being analyzed both by the index-ground test and by the Schober test.

At the initial evaluation, with the help of the FTF test, a flexion deficit of -15.41 ± 9.28 cm resulted, and at the final evaluation the deficit was reduced to -9.70 ± 10.66 cm, so a gain of 5.63 ± 4.76 cm and a small effect size (0.143). The Schober test also indicates a favorable evolution of the mobility of the spine, the final gain being 0.61 ± 0.50 cm, the size of the effect being also in this case a low one (0.160).

The favorable effects of the recovery program followed on the mobility of the spine are also noticed in the other evaluated movements, the results being highlighted in table 3 and figure 2.

Table 3. Spine mobility analysis

Movement	Initial	Final	Difference	Effect size
Flexion (fingertip-to-floor test)	-15.41 ± 9.28	-9.70 ± 10.66	5.63 ± 4.76	0.143
Flexion (Schober test)	13.88 ± 1.02	14.49 ± 0.89	0.61 ± 0.50	0.160
Extension (inverted Schober test)	8.91 ± 0.43	8.31 ± 0.56	0.57 ± 0.47	0.303
Right side tilt	12.67 ± 2.73	13.82 ± 2.58	1.16 ± 1.37	0, 108
Left side tilt	13.11 ± 3.20	13.91 ± 3.26	0.80 ± 1.12	0.062

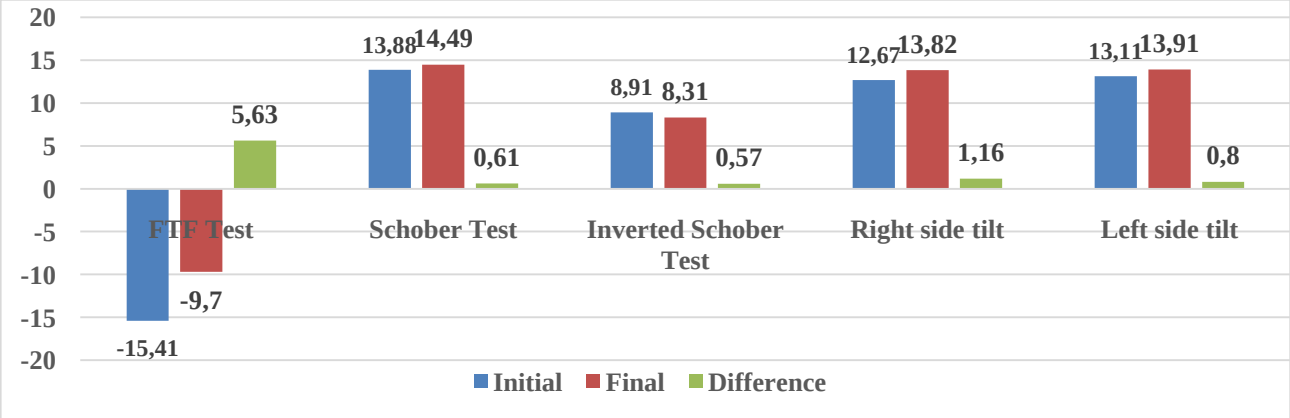

Figure 2. Analysis of the mobility of the spine - the average of the group

Discussions and conclusions

The main symptom in lumbar disc herniation is pain of varying intensities, which in most cases also reduces the mobility of the spine and consequently functional deficit. Therefore, the treatment to be followed consists of using the most complex and complete means to reduce pain intensity. In this context, Szasz et al. (2012) conducted a study on 100 patients divided into 2 groups of 50 people, the first group (A) benefiting from drug treatment, electrotherapy and muscle relaxant massage, and the other (B) having in addition kinetotherapy [12]. The authors found that the pain improved after 3 weeks of treatment in both groups, with no major differences between them, from an average of 7.48 ± 0.93 to 2.34 ± 1.00 in group A and from a value of 7.46 ± 0.95 to 2.02 ± 0.82 in group B, and a p<0.001 index value with a high degree of statistical significance. At 6 months after treatment, the pain increased again in intensity, in group A approaching the initial

value, while in group B it remained almost as it was after the 3 weeks of treatment. Thus, from a statistical point of view, the authors show that, between the initial assessment and the one at 6 months, in group A, the value of $p<0.06$ is therefore statistically insignificant, while in group B, which also benefited from physiotherapy, with a $p<0.001$, a high degree of statistical significance.

