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CASE REPORT

Is it possible to predict the physical function of lumbar disc herniation after aquatic exercises and Kotsuban Tyousei?

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Abstract

Background: Aquatic exercises (AE) have gained increased popularity and are widely used to treat specific and non-specific low back pain. The Kotsuban Tyousei (KT) method, which means "pelvic adjustment", proposes passive mobilization of body segments to restore or maintain pain-free movement in the musculoskeletal system and reduce disability. **Objective:** This study aimed to assess physical function through Simulation Modeling Analysis (SMA) time series approach in individuals diagnosed with lumbar disc herniation (LDH). **Methods:** Two participants with LDH were selected and underwent combined AE and KT treatment for 16 sessions (eight sessions of each treatment), over the course of eight weeks. Physical function was assessed using the Roland Morris Disability Questionnaire (RMDQ). Pre and during/post-intervention measurements of the RMDQ were analyzed by SMA (autocorrelation, r and significance) and the Minimum Clinically Important Difference (MCID) was reported. **Results:** Participant 1 exhibited improvements in pain in functional tests. The SMA results were autocorrelation = 0.58, r = - 0.69, P = 0.07. The MCID was not reached, however a 46.5 % RMDQ improvement (4.1 points) was found, exceeding the minimum amount of change that can be considered important. Participant 2 presented improvements in community ambulation and lower limb muscle strength. For SMA the results were autocorrelation = 0.19, r = - 0.29, P = 0.28. An 18 % RMDQ improvement (2.6 points) were reported, and at the end of the treatment, the patient did not report LBP or irradiation in the posterior region of the left thigh. **Conclusion:** After 16 sessions of aquatic and on land exercises, two individuals diagnosed with disc a herniation did not achieved the prediction model of physical function time series analysis, however, participant 1 exhibited a significant difference in MCID.

Keywords: Intervertebral disc displacement; hydrotherapy; musculoskeletal manipulations; forecasting; acupressure; case reports.

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BACKGROUND

Approximately 80 % of the global population suffers at least one episode of low back pain (LBP) in their lifetime. Such cases and their poor functions contribute to raising health system costs that exceed one hundred billion dollars in the United States of América every year[1]. LBP increases the longer it goes untreated[1-3]. In other developing countries, LBP is linked to physical incapacity, increased risk of disability retirement, and absenteeism[4]. Over the past 25 years, spinal disorders have increased considerably and are expected to increase with the aging of the population[5].

Lumbosciatic pain represents symptoms with specific and vast causes. Among these causes, possible intervertebral alterations are the most commonly reported, which may lead to degenerative disc disease and lumbar disc herniation (LDH)[1,6]. Herniated discs (HD) are considered as one of the main triggering factors of LBP, representing approximately 9 % of cases worldwide[7]. HD are also identified as the leading cause of radiating sciatic nerve pain, affecting between 1 and 5 % of the world population[8,9]. Petrosyan et al. (2021) state that 95 % of cases of HD occur in the L4-S1 segments[10].

HD is classified as bulging, protrusion, extrusion, or sequestration[11,12]. It is defined by the North American Spine Society Clinical Guidelines as the localized displacement of disc material beyond the normal margins of the intervertebral disc space resulting in pain, weakness, or numbness in a myotomal or dermatomal distribution[13]. Genetic, environmental, and lifestyle factors, overweight and obesity, as well as biomechanical, traumatic and psychosocial factors are considered prevailing risk factors for the development of LDH[14,15].

Several treatment strategies are available for lumbar radiculopathy, including surgery (intervertebral disc and percutaneous discectomy) and conservative treatments (injections, analgesics, acupuncture, traction, manual therapy, exercises and/or orthotics), the latter being considered the first treatment option. However, there are still gaps to be elucidated regarding lumbar radiculopathy treatment strategies[16]. When analyzing electromyography data from patients with LDH, Petrosyan et al. (2021) observed weakness in the trunk and leg muscle groups and stated that core stabilization with abdominal and lumbar muscle strengthening is indispensable for patients with LDH[10]. A recent study conducted by Golonka et al. (2021) suggests that isolated resisted lumbar extension exercises in a limited range of motion (ROM) can be an effective treatment alternative, as demonstrated in the literature for non-specific LBP[17].

Aquatic exercises (AE) have gained popularity as a therapeutic resource in recent decades[18]. The benefits of AE are partially attributed to fluid mechanics, such as hydrostatic pressure, buoyancy, water density, and viscosity[19]. Temperature is also considered a significant factor, with 32 ºC being the ideal temperature for these exercises. Some studies have analyzed the effects of AE on non-specific LBP[20,21]. However, no studies involving disc herniation or stenosis were found. The Kotsuban Tyousei (KT) method (Kotsuban means "pelvis" and Tyousei means "adjustment") was created about 70 years ago in Japan by Massayoshi Gomi[22].

