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Article

Biomechanical Approaches to quality of life in patients with chronic pain by personalized swimming rehabilitation program

Zunyi Ma[1], Shaoyin Li[2,*], Chang-Hwang[3]

[1] College of Cultural Tourism, Sichuan Vocational College of Cultural Industry, Chengdu 610213, China
[2] Ministry of Physical Education, Panzhihua University, Panzhihua 617000, China
[3] Culture Business School, Sichuan Vocational College of Culture Industry, Chengdu 610213, China
***Corresponding author:** Shaoyin Li, 18081738731@163.com

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Abstract: The management of chronic pain can be greatly assisted by rehabilitation techniques, such as personalized swimming rehabilitation programs, which have a major effect on Quality of Life (QoL). The goal of this research is to investigate how well a personalized swimming rehabilitation program can enhance the QoL for individuals with chronic pain, with a specific focus on biomechanical principles that underpin movement and function, 75 chronic pain sufferers participate in a personalized swimming rehabilitation program. The program, personalized to each participant's requirements, concentrated on improving physical function and pain reduction through biomechanical adjustments in swimming techniques. Key biomechanical factors, such as body alignment, stroke efficiency, and buoyancy effects, were integrated into the rehabilitation regimen to promote optimal movement patterns and reduce strain on affected areas. Pain and functional status were assessed before and following the one-month therapy period. Participants' VAS scores showed significant ($p < 0.05$) improvements after the intervention, indicating lower levels of pain. In addition, the Oswestry Disability Index (ODI) and several components of the SF-36 health showed significant improvements, particularly in physical functioning and mental well-being. The results show that a personalized swimming rehabilitation program, grounded in biomechanical principles, enables individuals with chronic pain to regulate their discomfort and enhance their QoL. The incorporation of biomechanical analysis in rehabilitation not only optimizes physical function but also fosters a deeper understanding of movement mechanics, contributing to long-term pain management strategies. These results provide support for the inclusion of personalized swimming in rehabilitation programs for chronic pain management highlighting the importance of biomechanical considerations in enhancing therapeutic outcomes.

Keywords: Quality of Life (QoL); chronic pain; personalized swimming rehabilitation program; biomechanics; physical function and reducing pain

1. Introduction

Manual therapy focuses mostly on pain and mobility. Most patients seek therapy because of discomfort, and most therapies involve movement in assessment, diagnosis, and management [1]. Chronic pain, particularly low back pain, is a leading cause of disability worldwide, significantly impacting quality of life and overall well-being. Many rehabilitation treatments are based on the notion that movement therapy can reduce pain and enhance functioning. Individuals with chronic pain frequently suffer long-term physical, mental, and social issues, highlighting the need for comprehensive treatment interventions [2]. Medical recommendations encourage physical activity and exercise for treating chronic pain

due to data demonstrating its advantages in lowering pain intensity, increasing physical functioning, mental well-being, and Quality of Life (QoL) [3]. Despite these established advantages, people with chronic pain frequently avoid physical activity and exercise. It indicates that long-term commitment and behavioral adjustments are required to fully reap the benefits of exercise and physical activity. Effective communication between chronic pain patients and their healthcare professionals is essential for following exercise and food advice. Interventions that promote mobility and physical exercise are increasingly being developed for persons suffering from chronic pain [4]. Chronic pain is often associated with clinical discomfort and persists beyond the typical healing period, serving no physiological purpose. It is generally defined as pain lasting longer than 3–6 months in non-malignant conditions. Chronic pain can stem from neuropathic, functional, or nociceptive origins, though they all share similar characteristics [5]. Inflammatory pain can be caused by tissue injury from trauma, surgery, chronic inflammatory disorders like rheumatoid arthritis, or joint degeneration like osteoarthritis. Under these conditions, damaged and inflammatory cells release chemicals that activate and sensitize peripheral nociceptors. Chronic pain is the greatest reason for permanent disability among working-age people [6]. Chronic pain has a significant cost impact on individuals and society as it affects many aspects of their lives. Pain is projected to cost, including both direct and indirect expenditures [7]. Chronic pain can lead to emotional anguish, disability, cognitive impairment, and lower QoL. Chronic pain is the finest agreed from a biopsychosocial viewpoint. It is a complicated skill influenced by a patient's biological state, feelings, sentiments, movements, & sociocultural factors [8]. Despite negative impact on rehabilitation QoL, there is yet no reliable and universal treatment. Antidepressant medications typically target the serotonergic, adrenergic, and/or dopaminergic systems to boost the synaptic availability of these neurotransmitters. Reduced physical exercise can lead to higher levels of depression [9]. Regular physical activity can improve depression symptoms and promote mental health. Exercise promotes social contact with others. Effective therapies can improve both mental and physical wellness for these individuals. One approach to addressing this issue is to evaluate the physical activity environment. Most patients find the water environment both distracting and pleasurable. Despite its negative impact on rehabilitation as well as QoL, yet, there is no reliable and universal treatment. Antidepressant medications typically target the serotonergic, adrenergic, and/or dopaminergic systems to boost the synaptic availability of these neurotransmitters [10]. Reduced physical exercise can lead to higher levels of depression. Regular physical activity can improve depression symptoms and promote mental health. Exercise promotes social contact with others. Effective therapies can improve both mental and physical wellness for these individuals. One approach to addressing this issue is to evaluate the physical activity environment. Most patients find the water environment both distracting and pleasurable.