Regarding the mobility of the spine, the importance of physical therapy as a means of recovery is highlighted in various scientific papers. A recent study by Cichon et al. (2019) [13] on 33 elderly women with degenerative problems in the lumbar spine, claims that through physical therapy the degree of lumbar mobility increases. Jeong et al. (2017) [14] state the same. The study was performed on 30 subjects divided into 2 groups of 15 patients. During a time period of 4 weeks, patients in a group performed resistance exercises to stabilize the center of balance 3 times a week, for 30 minutes. In conclusion, it was established that these exercises improve the stability of the sacroiliac joint and therefore this increases the range of motion in the lumbar spine.

In conclusion the application of a complex program of rehabilitation, which uses as rehabilitation means: massage, electrotherapy, hydrotherapy and physiotherapy in patients with herniated lumbar disc, reduces pain and improves mobility of the spine.

Bibliography

[1] Papageorgius, A., Croft, P.R., Ferry, S., Jayson, M.I., Silman, A.J. (1995). Estimating the prevalence of low back pain in the general population. Evidence from the South Manchester Back Pain Survey, *Spine*, 20 (17), pp. 1889-94. DOI: 10.1097 / 00007632-199509000-00009

[2] Cypress, B.K. (1983). Characteristics of physician visits for back symptoms: a national perspective, *Am J Public Health*. 73: 389-95

[3] Prostacchini F. (1999). Lumbar disc herniation, *Rome*: Springer-Verlag / Wien Publishing House. pp. 154

[4] Mundt, D.J., Kelsey, J. (1993). An epidemiologic study of non-occupational lifting as a risk factor for herniated lumbar intervertebral disc. *Spine*, 18, pp. 595-602. DOI: 10.1097 / 00007632-199304000-00012

[5] Șchiopu, O. (2008). Managementul radiculopatiilor lombare dicogene cronice şi recurente, *Analele Ştiinţifice USMF "Nicolae Testemiţanu"*, Ediția IX, Vol 3, pp. 374-379

[6] Mohan, A.G., Mihalache C., Moisa, H., Ciurea, A.V. (2013). Considerente asupra complicațiilor în chirurgia herniei de disc lombare, *Practica Medicală*, Vol VIII, Nr 3(31), p. 133

[7] Rodriguez, C.S. (2001). Pain measurement in the elderly: a review, *Pain Management Nursing*, 2 (2), pp. 38–46. DOI: 10.1053 / jpmn..23746

[8] Dworkin, R.H., Turk, D.C., Farrar, J.T., Haythornthwaite, J.A., Jensen, M.P., Katz, N.P. et al. (2005). Core outcome measures for chronic pain clinical trials: IMMPACT recommendations, *Pain*, 113 (1), pp. 9-19. DOI: 10.1016 / j.pain

[9] Hawker, G.A., Mian, S., Kendzerska, T., French, M. (2011). Measures of Adult Pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short - Form McGill Pain Questionnaire (SF - MPQ), Chronic Pain Grade Scale (CPGS), Short Form - 36 Bodily Pain Scale (SF - 36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP), *Arthritis Care & Research*, 63 (S11), pp. S240 – S252. DOI: 10.1002 / acr.20543

[10] Ferraz, M.B., Quaresma M.R., Aquino, L.R., Atra, E., Tugwell, P., Goldsmith, C.H. (1990). Reliability of pain scales in the assessment of literate and illiterate patients with rheumatoid arthritis, *J Rheumatol*, 17 (8), pp. 1022–4. PMID: 2213777

[11] Serbescu, C. (2007). *Kinetoprofilaxie primară: biologia condiției fizice (Ed. 2)*, University of Oradea Publishing House, p. 161

[12] Szasz, S., Papp, E., Georgescu, L. (2012). Importanţa tratamentului de recuperare în durerea lombară joasă, *Revista Română de Kinetoterapie*, 18 (29), p.62-64

[13] Cichon, D., Ignasiak, Z., Fugiel, J., Kochan, K., Ignasiak, T. (2019). Efficacy of Physiotherapy in Reducing Back Pain and Improve Joint Mobility in Older Women, *Orthop Traumatol Rehabil*, 21 (1), pp.45-55. DOI: 10.5604 / 01.3001.0013.1115

[14] Jeong, K.D., Choi, H.H., Kang, I.J., Choi, H. (2017). Effect of lumbar stabilization exercise on disc herniation index, sacral angle, and functional improvement in patients with lumbar disc herniation, *Journal of Physical Therapy Science*, 29 (12), pp. 2121-2125. DOI: 10.1589 / jpts.29.2121