This manual therapy involves the skillful use of passive movements to restore or maintain pain-free movement of the musculoskeletal system and reduce disability[23]. Within manual therapy, manipulation (high-speed, small-amplitude thrusts performed at the maximum of available movement) and mobilization (repetitive passive movements of varying range at low speed) of the spine are highlighted[23,24].

KT is a therapy for the whole body performed passively, utilizing mobilization and, at times, manipulation when indicated. It is derived from Shiatsu and involves acupressure, the use of hands, arms, elbows and feet, and the mobilization of all joints[22]. It is indicated for some comorbidities, offering improvement of clinical symptoms such as nausea, vomiting, fatigue, anxiety, insomnia, depression, and, especially, pain[25-28].

To predict data from case reports, some authors have suggested the use of the Simulation Modeling Analysis (SMA), which comes from a time series analysis approach[29,30]. SMA is based on bootstrapping methods and is designed to analyze small and autocorrelated datasets commonly encountered in clinical practice[31]. This analysis estimates the temporality (lag) of the associations between two variables throughout a single-case experimental design after adjusting for autocorrelation[29]. Given the above, this study aims to simulate physical function outcome values using SMA and to analyze potential changes in the Minimum Clinically Important Difference (MCID) among individuals with chronic LBP diagnosed with disc herniation, after two combined treatments: water-based (AE) and land-based (KT).

METHODS

Two participants were selected for this study. They were diagnosed with LDH based on magnetic resonance imaging (MRI) and had experienced LBP for more than three months, which was an inclusion criteria. The exclusion criteria included recent surgeries, previous water- or land-based treatment, comorbidities, fractures, and pregnancy. The participants were referred to the Laboratory of Biomechanics and Clinical Epidemiology and the Aquatic Physical Therapy Center (University Hospital/UEL) for evaluation and assistance. All process followed the recommendations of the CARE guidelines. The participants signed the informed consent form, and the study design was approved by the Institutional Review Board (# 17138413.1.0000.5231).

Participants

Participant 1. A 57-year-old male (Table 1) who had been complaining of LBP for five years, with inadequate postural and ergonomic habits, and who spent an extended amount of time in front of a computer or in a car. He also reported poor sleep quality due to the low back pain. In 2016, he had an acute disabling crisis that led him to see a physician. Only oral medication was prescribed to relieve the symptoms, which caused an occasional relief. In 2021, after a new acute event, an MRI revealed HD, with bulging discs from L3 to S1 accompanied by marginal osteophytes, mainly anterior to these segments. The MRI also indicated height reduction with dehydration of the intervertebral discs and diffuse bulging of the posterior margins of the intervertebral discs between L3 and S1. The disc bulge between L5 and S1, more evident on the right side, seemingly touched the neural roots emerging from L5 and descending from S1 (information from the MRI report). In the evaluation, the patient presented positive results in specific tests (Table 2). He reported LBP during activities that required forward bending of the trunk and squatting, especially in the first hours of the mornings. The LBP improved gradually throughout the day, except when exaggerating the overload. His right leg was the most affected (Figure 1A).

Table 1. Sociodemographic and initial clinical characteristics.

	Participant 1	Participant 2
Age (years old)	57	24
Profession	University professor	Housekeeper
Sex	Male	Female
Body mass index (BMI)	30.8 (Class I obesity)	39.9 (Class II obesity)
Chief complaint (CC)	Low back pain, especially when performing anterior trunk flexion	Low back pain radiating to the left leg. Neck pain radiating to shoulders and arms bilaterally

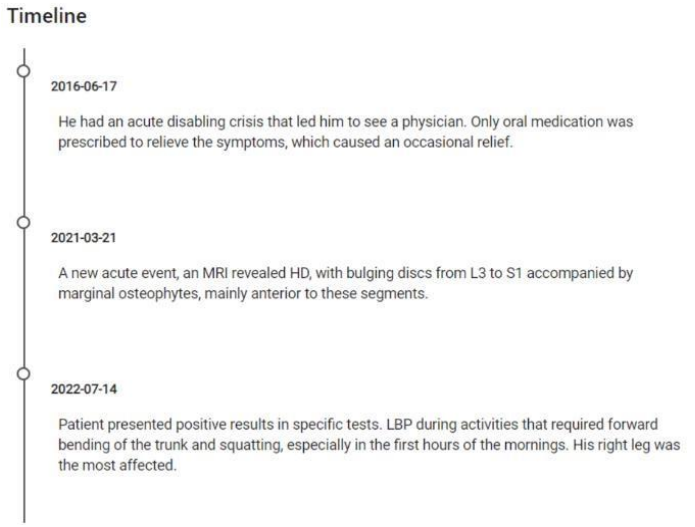
Table 2. Evaluation, pre- and during/post-intervention measures and SMA results.