The determination of this research is to measure the efficiency of a personalized swimming rehabilitation program on QoL in people suffering from chronic pain, with a particular emphasis on gains regarding bodily function, decreasing pain, and general mental well-being.

Key contributions of the research

- The research included 75 patients who were diagnosed with chronic pain and could swim; it excluded some due to grave health issues or recent surgeries for safety reasons.
- Three tools were utilized to measure the outcomes of participants: the Visual Analog Scale (VAS) for the level of pain, the Oswestry Disability Index (ODI) for the impact on daily activity, and the SF-36 Health Survey for QoL. Assessments were conducted before the program, immediately after it was completed.
- The scores obtained before and after the swimming program were compared using statistical methods. Since *p*-values less than 0.005 have been reported, it clearly shows that the program really works.
- During the pre- and post-intervention, the people who had less pain and improved physical ability were shown to the participants after undergoing the swimming program, indicating that, this indeed is a good intervention in managing chronic pain.
- In the discussion, it pointed out that swimming was good for chronic pain patients. However, the follow-up period was not adequate. The data used was self-reported and there was no control group; with these considerations, the findings could be more significant.
- The research concludes that with personal swimming rehabilitation, those experiencing chronic pain improved because of the level of change in the pain levels and better daily activities. More research should be conducted about the long-term effects of this treatment and the optimal duration of a treatment program. This can be implemented in combination with other treatment methods for enhanced recovery.

The work was divided into 5 stages: Stage 1 introduces the paper with a general summary of what the research aims to accomplish and is relevant. Stage 2 reports related work to set up the context. Stage 3 will discuss a methodology that is going to be used in the research. Stage 4 would deal with the results and discussion, and finally, Stage 5 concluded with findings and implications.

2. Related works

The effects of hydrotherapy and peloidotherapy on the medical condition and serum cytokine stages of people with chronic low back pain (CLBP) were examined in the presented research [11]. The patients were separated into binary groups: one pool established only home exercise, while the other group received hydrotherapy, heliotherapy, and domestic exercise. Treatment caused important developments in pain strength, pain during physical activity and rest, altered Schober test, Visual Analogue Scale-Patient Global Assessment (VAS-PGA), Visual Analogue Scale-Dissolved Gas Analysis (VAS-DGA), ODI, and SF-36 factors. The research group also had a substantial rise in IL-10 levels, and they used fewer nonsteroidal anti-inflammatory medicines. Comparing the cost-effectiveness of regular primary rehabilitation versus physiotherapy with integrative multimodal virtual reality (VR) in patients with difficult CLBP was the aim of Slatman et al. [12]. In this research, a

multicenter, two-arm, group-randomized controlled trial will be conducted with 120 patients and 20 physiotherapists. The experimental group will undergo 12 weeks of rehabilitation using therapeutic VR, focusing on pain education, activation, relaxation, and distraction. The research will look at the intervention's impact on both the primary and secondary indicators of outcome. The Body Knowledge Program (BKP) is an empowerment motivated by person-centered involvement that allows patients to accomplish chronic illness & enhance their health based on their beliefs, values, and preferences as proposed in the research [13]. Individual in-depth interviews & semi-structured focus groups were done with 58 patients at Norwegian specialty care locations to evaluate the process. The findings identified four primary areas in which the intervention improved health-related patient outcomes.

In the research [14], was published with significant social and economic ramifications, Persistent Musculoskeletal Pain (PMP) is a complex issue. An investigation of the function of Cognitive Functional Therapy (CFT) in integrated treatment was conducted on 3 patients with max-impact PMP. Following the intervention, the results revealed significant changes in discomfort, impairment, maladaptive effort performance, perceived total enhancement, health-related QoL, and job position. The associations between alterations were significant and happened concurrently. The clinically relevant difference thresholds were surpassed, and two patients improved in terms of work reintegration. Using a multi-step approach, Zmerly et al. [15] aimed to encourage exercise adherence in obese and Knee osteoarthritis (KOA) patients. Phase I includes determining eligibility, testing for sarcopenic obesity, and measuring discomfort. Phase II takes a patient-centered approach, integrating an active way of life through terrestrial or liquid-based training programs lasting 8 to 12 weeks. Phase III focuses on personalizing goal-setting, improving physical fitness, creating an environment that is sustainable, and minimizing pain to improve KOA intensity and weight control. This method can aid in improving the willingness of patients to exercise.