INFLUENCE OF THE EXPIRATORY PRESSURE LEVELS ON THE ALVEOLAR RECRUITMENT OF THE HEALTHY SUBJECTS

INFLUENȚA NIVELULUI DE PRESIUNE EXPIRATORIE ASUPRA RECRUTĂRII ALVEOLARE ÎN CAZUL SUBIECȚILOR SĂNĂTOȘI

Clement CRAVINHO[1], Dorina IANC[2]

Abstract

Few studies have analyzed the effect of different well-defined PEP levels on lung function since the majority of clinical trials use PEP mask and a pressure «fork». The objective of this study is to find out if there is a common level of PEP to be applied which allows optimization of alveolar recruitment, objectivity by tomography by electric impedance, for all subjects. The study was carried out on 14 healthy participants, 7 men and 7 women, aged 22 to 30. Participants had a exhale against four resistors of different values, determined by the tension of the spring, 5, 10, 15 and 20cmH_20. The measurement of alveolar recruitment during the experiment was carried out by an electrical impedance tomograph. Each participant reacted differently to the PEP levels, but by comparing the responses of the pulmonary function, it is noted that the individual characteristics can influence the alveolar recruitment, whatever the level of resistance applied. It would be interesting to investigate, on a larger sample and with several groups of participants with low inter-individual variability, whether there is a correlation between individual characteristics and the potential for alveolar recruitment. This would optimize care by adapting it to each subject.

Keywords: *positive expiratory pressure*, *pulmonary volume*, *expiratory impedance*

Rezumat

Există puține studii care au analizat efectul diferitelor niveluri de presiune expiratorie pozitivă (PEP) bine definite asupra funcției pulmonare, deoarece majoritatea studiilor clinice utilizează mască PEP și o „furcă” de presiune. Obiectivul acestui studiu este de a afla dacă există un nivel comun de PEP care trebuie aplicat, care permite optimizarea recrutării alveolare, relevate prin tomografie de impedanță electrică, pentru toți subiecții. Studiul a fost realizat pe 14 participanți sănătoși, 7 bărbați și 7 femei, cu vârste cuprinse între 22 și 30 de ani. Participanții au expirat împotriva a patru rezistențe de valori diferite, determinate de tensiunea arcului, 5, 10, 15 și 20cmH_20. Măsurarea recrutării alveolare în timpul experimentului a fost efectuată de un tomograf de impedanță electrică. Fiecare participant a reacționat diferit la nivelurile PEP, dar prin compararea răspunsurilor funcției pulmonare, se

Acceptat pentru publicare în 29.06.2021; Publicat pentru prima dată online în 30.06.2021
Pentru citare: Cravinho, C., Ianc, D. (2021). Influence of the expiratory pressure levels on the alveolar recruitment of the healthy subjects, *Revista Română de Kinetoterapie*, 27(46), 27-35
[1] Helfaut Hospital, St Omer Region, France
[2] Autor corespondent, Universitatea din Oradea, Departamentul de Educație Fizică, Sport și Kinetoterapie; dianc@uoradea.ro

observă că recrutarea alveolară poate fi influențată de caracteristicile individuale, indiferent de nivelul de rezistență aplicat. Ar fi interesant de investigat, pe un eșantion mai mare și cu mai multe grupuri de participanți cu variabilitate interindividuală scăzută, dacă există o corelație între caracteristicile individuale și potențialul de recrutare alveolară. Acest lucru ar optimiza tratamentul prin individualizarea lui la fiecare subiect.

Cuvinte cheie: *presiune expiratorie pozitivă, volum pulmonar, impedanță expiratorie*

Introduction

Alveolar recruitment (AR) is a dynamic phenomena and is defined as the re-expansion of previously collapsed lung areas by means of a brief and controlled increase in transpulmonary pressure [1].

The idea of AR is to create and maintain a collapse-free situation with the purpose of increasing the end-expiration volume and improve gas exchange. We more talk about alveolar recruitment and not pulmonary recruitment because the alveoli are located in the pulmonary lobules who constituted the functional element of the lung and responsible of the blood oxygenation. But the recruitment also appears in the bronchial level. The goals of alveolar recruitment are to stabilize unstable alveoli in order to limit closing-reopening phenomena but also to recruit collapsed areas in order to make ventilation more homogeneous.

Positive expiratory pressure consists of breathing against expiratory resistance, affixed to the nose or the mouth [2]. The subject must exhale against resistance, also called PEP, in order to successfully extract previously inspired air. In order to achieve this expiration, the oral pressure must therefore be lower than the alveolar pressure.