	Pre-Intervention	Post-Intervention	Change
Participant 1			
Specific tests			
Anterior trunk flexion	VAS 0	VAS 0	-
Lateral trunk flexion	R = 48 cm mild pain L = 45 cm mild pain	R = 33.5 cm L = 31.5 cm. No pain complaints	R = 14.5 cm L = 13.5 cm from the floor
Trunk extension	VAS = 4	VAS = 0	4
Lasègue	Positive (R)	Negative	100 %
Gaenslen´s sign	Negative	Negative	-
Milgram	Negative	Negative	-
Ambulation	VAS = 0	VAS = 0	-
Walking with toes support	VAS = 0	VAS = 0	-
Walking with heel support	VAS = 0	VAS = 0	-
Measurements			
RMDQ	10	3	7
Average RMDQ	8.8	4.7	4.1 (46.5)†
VAS	6	0	6
Participant 2			
Specific tests			
Ambulation	VAS = 5	VAS = 0	5
Walking with toes support	VAS = 3	VAS = 0	3
Walking with heel support	VAS = 3	VAS = 0	3
Measurements			
RMDQ	18	1	17
Average RMDQ	14.4	11.8	2.6 (18 %) †
VAS	6	0	6
Muscle strength (kgf ǀ time in seconds)			
Hip flexion	R = 16.0 ǀ 4,8 L = 8.5 ǀ 5.0	R = 15.8 ǀ 5.0 L = 14.2 ǀ 5.4	R = -0.2 L = +5.7
Knee extension	R = 10.7 ǀ 5,6 L = 9.2 ǀ 5.0	R = 15.9 ǀ 5.0 L = 17.7 ǀ 5.4	R = +5.2 L = +8.5
Dorsiflexion	R = 16.8 ǀ 4,8 L = 15.5 ǀ 5.0	R = 15.9 ǀ 4.4 L = 16.0 ǀ 5.0	R = -0.9 L = +0.5

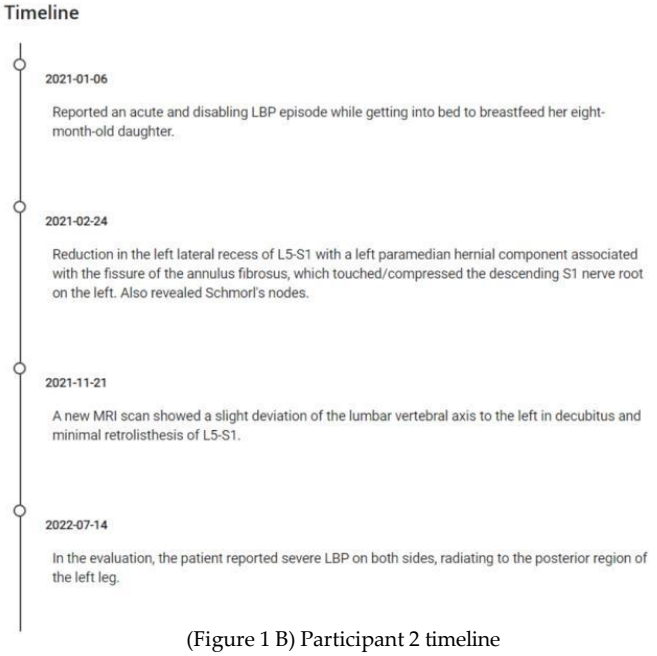
Note*: Cm = centimeters; R = right; L = left; VAS = Visual Analog Scale; RMDQ = Roland Morris disability questionnaire; MCID = Minimal Clinically Important Difference, and †MCID ⩾ 30 %.

Participant 2: A 24-year-old female (Table 1) who reported an acute and disabling LBP episode in January 2021 while getting into bed to breastfeed her eight-month-old daughter. During that period, tramadol hydrochloride, pregabalin, codeine phosphate, duloxetine hydrochloride, and dexamethasone injections were prescribed for pain control. At the end of February 2021, an MRI examination showed a reduction in the left lateral recess of L5-S1 with a left paramedian hernial component associated with the fissure of the annulus fibrosus, which touched/compressed the descending S1 nerve root on the left. The MRI also revealed an irregularity in the vertebral plateaus between T12 and L1 and between L5 and S1 with associated Schmorl's nodes (information from the MRI report).