Kim et al. [16] proposed learning about the opinions and experiences of patients with chronic pain and their doctors regarding patient-centered pain care. Five doctors from an outpatient spine care clinic and fifteen members of the community participated in qualitative descriptive research. The data was evaluated using Erlingsson & Brysiewicz's investigation of content to discover melodies and brand references. 4 broad themes appeared: provider and patient characteristics that influence pain management, methods and results, and visual representations of these variables. The severity of chronic pain [17] was intended to change over time. According to a functional Magnetic Resonance Imaging (MRI) functional Magnetic Resonance Imaging(fMRI) research, the prior insular cortex, forehead operculum, and pons store the level of pain for people with chronic back pain, while the prior isolated cortex primarily encodes the change in pain for people with ongoing migraine and back pain. Individually, the separate patient had their own unique profile of innate pain encryption. The variability of specific cortical markers of chronic pain encoding helps to connect the gap between experimental findings & neuroimaging, resulting in improved comprehension of chronic pain as a multifaceted and complicated disease. Öztürk et al. [18] examined the properties of workout on prefrontal cortex efficient action, so the people with osteoarthritis of the

knee and chronic pain. The participants' exercise regimen consisted of three sessions per week for six weeks. Paincatastrophization, movement phobia, and functioning scores all improved dramatically, although the dorsolateral frontal cortex's activity levels decreased significantly under painful stimuli. The research discovered that variations in cortical hemodynamic activities in the Dorsolateral Prefrontal Cortex (DLPFC) were substantially associated with changes in the feelings of pain and pain catastrophization ratings. Exercise improved the intensity of pain and catastrophization ratings, as well as changes in prefrontal brain activation. Consuming Patient-Reported Outcome Measures (PROMs) from the database for pain therapy was suggested by Ghafouri et al. [19], it compares the properties of the International Pharmaceutical Regulators Programme (IPRP) on individuals with chronic neuropathic pain. A neuropathy group of 1654 patients was likened to a non-neuropathic cohort. The neuropathic group had more medical visits, was older, had lower pain durations, and experienced less pain in specific locations. Only clinically insignificant variations were detected among 22 required outcome factors. The neuropathic group performed equally or slightly better than the non-neuropathic group.

Sousa et al. [20]. explored the impact of incorporating Pain Neuroscience Education (PNE) into an aquatic therapy protocol on pain, fibromyalgia (FMS) impact, quality of life, and sleep outcomes According to the current findings, PNE coupled to an aquatic exercise program failed to reduce pain intensity in individuals with FMS compared to aquatic exercises alone, however it did improve their health-related standard of life. The research relied on self-reports of aching extent, measurements, body defense, and medical indicators of fundamental sensitization. Chronic pain problems are linked to a 51% higher risk of suicide developed by Chen et al. [21], which linked Swedish identical research with ten years of longitudinal suicidal behavior data. Created on 9 self-reported chronic pain situations, the proposed method developed a general pain factor as well as two separate specific pain factors. After adjusting for genetic confusion, the relationships were considerably reduced and no longer of statistical significance within zygotic twin pairs. According to the findings, pain comorbidity and certain pain disorders could have a greater impact on eventual suicide behavior. Investigating the connection between concern and unhappiness in Americans with chronic pain was the aim of the research [22]. The chronic pain module, as well as the unhappiness and concern scales, was analyzed using the National Health Interview from 2019. There were univariate associations among chronic pain along with both concern and unhappiness scores, along with the usage of antidepressant medicines. The research discovered that persistent pain in elderly patients resulted in suggestively sophisticated ratings of strictness for concern& despair. Bruneauet al. [23], was proposed to look at how opioid removal indications & opioid passion disturb patients with chronic pain daily. They also looked into whether adverse effects and fearful thinking mediated this relationship. In the present longitudinal trial, chronic pain patients $n = 79$ who were approved for short-acting opioids kept regular chronicles for 14 days. Chronicles investigated a wide range of aching, emotional, & opioid-related appearances. A multilayer mediation analysis found that patients' day-to-day practices with undesirable effects& catastrophizing facilitated the suggestion ($p < 0.001$).

Richardson et al. [24], examine children's pain, physical development, and socioemotional indicators in relation to opioid prescriptions in pediatric patients. 1155 patients and their caregivers, ages 8 to 17, were included. Data were collected between 2015 & 2019 &examined in 2020. The results revealed that stage, pain length of time, and physical constraints were the most significant clinical predictors of a hopeful opioid state in both children and caregivers. Modifications in the Nitric Oxide (NO) strategy in people with external chronic pain conditions were discussed. It addresses the part of NO & NO synthase, nitric oxide synthase (NOS) isoforms in central pain onset & chronic illnesses with neuronal NOS receiving the greatest attention was published by Shnayder et al. [25]. The function of stimulated NOS with NOS produced by endothelial cells is being investigated. Single nucleotide variations (SNVs) of the NOS1, NOS2, & NOS3 genetic factors, which encode neuronal NOS (nNOS), inducible NOS (iNOS), and endothelial NOS (eNOS), have been linked to both chronic as well as acute peripheral pain, according to association studies. The result investigated the possible usage of NOS inhibitors to regulate the effects of medicines utilized to treat regional pain disorders.