This PEP allows an increase in intrabronchial and alveolar pressure, causing an increase in the size of the bronchi by increasing transpulmonary pressure. Resistance of the airways which depend on the diameter of the bronchi decrease.

The application of Positive Expiratory Pressure (PEP) is used when patients have excess secretions in their airways but also during the presence of alveolar collapse and finally as a prevention of respiratory complications [3]. Each physiotherapist applies these positive expiratory pressures in their own way.

Few studies have analyzed the effect of different well-defined PEP levels on lung function since the majority of clinical trials use PEP mask and a pressure «fork» [4, 5, 6, 7].

This research problem focused on the methods of using PEP: How a common PEP level would improve alveolar recruitment in healthy subjects with different individual characteristics?

The objective of this study is to find out if there is a common level of PEP to be applied which allows optimization of alveolar recruitment, objectivity by tomography by electric impedance, for all subjects.

The hypotheses of research are:

- PEP allows an objective alveolar recruitment by EIT, in all healthy subjects.
- There is a common PEP level where recruitment would be higher in all subjects.
- The level of PEP allowing the strongest recruitment is also the most durable during the five post PEP respiratory cycles.

Study population

The experimental study was developed at Helfaut Hospital in the St Omer Region, France. Each participant was informed, before the experiment, of the modalities of this one. The study participants were selected according to several inclusion criteria:

- Age > 18
- Tidal Volume > or equal at 80% of its theoretical value
- MEVS > or equal at 80% of its theoretical value
- Vital Capacity > or equal at 80% of its theoretical value

Indeed, a tidal volume and vital capacity value equal to 80% of the theoretical value is considered normal.

The exclusion criteria were:

- Airway congestion at the time of the experiment
- Obstructive ventilatory disorder with a Tiffeneau ratio < 70%
- Misunderstanding of the instructions
- History of pneumothorax

The study was carried out on 14 healthy participants, 7 men and 7 women, all being members of the hospital medical teams, aged 22 to 30.

Protocol

The subjects were seated in an armchair with a backrest. A belt of electrodes connected to the tomograph was located under the chest, at the level of the sixth intercostal space.

The subjects were asked beforehand to remain well seated at the bottom of the seat during the whole experiment so that the electrodes pick up correctly, and not to speak during the latter.

Participants had a exhale against four resistors of different values, determined by the tension of the spring, 5,10,15 and 20 cmH20. The order of the applied PEP levels, set by the examiner via software and varied from subject to subject. This made it possible to limit the fatiguability effect which could have been an experience bias, if PEP had been applied increasingly.

Following the launch of the recording, the subjects were asked to breathe calmly, on their rest ventilation (tidal volume), for one minute, objectified by a stopwatch. Then, they had to breathe in at most of their inspiratory reserve volume outside the PEP, and exhale in a slightly active way in the resistance imposed by the threshold PEP, until the end of their expiratory reserve volume. They were therefore asked to empty their lungs as much as possible.

They repeated this maximum inspiration and expiration against the resistive pressure 5 times. Then, the subjects ventilated spontaneously, in order to find a ventilation of rest, during one minute. Another resistive pressure was applied to their mouth, and 5 new repetitions of expiration against it, following maximum inspiration, were asked of them.

There was thus during the experiment, a minute of spontaneous ventilation of rest followed by 4 sets of 5 repetitions of maximum inspiration and total expiration against PEP, each interspersed with a minute of rest, and finally a minute of rest after the fourth series.

At the end of the experiment, participants were asked how they felt about PEP if they had been bothered by resistance-induced side effects.

Equipment used and measurements carried out:

a) Spirometry

A forced and simple spirometry was carried out before the experiment to determine if the subjects fulfilled all the inclusion criteria, thanks to a portable USB spirometer connected to a computer. Spirometry was performed with a nose clip, which will be kept throughout the experiment.

b) EIT measurements

The measurement of alveolar recruitment during the experience was carried out by an electrical impedance tomograph, the Pulmo Vista 500. The belt comprising the 16 electrodes and connected to the tomograph was placed under the chest, around the thorax.

The impedance measurements will be expressed as a percentage of a reference impedance in order to be able to compare the subjects with each other.

Following a transposition of the Pulmo Vista files on Microsoft Excel, we obtain an impedance curve over time. The tomography provides a large number of recorded measurements per second. For the analysis of these measurements, we retained only the points corresponding to the lower vertices of the curve which represent the impedance at the expiratory tele volume (minimum impedance) and the upper of the curve (+1) which represent the impedance at the end of inspiration volume.