Accompanied by the neurosurgeon, the patient underwent the percutaneous rhizotomy procedure, which improved the pain by 80 % and decreased it to 50 % after two months. In November 2021, a new MRI scan showed a slight deviation of the lumbar vertebral axis to the left in decubitus and minimal retrolisthesis of L5-S1. She had been living with LBP that radiates to the posterior region of her left thigh for 10 months. The patient had experienced several falls from her own height during childhood, with acute trauma to the sacral region and coccyx, without serious consequences. She reported a limping gait since adolescence and poor sleep quality. In the evaluation, the patient reported severe LBP on both sides, radiating to the posterior region of the left leg (Figure 1B).



(Figure 1A) Participant 1 timeline



(Figure 1 B) Participant 2 timeline

Figure 1. Timeline – Participants 1 (1A) and 2 (1B).

Outcome Measures

The assessments were carried out by members of the Laboratory of Biomechanics and Clinical Epidemiology who were not involved in the treatment. The Visual Analog Scale (VAS) was used to assess pain, with values ranging from zero (no pain) to 10 (extreme pain), measured in centimeters (cm)[32].

Participants also completed the Roland Morris Disability Questionnaire (RMDQ) pre- and during/post-intervention. The questionnaire consists of 24 statements that

characterize the physical function status of participants experiencing LBP in the previous 24 hours. Participants marked only the statement(s) that best described them at that moment. The score ranges from 0 to 24, where 0 is the ability to perform tasks and 24 is the maximum inability to perform everyday tasks. The more questions marked, the greater the severity of lumbar spine dysfunction[33].

The MCID is the smallest difference in score that can signify true change, and was used to assess the magnitude of change in the RMDQ dysfunction domain for each participant[34-36]. Jordan et al. (2006) recommend five points of MCID in patients with LBP after three to six weeks of treatment[37]. Ostelo et al. (2008) obtained the value of five points for the RMDQ and, when considering the initial score, classified a 30 % improvement as a useful threshold for identifying clinical improvement[38]. Froud et al. (2018) found an MCID threshold of 1.5 to 5 points and a clinical improvement of 28 % when considering the baseline[36]. These data corroborate the study by Ostelo et al. (2008)[38]. Therefore, a cut-off point of five points was defined for clinical improvement in the RMDQ or 30 % when considering the baseline.

To assess lower limb muscle strength, the hand-held dynamometer microFET®2 Digital Handheld Dynamometer (Salt Lake City, USA) was used[39]. Muscle strength (kgf) was assessed only for participant 2, as there were suspicions of neuropraxia of the deep fibular nerve during the assessment.

Procedures

The study lasted eight weeks, with one AE session and one KT session each week, totaling sixteen sessions for each participant. The patients answered the RMDQ five times before the beginning of the sessions, in order to comply with the method necessary to conduct the adopted simulation model (SMA). After the therapy sessions begun, each participant also answered the questionnaires weekly[31].

Aquatic Exercises

The aquatic exercises were performed in individual weekly sessions of one hour, for eight weeks. The AE program included: warm-up (frontal walking, frontal walking with waist dissociation, and lateral walking with abduction of legs and arms); stretching (hamstrings, triceps surae, and piriformis); and specific exercises: anteversion/retroversion; lateral pelvic tilt; slump stretching; posterior muscle chain posture according to Global Postural Reeducation; frontal reach with the sacral region resting on the pool wall; Bad Ragaz Concept — diagonal number 207 — lateral trunk flexion with support from cervical and pelvic floats, with key point of lower limb performed with short lever; aerobic exercise (bicycle); relaxation in supine (with cervical float support and support under the knees), and a massage ball in the sacral and lumbar regions.

Kotsuban Tyousei Method

The KT method is an intentional and standardized mobilization technique of the musculoskeletal system and neural stimuli with the intention of promoting minimal movement, particularly of the sacroiliac joint. This results in pelvic and lumbosacral alignment, in addition to modifying muscle stiffness and improving ROM. The KT method makes it possible to activate blood circulation by reducing concentric and eccentric forces in the intrinsic paravertebral musculature. This reduction enables blood to effectively

reach all the body cells to meet the physiological demands and also accelerate the removal of waste from cellular metabolism[22].

The KT method was performed in individual weekly sessions of 45 minutes for eight weeks. During these sessions, a mat is laid on the floor, and the therapist utilizes their hands and feet to perform the movements. A towel is used to avoid friction between the therapist's hands and feet and the patient's body. The KT method program included: circular movements of the ankle, in ventral decubitus position with knees flexed at 90 º, in both directions; double flexion of knees and ankles; pressure on the lower part of the hamstrings and posterior thigh, with the therapist's feet; kneading of the triceps surae muscles with the therapist's hands; double knee and hip flexion with external hip rotation; acupressure in triceps surae and tibialis anterior muscles; passive knee flexion to bring the heel closer to the gluteos; kneading of the posterior regions of the thigh and lateral gluteus with the therapist's feet; hip hyperextension with a support point in the sacral region and ankle traction; kneading of the scapular region with the therapist's feet; adjustment of the sacroiliac joint, in which the therapist pushes the posterosuperior iliac region with the heel and with the support on the dorsum of the individual's feet with the aim of keeping both heels of the individual symmetrical when observing them side by side, after adjustment. Subsequently, the therapist applies acupressure in regions of the cervical, thoracic, lumbar, and sacral columns, as well as in the lateral region of the face (behind the ears, temples, lateral eyes, masseter muscle) and the posterolateral cervical musculature.