3. Methodology

The methodology included 75 people with chronic pain who were chosen based on predetermined inclusion & exclusion criteria. The inclusion criteria were limited to persons with chronic pain, while individuals with illnesses that might interfere with the intervention were excluded. The suggested goal was to determine the efficiency of an individualized swimming rehabilitation program in lowering pain and improving QoL for these people, thus offering insights into alternative pain-management options, as displayed in **Figure 1**.

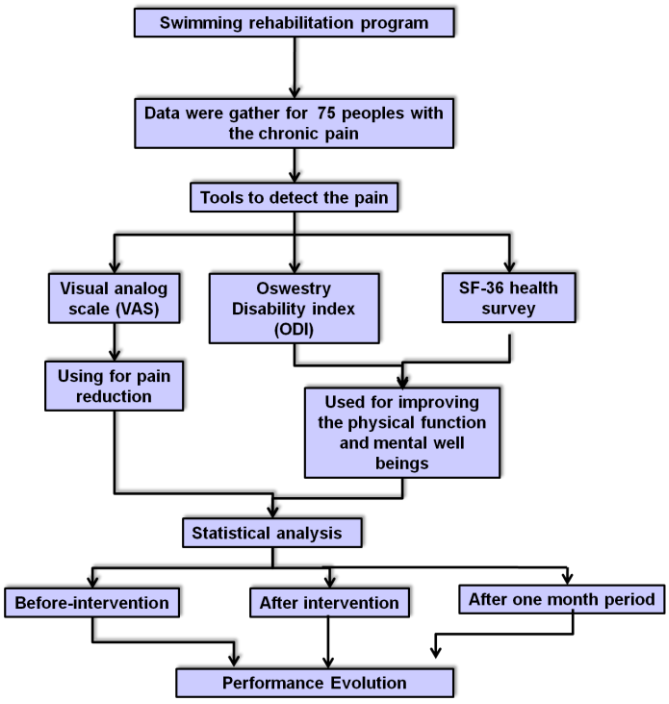

Figure 1. Framework of the personalized swimming rehabilitation program

Data collection

Out of 100 volunteers, 75 were chosen for this research because they met particular criteria linked to chronic pain. The remaining 25 participants were removed due to circumstances that potentially influenced research results. 75 participants chosen to represent the dataset used to assess the impact of a tailored swimming rehabilitation program on QoL in chronic pain sufferers, with thorough demographic and clinical data collected for each displayed in **Table 1**.

Table 1. Appearances of chronic pain contributors in the swimming rehabilitation

Attribute	Segment	Number of Participants	Percentage (%)
Age	30–40 years	15	20
	41–50 years	18	24
	51–60 years	20	27
	61–75 years	22	29
Gender	Male	40	53
	Female	35	47
Weight	Under 60 kg	10	13
	60–75 kg	25	33
	76–90 kg	28	37
	91 kg and above	12	16
Height	150 to 160	18	24
	161 to 170	27	36
	171 to 180	22	29
	181 and above	8	11
BMI	Underweight < 18.5	2	3
	Standard weight 18.5–24.9	20	27
	Heavy 25–29.9	35	47
	Obese ≥ 30	18	24
Duration of Chronic Pain	< 2 years	10	13
	2 to 5 years	32	43
	6 to 10 years	22	29
	More than 10 years	11	15
Primary Pain Diagnosis	Arthritis	30	40
	Fibromyalgia	20	27
	Lower Back Pain	15	20
	Other (e.g., neuropathic pain)	10	13

Inclusion criteria: 75 people participated in the trial because they fit certain requirements, such as having chronic pain problems including arthritis, fibromyalgia, or lower back pain. Participants had to be in the research's age range with the ability to safely participate in a swimming rehabilitation program aimed at improving QoL.

Exclusion criteria: The remaining 25 subjects were removed due to circumstances that could affect the research's results. These considerations included acute health difficulties, recent operations, or illnesses that could impede movement,

such as significant cardiovascular or pulmonary problems, all of which could pose health risks throughout the swimming therapy program, as indicated in **Figure 2**.