The measured variables are:

- Minimum impedance during PEP and post PEP over over 5 respiratory cycles

It's possible to objectify alveolar recruitment when an increase in functional residual capacity is observed, so an increase in the expiratory reserve volume and the residual volume. In addition, the study participants didn't have respiratory, and therefore theoretically no bronchial congestion or pulmonary hyperinflation. The alveolar recruitment induced by PEP will then be clearly objectible by the increase in the pulmonary volume, that is to say the increase in the functional residual capacity and in the tidal volume. Thus, thanks to the points -1 of the curve (end of expiration point) of the impedance with respect to time, it's possible to observe an alveolar recruitment during an increase in their value.

The average of the points -1 during the first minute of the experiment was calculated so that it serves as the minimum reference impedance (Iref). The comparison of the minimum impedance between the different PEP levels is expressed as a percentage of the Iref for each subject. The minimum post PEP impedance was measured over 5 respiratory cycles following PEP. It's expressed as a percentage of Iref.

- Variations in overall impedance to objectify impedance during inspiration

Recruitment can also be objectified during an increase in tidal volume, so we measured the variations in impedance during inspiration (corresponding to the difference between points +1 and -1). These variations are expressed as a percentage of the variations in impedance during the inspiration of rest.

- The number of respiratory cycles where alveolar recruitment would occur

According to the method based on increasing or decreasing the minimum impedance, whether or not representing alveolar recruitment, it's possible to objectify the number of respiratory cycles where effective recruitment takes place. We can speak of recruitment during PEP when we observe an increase in the minimum impedance compared to the Pref. Which would represent an increase in the residual volume at the respiratory level.

The evolution of the impedance during PEP was measured by calculating the difference between the minimum impedance values after expiration and the point -1 following the first expiration against

PEP. The difference can be positive or negative, and the increase or decrease with respect to Pref is expressed in % of Pref. When this difference is positive, there is a recruitment that can be objectified directly by the Tomograph by Electrical Impedance. In post-PEP, recruitment is carried out when the value of the minimum impedance is greater than that of rest Iref, which means that the functional residual capacity has increased.

- Respiratory rate

It was calculated during the minute of rest following each PEP. The summary of respiratory frequencies after each level of PEP will be presented later.

Results are expressed as means and standard deviations. The comparison of the means was carried out using an analysis of variance for repeated measurements when the results followed a normal distribution, otherwise a non-parametric test (Friedman's test) was used. Indeed we are in the framework of an experiment where the same quantity was measured several times on the same subjects, in order to follow its evolution during different situations, in particular during the different PEP levels.

Results

Due to electrode belt capture defects during maximum expirations, a subject's data could not be analyzed. The data of thirteen participants were therefore analyzed, the table of their individual characteristics is presented in Table 1. Among these thirteen participants, some outliers, related to the electrode belt, were excluded; this is indicated when the n (number of participants) is decreased.

Table 1. Results obtained during respiratory cycles performed with PEP

	PEP $5cmH_20$	PEP $10cmH_20$	PEP $15cmH_20$	PEP $20cmH_20$	P
n	12	12	12	12	
Minimum impedance (% Iref) average; SD	71,1; 56,6	72,2; 55,3	63,9; 50,0	68,4; 55,0	NS
n	10	10	10	10	
Variation in impedance (%) average; SD	620,6; 232,2	630,5; 255,1	621,3; 263,4	627,7; 224,9	NS