In the lateral decubitus position, waist dissociation, internal and external hip rotation with knee extension, and shoulder flexion and extension are promoted. In the dorsal decubitus position, rotation of the glenohumeral joint is promoted. Flexor and extensor muscles of wrists and fingers are kneaded, and wrists are rotated to both sides. The therapist applies pressure in the regions below the xiphoid process and supra pubis. The KT method also included palpation and kneading in the abdominal region; acupressure in the greater trochanter region, kneading in the anterior region of the thigh, friction in the patellar region; acupressure in anterior tibial muscles; dorsiflexion and pressure on the tibiotarsal joint with the patient's foot resting on the therapist's knee; waist dissociation by crossing the legs and stabilizing the shoulder girdle region. Finally, the therapist performs cervical traction using a towel and performs acupressure in the cervical, frontal, temple and top of the head, eyebrows, around the eyes and masseter regions.

In the sitting position, a slight traction of the glenohumeral joint is performed and acupressure is applied in the occipital and posterolateral cervical regions. Superficial massage is used in regions of the trapezius muscles, latissimus dorsi, and around the scapula. Light blows, using the back of the hands intertwined and a flexible fist, are delivered in the region of the trapezius muscle to promote relaxation in the finalization[22].

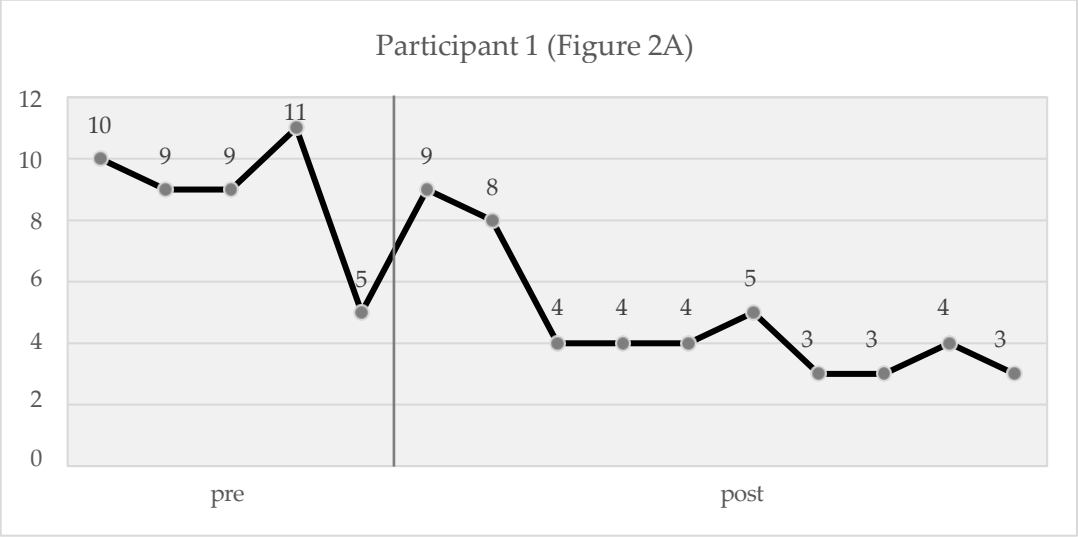
Statistical Analysis

Data are presented descriptively, including SMA the Simulation Modeling Analysis (SMA – Windows v. 11.10) and MCID values. The times series approach is a technique that analyzes the set of few data autocorrelated, in addition to simulated information from parameters of the selected variables. SMA provides a value representing the proportion of random correlations within the total flow of variables, capable of predicting the pre- and during/post-treatment results, based on a sample of five thousand cases[31]. The

autocorrelation function measures the correlation between observations in a time series that are separated by k time units (yt and yt–k). The program uses the lags to calculate the autocorrelation coefficients[29,31]. The *r* and the significance generated are related to the autocorrelation and changes in pre- and during/post-treatment values. Significance was set at 5 %.