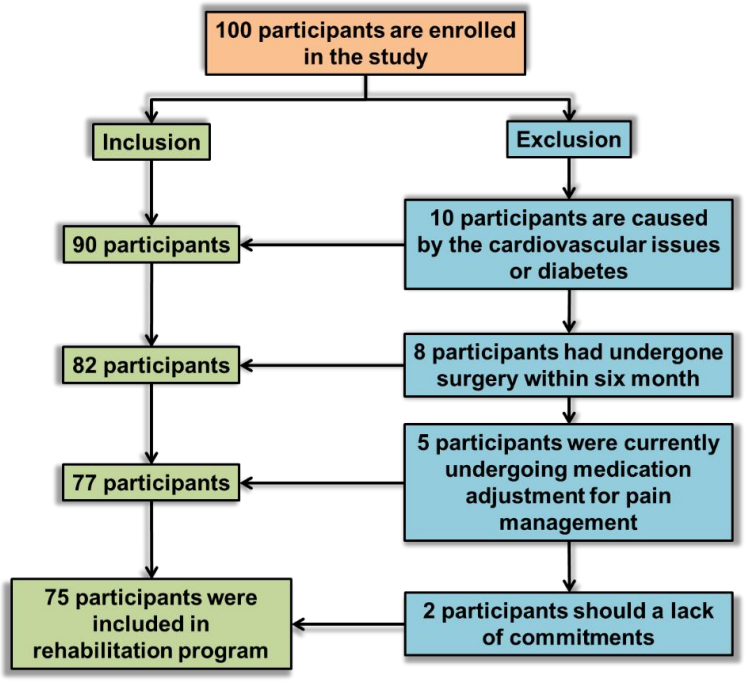

Figure 2. Participants selection criteria

VAS score: This is one of the tools broadly used in clinical practice and research, to measure the intensity of the pain, and its form, is a straight line with an average length of 10 centimeters having endpoints on the "no pain" and "worst pain imaginable." The participants mark on the scale the point corresponding to the intensity of pain they qualified at a definite instance in time. The distance between the "no pain" end and a participant's mark is equal to the VAS score. Therefore, a score from 0 to 10 is obtained. Such a measure is efficient to apply in pain assessment as it is fast; it can be very effective if applied to monitor the outcome of interventions, such as the rehabilitation program of a specific person. The VAS enables patients to subjectively express their pain levels, giving clinician's useful data for tracking changes over time. Healthcare practitioners can assess the impact of various therapeutic techniques on pain management in chronic illness populations through comparisons of pre- and post-intervention VAS scores. These approaches include physical therapy, medication, and rehabilitation programs. This objective assessment helps to develop individualized treatment regimens and enhance patient results.

The Oswestry Disability Index (ODI): It is a widely recognized questionnaire designed to measure a patient's degree of disability connected to an inferior spinal ache. It evaluates the impact of pain on various daily activities, including personal care, lifting, walking, and social life. The ODI generates a score that helps clinicians understand the severity of disability, guiding treatment decisions. In the research, the ODI was employed to evaluate the efficiency of a personalized swimming rehabilitation platform for chronic pain patients. By comparing pre- and post-

intervention ODI scores, they aimed to determine improvements in physical function & QoL, supporting the program's inclusion in pain organization strategies.

SF-36 variables: This questionnaire relies on the short form 36, a widely used health survey intended to measure generic health status across eight concepts: physical functioning, body pain, common health, vitality, social functioning, degree of role limitation, physical problems and roles limited by emotional problems & mental health. Every measure reflects some aspect of wellness in both terms of the physical and psychological condition of a person. The SF-36 is a valuable tool in the practice of clinical medicine since it helps providers understand how health problems affect daily life and aids in the measurement of treatment outcomes. The present research uses SF-36 in assessing patients undergoing a rehabilitative program of personalized swimming exercises on chronic pain improvement concerning improvement in physical functioning, diminishment of pain, and enhancement of emotional well-being. Pre intervention to postintervention SF-36 scores comparison of this research is helpful in improving estimates through various QoL dimensions. The conclusion supports rehabilitation measures aligned with personalized swimming training on chronic pain treatment.

4. Statically analysis

For statistical analysis in this research utilized SPSS version 16. The analysis began by importing necessary libraries and loading the dataset containing pre- and post-intervention scores for pain levels (VAS), functional status (ODI), and SF-36 components. Data manipulation was handled with Pandas, allowing for efficient calculations of means and standard deviations. Paired t-tests were conducted using the SciPy library to determine the significance of changes in scores, with a threshold set at $p < 0.05$. Finally, Matplotlib was employed to visualize the results, illustrating significant improvements in pain reduction and enhancements in both physical and mental well-being, thereby supporting the effectiveness of the personalized swimming rehabilitation program for chronic pain management.

5. Result and discussion

The result found significant decreases in pain (VAS, $p < 0.05$), as well as increases in physical function (ODI) and quality of life (SF-36), with a focus on physical and mental health. This individualized swimming therapy program substantially reduced impairment and improved participants' daily lives and mental well-being, indicating its potential application in chronic pain treatment.