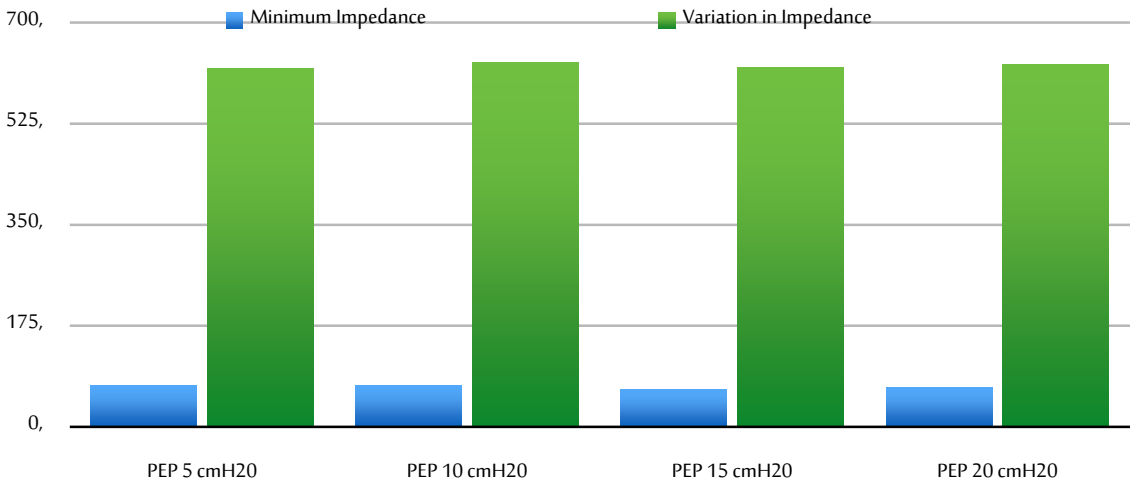

Figure 1. Comparison of the influence of the different PEEP levels on the minimum impedance and the variations in impedance on inspiration

No significant difference between the different PEEP levels was shown on the minimum impedance and on the variation of impedance during inspiration.

Table 2. Comparison of the increase in the minimum impedance compared to the Pref impedance and the number of cycles in which a recruitment can be objectified, according to the different pep levels

	PEP 5cmH20	PEP 10cmH20	PEP 15cmH20	PEP 20cmH20	P
n	8	8	8	8	
Increase in impedance (% Pref) average; SD	41,8; 59,3	0,1; 22,2	-8,6; 17,8	-0,8; 30,5	0,036
n	10	10	10	10	
Number of recruitment cycles (%) average; SD	78; 30	55; 39	60; 36	55; 40	NS

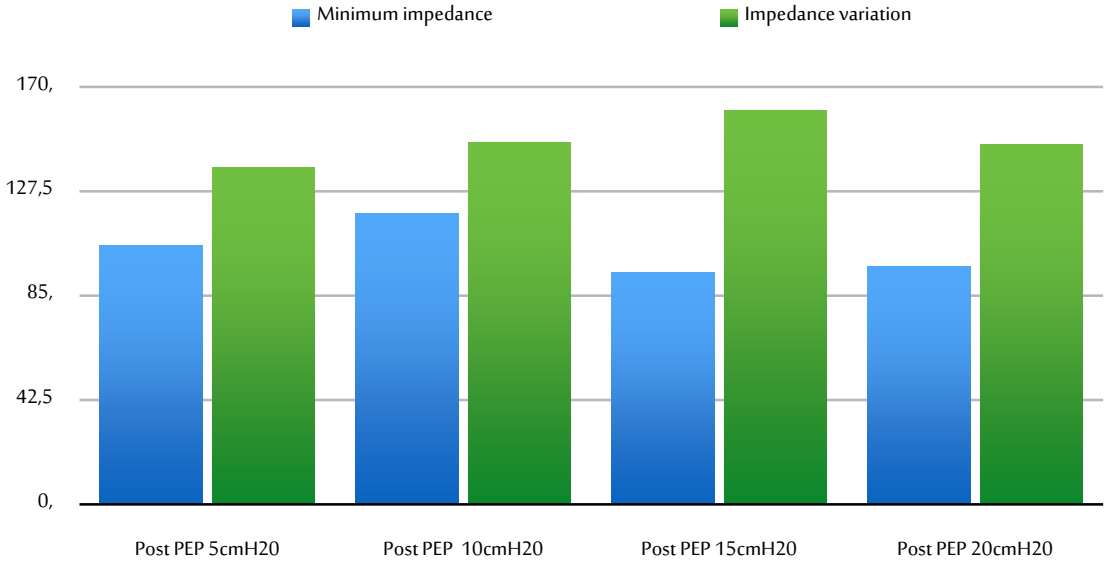

Figure 2. The minimum impedance and the inspiration impedance variation during the 5 Post-PEP respiratory cycles

We obtain significant differences concerning the increase in impedance during respiration against the four levels of pressure.

There is no significant difference between the PEP levels in the number of respiratory cycles in which a directly objectifiable alveolar recruitment takes place.