RESULTS

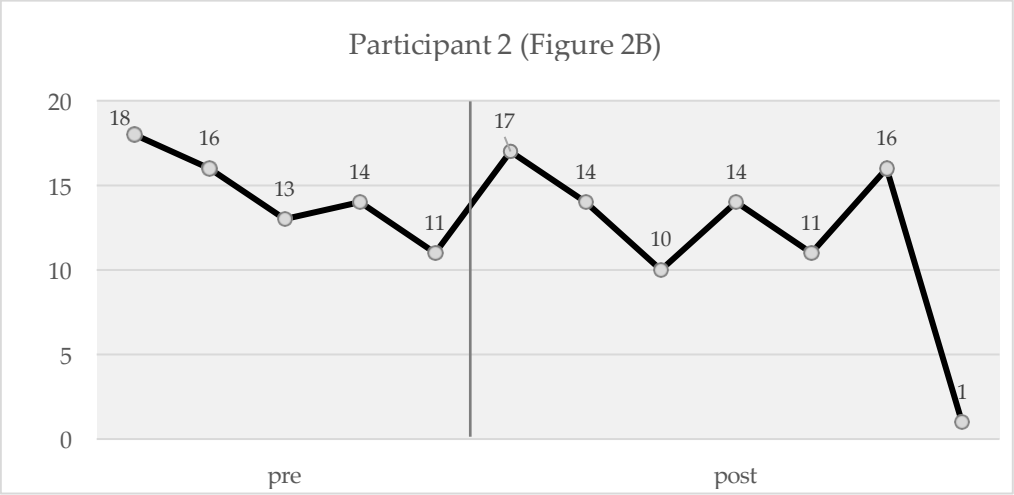
Participant 1 (Figure 2A) underwent specific tests of lateral trunk flexion and extension, as well as the Lasègue test, reporting no pain complaints, as shown in Table 2. When analyzing the SMA data, the proportion of randomly generated correlations of the total variable flow showed an autocorrelation of 0.58, indicating a moderate correlation between physical function values. The other SMA results for this patient were $r = -0.69$, $P = 0.07$ when comparing the two time series. For the prediction of the line slope, that is a number that describes the direction and steepness of the line the results were $r = 0.72$ and $P = 0.52$. Regarding the MCID analysis, the 4.1 points difference obtained by the participant was not enough to determine clinical improvement, considering the baseline of five points[37,38]. However, the participant achieved 46.5 % improvement, expressed as the percentage difference between pre- and during/post-intervention means (8.8 and 4.7, respectively). This result exceeded the baseline of 30 %, which is the minimum amount of change that can be considered important, as suggested by Ostelo et al. (2008) and supported by Froud et al. (2018)[36,38]. In addition, the participant reported 10 points of RMDQ score before starting the treatment, (first pre-treatment evaluation) and 3 points after (last during/post-treatment evaluation) (Table 2 and Figure 2A).



Autocorrelation = 0,58; $r = -0,69$ (*); $P = 0,07$. * relates to the test for changing values in phases.

Figure 2A. Pre- and during/post-intervention RMDQ values for both participants

Participant 2 (Figure 2B) showed significant overall improvement in community walking and in the strength of the left hip flexion muscle groups (+ 5.7 kgf), knee extension (right + 5.2 kgf; left + 8.5 kgf), and dorsiflexion of the left foot (+ 0.5 kgf), as described in Table 2. No other tests were performed in the reassessment. At the end of the treatment, she did not report LBP or irradiation in the posterior region of the left thigh.



Autocorrelation = - 0,19; r = - 0,29 (*); P = 0,28. * relates to the test for changing values in phases.

Figure 2B. Pre- and during/post-intervention RMDQ values for both participants

When analyzing the SMA data, the proportion of correlations of the randomly generated variables showed an autocorrelation of - 0.19. The other SMA results for this patient were r = - 0.29 and P = 0.28 when comparing the two time series. For the prediction of the line slope, the results were r = 0.049 and P = 0.048. In the MCID analysis, the participant's average difference of 2.6 points obtained was not enough to determine clinical improvement, considering the baseline of five points[37,38].

The clinical improvement of 18 % (percentage difference between 14.4 pre-treatment and 11.8 during/post-treatment) did not reach the minimum threshold of 30 %[36,38]. Despite this, the participant reported 18 points on the RMDQ score before the therapy sessions (first pre-treatment evaluation) and one point after (last during/post-treatment evaluation) (Table 2 and Figure 2B). Both participants achieved 100 % adherence to treatment. Figures 3 (A, B, C, and D) demonstrate the behavior of the Visual Analogue Scale (cm) before and after the sessions with aquatic exercises and KT.