The VAS score measured all the various key variables as an outcome measure to monitor the efficacy of the individualized swimming rehabilitation program on outcomes related to chronic pain. Reducing pain level quantified by VAS, from 6.5 (SD 1.2) at the beginning, to 3.2 (SD 1.0) after- intervention, and, finally, to 3.5 (SD 1.1) at a one-month follow-up. The physical functioning improved remarkably from 45.0 (SD 10.0) to 70.0 (SD 12.0) and 72.0 (SD 10.5) for the same periods. Increased Mobility scores enhanced from 4.5 (SD 1.5) to 7.8 (SD 1.2) and then 7.5 (SD 1.0). Enhanced Quality of Life showed a significant increase from 50.0 (SD 12.0) to 80.0 (SD 10.0) and 78.0 (SD 9.5). Participants' Better Emotional Well-Being scores

increased from 5.0 (SD 1.0) to 8.0 (SD 0.9) and 7.9 (SD 0.8). Functional capacity has improved from 40.0 (SD 9.0) to 75.0 (SD 8.0), while Sleeping Quality improved from 4.0 (SD 1.3) to 7.0 (SD 1.0) and 6.8 (SD 1.1). These results show that the VAS scores displayed a significant decrease in pain levels (p<0.05) after the specific swimming rehabilitation program, as indicated in **Table 2**.

Table 2. VAS score for the pain reduction

Outcome Factor	Before-Intervention	After- Intervention	After One-Month Period	Change Δ	*p*-Value
	Mean (SD)	Mean (SD)	Mean (SD)		
Reduction in Pain Levels	6.5 (1.2)	3.2 (1.0)	3.5 (1.1)	−3.3	< 0.001
Physical Functioning	45.0 (10.0)	70.0 (12.0)	72.0 (10.5)	+25.0	< 0.003
Increased Mobility	4.5 (1.5)	7.8 (1.2)	7.5 (1.0)	+3.3	< 0.002
Enhanced Quality of Life	50.0 (12.0)	80.0 (10.0)	78.0 (9.5)	+30.0	< 0.001
Better Emotional Well-Being	5.0 (1.0)	8.0 (0.9)	7.9 (0.8)	+3.0	< 0.001
Functional Capacity	40.0 (9.0)	75.0 (8.0)	7.9 (0.8)	+35.0	< 0.005
Sleeping Quality	4.0 (1.3)	7.0 (1.0)	6.8 (1.1)	+3.0	< 0.001

Table 3 and **Figure 3** summarize the results of 75 cases for the Oswestry Disability Index and the effectiveness of patient-customized swimming rehabilitation for alleviating chronic disabilities because of chronic pain. For personal care, 40 improved scores. Their mean score changed from pre-intervention (3.5, SD 1.0) to post-intervention (1.5, SD 0.8). *P*-value is < 0.001 and indicates a change in condition from Moderate disability. Lifting, in 50 participants, scores changed from 4.0 (SD 1.2) to 2.0 (SD 1.0) at the time of 3.0 (SD 1.1) and a *p*-value of < 0.005 indicating an alteration in condition from Severe to Moderate disability. For standing, the results showed that the scores of 47 subjects decreased from a mean of 3.6 (SD 1.2) to 2.1 (SD 1.0 as noted through a *p*-value of < 0.001), with the one-month score showing 2.9 (SD 1.1) representing moderate disability. In social life, results were positive, and improvement in scores for 38 participants became 3.9 (SD 1.1) to 1.8 (SD 0.7, while also showing a one-month score of 2.8 (SD 0.9 indicating extreme disability. The traveling scores for 34 participants increased from 4.1 (SD 1.2) to 2.3 (SD 1.0) through a *p*-value of < 0.005, indicating moderate disability. The employment scores declined from 3.5 (SD 1.3) to 1.6 (SD 0.9) for 46 participants with a *p*-value of < 0.001 which signifies severe disability pre-intervention. It indicated significant improvement because the physical function scores declined from 3.9 (SD 1.2) to 1.7 (SD 0.9), which had a *p*-value of less than 0.003. For mental well-being, 30 patients improved, and the score declined from 4.0 (SD 1.1) to 2.0 (SD 0.8) with the one-month score being 3.0 (SD 1.0). The *p*-value was found to be less than 0.001, suggesting that there was moderate disability as well as emotional health recovery. Overall, the ODI results reveal significant improvements in various categories of daily life for participants, demonstrating the effectiveness of the tailored swimming rehabilitation program in reducing impairment caused by chronic pain. These findings support the program's efficacy in increasing physical abilities and mental well-being, which aligns with the goal of enhancing the QoL for people alive with chronic pain.

Table 3. ODI disability ratings and mean scores for chronic pain patients

ODI Variable	Number of Participants	Before-Intervention	After-Intervention	After One-Month Period	*p*-Value	Disability Rating
		Mean (SD)	Mean (SD)	Mean (SD)		
Personal Care	40	3.5 (1.0)	1.5 (0.8)	2.5 (0.9)	< 0.001	Moderate (1–2)
Lifting	50	4.0 (1.2)	2.0 (1.0)	3.0 (1.1)	<0.005	Severe (3–5)
Standing	47	3.6 (1.2)	2.1 (1.0)	2.9 (1.1)	< 0.001	Moderate (1–2)
Social Life	38	3.9 (1.1)	1.8 (0.7)	2.8 (0.9)	< 0.001	Severe (3–5)
Traveling	34	4.1 (1.2)	2.3 (1.0)	3.2 (1.1)	<0.005	Moderate (1–2)
Employment	46	3.5 (1.3)	1.6 (0.9)	2.6 (1.1)	< 0.001	Severe (3–5)
Physical Functioning	33	3.9 (1.2)	1.7 (0.9)	2.8 (1.0)	<0.003	Moderate (1–2)
Mental Well-Being	30	4.0 (1.1)	2.0 (0.8)	3.0 (1.0)	< 0.001	Moderate (1–2)