Table 3. Comparison of the minimum impedance and he variation of impedance during inspiration during the 5 post PEP cycles, after each level of PEEP

	PEP 5cmH20	PEP 10cmH20	PEP 15cmH20	PEP 20cmH20	P
n	12	12	12	12	
Minimum impedance (% Iref) average; SD	105; 45,2	118,6; 62,4	94,6; 22,2	96,9; 28,9	NS
n	13	13	13	13	
Impedance variation (%) average; SD	137,1; 66,3	147,5; 55,4	160,6; 92,4	146,4; 60,8	NS

Table 4. Comparaison of the number of respiratory cycles in which recruitment takes place during the Post-PEP respiratory cycles

	Post PEP 5cmH20	Post PEP 10cmH20	Post PEP 15cmH20	Post PEP 20cmH20	P
n	12	12	12	12	
Number of recruitment (%) average; SD	33; 39	35; 41	22; 27	28; 39	NS

Discussion

No level of PEP shows a significantly greater effect than the others. Indeed, in view of our results, we cannot conclude on a level of PEP which would increase the RFC or the volume inspired for all subjects, in a way superior to the others.

Subjects were asked to breathe out against the threshold PEP until the end of their expiratory reserve volume, so it's normal for the expiratory impedance to be lower than the Iref where subjects were breathing at their tidal volume. It's noted however that the PEP at 5cmH_2O and at 10cmH_2O give a minimum impedance greater than the other two and therefore induce a residual volume greater than the other PEP, but this insignificantly.

No conclusion is possible regarding the evolution of recruitment during PEP. Indeed, some subjects show a linear increase in the minimum impedance over the repetitions of expirations, and therefore increase their RV. While others tend to hire, by decreasing their RV. This varies according to each subject and each level of PEP. The alveolar recruitment cannot therefore be directly objectified by EIT in all subjects, during a complete expiration. One of our hypotheses isn't verified.

It should be noted, however, that PEP at 5cmH_2O shows a very disparate increase in recruitment of up to more than 100% of the value of Pref. In addition, it's with this level that we observe the greatest number of cycles in which an alveolar recruitment is affected by a minimum impedance greater than that of Pref (Table 2).

Over the 5 post-PEP respiratory cycles, the comparisons of the means (Tables 3 and 4) don't reveal a more beneficial level of pressure. While the minimum impedance means are higher for pressures of 5 and 10cmH20, the standard deviations are also higher. The objective of this work is to find a common level of PEP which would optimize recruitment by increasing it in its value and duration, for all subjects. The standard deviations, representing the dispersion of the values around their mean and therefore the difference in response of subjects to each level of PEP, therefore play an important role in the interpretation of the results.

When we compare all of the study participants together, we can see that no meaningful results can be drawn. The study carried out does not allow the assumptions made to be validated. The PEP levels of 5 and 10cmH_2O seem to be the pressures where the majority of subjects is recruiting, but we can't speak of clinical relevance because some subjects will shift their ventilation in their ERV for these same levels, which would be contrary to the clinical objective of opening airway.

However, in view of the curves of the subjects during their ventilation with PEP, it's possible to group them into two groups: one where the minimum impedance remains very high even during total expiration (> 90% Iref), and one where the impedance remains significantly lower.

When looking for a relationship between the individual characteristics of the subjects and the measured impedance testifying to alveolar recruitment, we note that in subjects whose BMI is

less than 22, the minimum impedance is much higher at the end of expiration than that of other topics for any level of PEP.

BMI is said to influence the potential for individual recruitment. But to confirm this new hypothesis, it would be necessary to conduct a study with more participants to draw any conclusion from these observations.

Concerning the methodology, we realized that it would have been more judicious to carry out inspirations and expirations at tidal volume while the PEP was applied. Indeed, the curves obtained would have immediately assessed recruitment during PEP by whether or not the minimum impedance was greater than the Iref. We would have directly seen the evolution of the RFC, and not only that of the RV that can be observed in my experience when applying the PEP. We would also have directly seen the increase in inspired volume, compared to that of rest, if the subjects ventilated at tidal volume.

The instructions for maximum inspiration and expiration until the end of their ERV were clear instructions, which enabled participants to perform respiratory cycles against PEP in a repeatable manner. However, when calculating the variations in impedance between the end of expiration and the end of inspiration, we realize that some subjects repeated almost similar expirations but that others expired up to 31,6% less. That the expirations carried out against the first PEP put in place. This may be due to the increased difficulty when the level of PEP is high but can also be considered as a follow-up bias.

Attrition biases are also present in our study. The electrodes didn't always pick up correctly when exhaling against PEP. This forced me to sometimes exclude certain subjects and is responsible for missing data.

The EIT is recognized as a validated measurement tool and constitutes a strong point of the experiment. However, it does not distinguish recruitment from pulmonary hyperinflation.