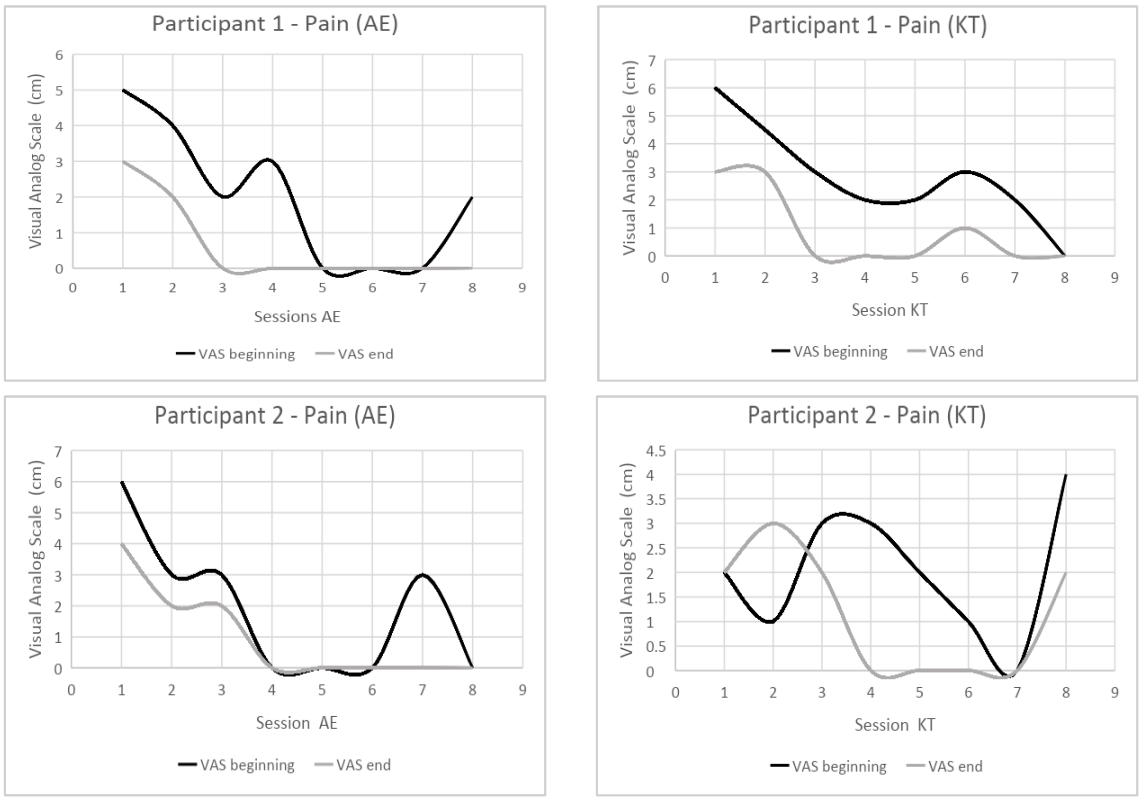


Figure 3. Visual Analog Scale (VAS) of participants 1 (3A and 3B) and 2 (3C and 3D) at the beginning and end of each session

DISCUSSION

This case series report aimed to describe the changes associated with aquatic exercises and the Kotsuban Tyousei method, after eight weeks of intervention in two individuals with LBP due to lumbar disc herniation, and to predict, using SMA, a correlation between pre- and during/post- results in an estimated sample of five thousand cases. In addition to the autocorrelation data and mean value of the pre- and during/post-treatment phases, the SMA generated *r* and significance values for the participants. The *r* values indicate a shared variance of 47 % for participant 1 and of 8 % for participant 2 for changes in values between the dependent and independent variables (physical function outcome and pre- and during/post-treatment values), without significance. These results preclude the prediction of the physical function outcome by analysis of time series, as they did not show significant differences. However, both patients showed an important difference between the first and last results (Figures 2A and 2B).

Recent studies indicate positive effects of sets of exercises on physical performance, such as: aerobics (bicycle or treadmill), stretching, resistance, mobility, stabilization, and functional exercise of spinal muscle. They also demonstrated benefits of core stabilization with an emphasis on muscle strength and endurance in the short term[41]. When associated with cognitive-behavioral therapy, core stabilization was more effective than exercises alone, allowing patients to return to their daily activities more quickly, especially in the acute and subacute periods[40].

Prescribing specifics exercises to reduce pain has become a challenge, as the pain often makes it difficult for the patient to exercise, especially if the patient's self-efficacy is low[42,43]. The AEs used in this study focused on stretching the muscles of the lower limbs (hamstrings, triceps surae, and piriformis), the mobility of the pelvic region, the muscular resistance of the trunk and abdomen, balance and aerobic exercises. This approach corroborates the findings in the literature[18,40,41]. The effect of body weight and buoyancy forces in the aquatic environment is reduced compression, which, combined with temperature, are components that reduce pain[18].