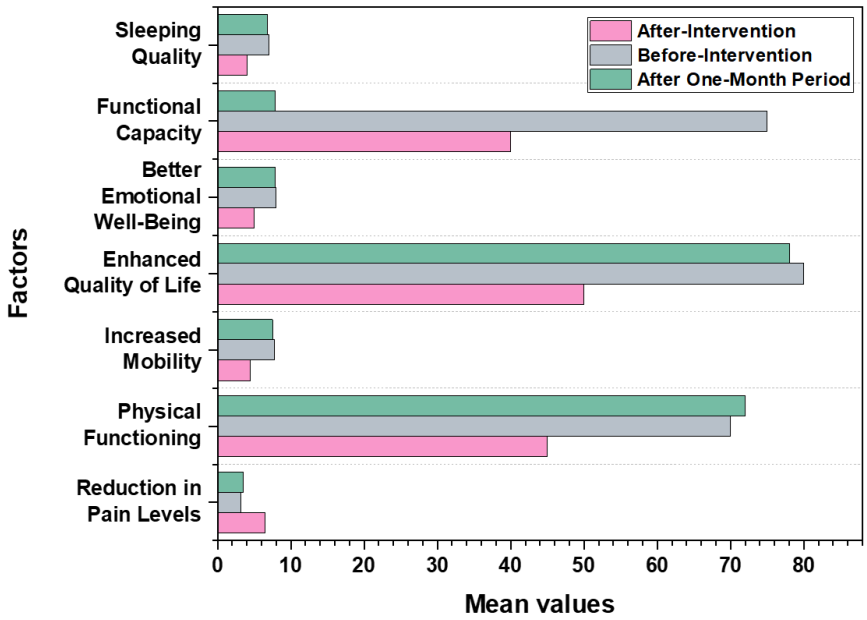

Figure 3. Calculating the mean values for ODI

Table 4 and **Figure 4** summarize the overall outcome of the SF-36 QOL survey for participants in a tailored swimming program for chronic pain management. Dimensions measured increased significantly before and after the intervention. Starting with bodily pain, the mean was 5.4 (SD 1.2) at baseline, significantly reduced to 2.9 (SD 1.1) post-intervention, and further reduced to 4.0 (SD 1.05) at one-month follow-up, with a *p*-value of < 0.001. This signifies a marked relief in the degree of pain after the intervention. This significantly affected vitality scores, moving up from 4.6 (SD 1.4) before the intervention and afterward moving up to 6.1 (SD 1.0). However, there is a reversal back down one month after the intervention, which attains 5.5 (SD 1.2; $p < 0.001$). It showed people gaining energy. This condition of general health is the next aspect where the improved score moved from 3.9 (SD 1.0) during the pre-intervention state into a post-intervention time to 5.7 (SD 1.2). Again, one month following that period, the rate lowered once again to 4.8 (SD 1.1; $p < 0.001$). Scores for sleep quality declined from 4.8 (SD 1.3) to 3.2 (SD 1.0) at the end of the intervention but improved to 4.1 (SD 1.1) at the end of the month. The

above result signifies sleep pattern disturbances. Social functioning rose from a pre-intervention value of 4.3 (SD 1.1) to 5.6 (SD 1.2) post-intervention, then decreased marginally to 4.9 (SD 1.15) after one-month follow-up and indicated social activity. The scores on physical functioning increased from 4.7 (SD 1.3) before intervention to 6.0 (SD 1.0) after intervention and remained the same at 5.3 (SD 1.05) ($p < 0.001$). For patients with imitations in physical health, scores on the quality-of-life indicators improved over time from baseline values of 4.0 (SD 1.2) to 5.4 (SD 1.1), averaging 4.7 for the entire month ($p < 0.001$). Emotional problem scores worsened at each assessment as follows: for the four patients who died, these scores increased dramatically from the baseline of 3.8 (SD 1.2) to an average of 5.2 (SD 1.1; $p = 0.005$). These results demonstrate the efficacy of this patient-tailored swimming rehabilitation program in improving numerous aspects of QoL among clients with chronic pain in positive contributions to their well-being.