The randomization of the order of applied PEP levels allowed my study to position participants blind opposite the treatment received, and the choice of threshold PEP allowed subjects to expire against the same level of PEP, not dependent on their expiratory flow [8].

This study is limited because the subjects included aren't representative of the population affected by the use of PEP. But it constitutes a study preliminary to a next study which would include subjects suffering from respiratory pathologies.

As mentioned earlier, there are few studies that have accurately compared multiple pressure levels using a threshold resistor. And when they show a more beneficial level than the others, one realizes their methodological weaknesses [9]. During clinical application, the pressure to be applied should be higher in affected patients because the pressure to open the alveoli is higher when they are collapsed, as described by [10].

Conclusions

Studying the literature made we realize that there was no consensus on how PEP should be used. In order to show the effects of different levels of PEP on respiratory function, an experimental protocol where 4 different levels were tested was implemented. The EIT made it possible to analyze the alveolar recruitment by increasing the RFC or RV as well as tidal volume. Analysis of the results does not show a level of PEP common to all subjects which would induce a higher alveolar recruitment than the others.

This study constitutes a preliminary study which makes it possible to observe the adaptations of the respiratory function, according to the pressure levels applied, in each participant. The interest of this study was to determine a level of beneficial PEP in all healthy participants, which would then have been implemented in subjects suffering from respiratory pathology. The clinical objective would be to optimize the use of this instrumental technique by knowing the level of PEP adapted to the patient.

Each participant reacted differently to the PEP levels, but by comparing the responses of the pulmonary function, it is noted that the individual characteristics can influence the alveolar recruitment, whatever the level of resistance applied. It would be interesting to investigate, on a larger sample and with several groups of participants with low inter-individual variability, whether there is a correlation between individual characteristics and the potential for alveolar recruitment. This would optimize care by adapting it to the subject in front of us.

This work allowed as to take a critical look at what is done in professional practice. By studying the literature, and taking into account the methodological quality of the studies, we was able to take a step back from the conclusions that emanate from clinical trials.

Bibliography

[1] Richard J.C., Maggiore S.M., Mercat A. Clinical review: bedside assessment of alveolar recruitment. *Crit Care*, 8. 2004, pp. 163-169, http://dx.doi.org/10.1186/cc2391

[2] Frownfelter DL, Dean E. Cardiovascular and pulmonary physical therapy: evidence and practice. *4th ed. St. Louis*, Mo.: Mosby/Elsevier, 2006.

[3] Constantin, J. et al. Les manoeuvres de recrutement alvéolaire au cours du syndrome de détresse respiratoire aigue. *Reanimation*. Vol. 13, Issue 1, 2004. Pages 29-36

[4] Osadnik, C.R., McDonald, C.F., Miller, B.R. et al. The effect of positive expiratory pressure (PEP) therapy on symptoms, quality of life and incidence of re-exacerbation in patients with acute exacerbations of chronic obstructive pulmonary disease: a multicentre, randomised controlled trial. *Thorax*; 2014. 69:137-143.

[5] Russo D., Simonelli C., Paneroni M. et al. Is there an optimal level of positive expiratory pressure (PEP) to improve walking tolerance in patients with severe COPD*? Archivos de Bronconeumologia*. 2016 Jul; 52(7):354-360. DOI: 10.1016/j.arbres.2015.11.019.

[6] FagevikOlsén M., Lannefors L., Westerdahl E. Positive expiratory pressure - Common clinical applications and physiological effects. *Respir Med*. 2015 Mar;109(3):297-307. doi: 10.1016/j.rmed.2014.11.003. Epub 2014 Nov 12. PMID: 25573419.

[7] McIlwaine, M., Button, B., & Nevitt, S. J. Positive expiratory pressure physiotherapy for airway clearance in people with cystic fibrosis. *The Cochrane database of systematic reviews*, 2019 (11), CD003147. https://doi.org/10.1002/14651858.CD003147.pub5

[8] Christensen, E.F., Jensen, R.H., Schønemann, N.K., Petersen, K.D. Flow-dependent properties of positive expiratory pressure devices. *Monaldi Arch Chest Dis*. 1995 Apr; 50(2):150-3. PMID: 7613548.

[9] Van der Schans, C.P. et al. Effect of positive expiratory pressure breathing in patients with cystic fibrosis. *Thorax*, 46, 1991. pp.252-256

[10] Gattinoni, L. et al. Positiveend-expiratory pressure. *Current opinion in critical care*, 16(1), 2010. pp.39-44.