There are few studies regarding aquatic exercises and specific LBP due to herniated disc or stenosis. However, in a recent study on the effectiveness of aquatic therapy using the Williams and Mackenzie methods in the treatment of chronic LBP, the authors used herniated disc as an inclusion criterion in a group of non-specific chronic LBP lasting over one year[44]. Such approach led to improvements in non-specific LBP symptoms, however it is important to encourage further discussion about the classification of LBP as specific or non-specific pain.

Regarding manual therapies, a meta-analysis by Basson et al. (2017) revealed benefits of neural mobilization for neuromusculoskeletal conditions, especially for low back and neck pain, which aims to restore homeostasis of the nervous system, through manual techniques and exercises[45]. Mo et al. (2019) compared the efficacy and safety of Tuina, acupuncture, traction, and Chinese herbal methods for treating LDH[46]. In this meta-analysis, Tuina (SUCRA = invalid rate: 77.3; cure rate: 95.1; and VAS: 63.7) and acupuncture (SUCRA = invalid rate: 89.3; cure rate: 71.4; and EVA: 59.8) were superior to other practices, without statistically significant difference between them, while Chinese herbs (SUCRA = invalid rate: 33.5; cure rate: 33.6; and EVA: 76. 3) were superior to lumbar traction (SUCRA

= invalid rate: 0.0; cure rate: 0.0; VAS: 0.3; JOA: 1.1). The authors demonstrated that the four therapeutic modalities had different efficacy in the treatment of LDH, with Tuina, acupuncture, and Chinese herbs having direct analgesic effects, while lumbar traction has an indirect effect, producing more slow analgesia.

Oriental therapies are millenary and have the same origin. Similarly to the KT method, Tuina involves technical maneuvers such as rocking, pushing, vibrating, and joint movements using fingers, hands, elbows, knees, or feet and can cause mechanical effects on the skin, muscles, meridians, acupuncture points, and joints contributing to relaxation. It helps to enhance blood flow, reduce edema, regulate spinal balance, and treat different types of diseases, including LDH, by reducing nerve root compression, relieving adhesion between nerve root and disc herniation, in addition to reducing pain-conducting neurotransmitters (5-hydroxytryptamine) and cytokines related to the inflammatory process (TNF-α, IL-6), and increase the action of the immune system (ß-endorphin)[46]. Thus, the effects found in the literature may corroborate those described by Oda (2017)[22].

Based on the literature presented, the association of AE and KT may have promoted spinal balance, increased resistance of muscle groups, and physiological effects such as: improved blood flow, increased anti-inflammatory processes, nervous system homeostasis, and improvement of the immune system and consequently reduced pain[42,46]. At the end of eight weeks of treatment, both participants reported improvement in pain and physical function outcomes (Figures 2 and Figures 3), returning to perform activities previously difficult to execute. Haugen et al. (2011) state that although the patient presents great improvement on an average, in reality, it may not present a good result or success[34]. Therefore, it was necessary to find a baseline that would determine the MCID. There are some studies in the literature on the MCID of the RMDQ, but they refer to non-specific LBP. Yao et al. (2020) published a study comparing LBP scales for patients with herniated disc, which found an MCID of 1.74 points[47]. The study's focus was on approaching HD, but its omission/exclusion from the analysis was based on the acknowledgement that this value is lower than that found in other studies on less severe low back pain[36-38].

Some factors were observed as limiting in this study. While the participants were assiduous, they occasionally rescheduled the AE and KT sessions, with justifications, according to their personal commitments. Throughout the intervention period, participants reported heavy work activity, long journeys driving a vehicle, and falls that led to hospitalization. Both reported impairments caused by pain levels and physical function outcomes. Despite the participants' short-term clinical improvements, the SMA results indicated a low correlation between the time series. Also, the design of the case series study may incur a risk of selection bias. Additionally, the literature references found in the databases did not contemplate the study of individuals with HD in a moment prior to a potential surgery when treated with aquatic exercises. Gugliotta et al. (2016) pointed out that, compared to conservative treatment, the surgical approach did not demonstrate benefits, in the medium and long terms, in reducing the severity of sciatic symptoms or improving the quality of life of individuals with LDH[48]. Therefore, further studies are recommended, preferably in the form of randomized controlled trials that include AE associated with the KT method versus the KT method alone for individuals with lumbar disc herniation.

CONCLUSION

The combination of aquatic exercises and Kotsuban Tyousei method performed in this study showed a weak to moderate result in an analytical approach through the Simulation Modeling Analysis. Only participant 1 achieved significant change (MCID) in terms of physical function outcome. However, both participants demonstrated improvements in function and a reduction in pain when looking at their first and last sessions.

Conflict of interest: The authors declare no conflicts of interest.

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