Table 4. SF-36 for QOL variables with chronic pains

SF-36 for QoL attributes	Before-Intervention		After -Intervention		After One-Month Period		*p*-Value
	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)	Mean (SD)	Min (Max)	
Bodily Pain (BP)	5.4 (1.2)	3 (8)	2.9 (1.1)	1 (5)	4.0 (1.05)	2 (7)	< 0.001
Vitality (VT)	4.6 (1.4)	2 (8)	6.1 (1.0)	4 (10)	5.5 (1.2)	2 (7)	< 0.001
General Health (GH)	3.9 (1.0)	2 (6)	5.7 (1.2)	4 (9)	4.8 (1.1)	3 (8)	< 0.001
Sleep Quality (SQ)	4.8 (1.3)	3 (8)	3.2 (1.0)	1 (5)	4.1 (1.1)	2 (7)	< 0.005
Social Functioning (SF)	4.3 (1.1)	3 (7)	5.6 (1.2)	4 (9)	4.9 (1.15)	3 (8)	< 0.001
Physical Functioning (PF)	4.7 (1.3)	3 (8)	6.0 (1.0)	4 (10)	5.3 (1.05)	3 (9)	< 0.001
Limitation of Physical Health (RP)	4.0 (1.2)	2 (6)	5.4 (1.1)	3 (9)	4.7 (1.2)	3 (8)	< 0.001
Limitation of Emotional Problems (RE)	3.8 (1.2)	2 (6)	5.2 (1.1)	3 (8)	4.5 (1.2)	2 (7)	< 0.005

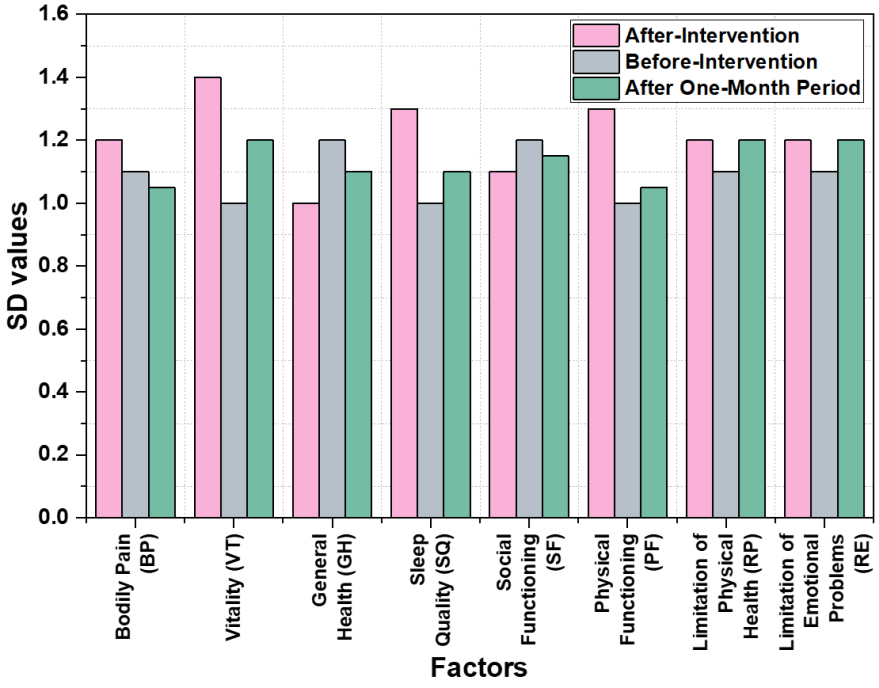

Figure 4. Standard deviation values for SF-36 variables

This research demonstrates the efficacy of a tailored swimming rehabilitation program in treating chronic pain and enhancing overall QoL. Physical functioning and mental well-being both showed significant gains. However, one weakness was the relatively small sample size of only 75 participants, which could have an impact on the findings' generalizability. Furthermore, the usage of self-reported metrics increases the opportunity of bias since contributors could exaggerate their progress. The brief period of follow-up assessments hinders comprehension of the intervention's long-term impacts, prompting caution when interpreting the findings and applying them to larger populations.

6. Conclusion

A personalized swimming rehabilitation program benefits individuals with chronic pain by showing reduced levels of pain as well as the development in general QoL. The conclusion drawn after the research demonstrates a significant difference in nearly all areas: pain, physical functioning, and emotional wellbeing, and there was highly significant improvement in the components of the Oswestry Disability Index (ODI) and SF-36 health questionnaire. Participants had low pain rates as shown in VAS scores, while enhanced bodily functions and emotional wellness performed well, showing all-round competence in daily life activity enhancement. The results help to support the utility of the swimming intervention. Furthermore, the findings bring with the prospect that a swimming program might constitute, one of the valuable interventions in chronic pain treatment protocols in the future, since many critical outcomes had *p*-values at below <0.005. Finally, findings of the research would set across the significance of tailoring individualized rehabilitation methods in typical pain management plans, in terms of improving patient recovery outcomes. Future studies are expected to highlight long-term swimming-based rehabilitation and mechanisms of producing effects of pain relief to ensure proper comparison of such treatment methods with other therapies designed for rehabilitation in enhancing deeper understanding and effectiveness of management in chronic pain patients. Future research will look at the long-term impact of personalized swimming rehabilitation programs on chronic pain patients, focusing on pain reduction mechanisms, psychological benefits, and better functional results and concentrate on optimum program design and patient-tailored treatments.

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