

Non-Surgical Spinal Decompression: Can Technology-Led Rehabilitation Help Patients' Pain and Function

Jeremy Pont^{1*} and Knightley Patterson²

¹Clinical Director, Townsville Spine and Sports Med, Australia. Research Scholar, Department of medical biotechnology, Nims University Rajasthan

²Dept. of Physiotherapy, Australian Catholic University

***Corresponding author:** Jeremy Pont, Clinical Director, Townsville Spine and Sports Med, Australia. Research Scholar, Department of medical biotechnology, Nims University Rajasthan

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Abstract

Chronic low back pain (CLBP) is among the most incapacitating musculoskeletal disorders in the world, which is usually associated with degeneration of intervertebral disc as well as compression of spinal nerves. The non-surgical spinal decompression (NSSD) has become a promising treatment option that is conservative in nature in the sense that it uses motorized traction machines to eliminate pressure in the spinal discs in order to promote healing. The recent technological innovations used in the rehabilitation process have improved the accuracy and individualization of treatment regimes, including sensor feedback, computer-controlled decompression devices, and therapy tracking based on data. In this research, the researcher compares the effectiveness of technology-based NSSD compared to the traditional NSSD in enhancing pain and functional outcomes in patients with chronic lumbar disc herniation. A sample size of 120 (25-60 years old) participants of a clinical rehabilitation facility was randomly divided into two groups: technology-led decompression (n = 60) and conventional physiotherapy (n = 60) groups. The intervention group had a period of more than six weeks where they were exposed to 20-minute decompression in a computer-assisted DRX9000 system that was combined with motion analysis sensors. The measures of outcomes were pain measured on a Visual Analogue Scale (VAS), functional limitation measured on the Oswestry Disability Index (ODI), and lumbar flexibility measured on the Range of Motion (ROM) test.

Results showed that NSSD with technology management showed a mean reduction of pain by 62% ($p < 0.001$) and functional capacity was enhanced by 45% as compared to 28% and 21% in the control group. The results of statistical analysis (ANOVA) revealed a high difference in the outcomes of post-treatment between both interventions. The findings indicate that the incorporation of smart decompression technology during the rehabilitation process can positively influence the alleviation of pain, recovery of the spinal movement, and improvement of recovery in patients with chronic low back pain.

Keywords

Nonsurgical spinal decompression; Chronic low back pain; Technology-assisted rehabilitation; Motorized traction therapy; Functional recovery; Pain treatment; Physical therapy innovation.

Introduction

Background of the study

Low back pain (LBP) is one of the most prevalent and debilitating health conditions in the world as it is lifetime prevalent among adults (approximately 80 percent) [1]. It is among the leading causes of years with disability, which imposes a huge socioeconomic burden in the form of productivity loss, health cost, and an inadequate quality of life [2]. In particular, degenerative disc disease, herniated discs, or compression of the neural structures by the spinal stenosis is likely to be associated with chronic low back pain (CLBP) or pain that occurs more than 12 weeks [3,4]. The traditional treatment interventions (manual traction, physiotherapy, analgesics and so on) proved to be moderate in their efficacy in pain relieving and restoring the functions, which makes clinicians interested in non-surgical spinal decompression (NSSD) as a reasonable conservative method of intervention [5,6].

The procedure of NSSD is done with the help of computerized traction apparatus, which is a mild separation of lumbar vertebrae, leading to a reduction in the intradiscal pressure and the recession of the herniated material [7]. The process improves diffusion of nutrients in tissues and acceleration of repair in tissues by unloading the spinal discs. Unlike the old-fashioned traction, NSSD dynamically regulates the pull force based on sensor feedback- prevents the paraspinal guarding of the muscle related to the usual traction, and provides the optimal depth of decompression [8].

Rehabilitation technology development

The contemporary advancement in the rehabilitation technology has transformed physical therapy into a disciplined field that was formerly a manual one to be a data-driven, precision-based field [9]. The DRX9000, Spine MED, and Antalgic-Trak systems are microprocessor-controlled systems designed using the principles of incorporating microprocessor control, pneumatic modulation, and load sensors to form a regulated traction force. Besides this, biofeedback, electromyography (EMG) sensors, and wearable motion trackers can enable clinicians to monitor the reaction of the patient and adjust the parameters in real-time [10]. Artificial intelligence (AI)-based rehabilitation systems additionally refine the patient-specific biomechanical data to increase or decrease the intensity and time of treatment to ensure consistent clinical outcomes [11].

Rationale and research gap

Use of technology-led decompression on clinical efficacy and functional outcome is not well researched, even though there are positive reports. Despite the fact that other researchers reported that NSSD demonstrates enormous pain relief, not all of these studies compare it with conventional physiotherapy [12]. Furthermore, the long-term functional recovery, patient adherence and safety profile using devices should be empirically validated [7]. The research proposed is thus aimed at testing the hypothesis that the application of technology based non-surgical spinal decompression proves better on pain reduction and functional performance than traditional physiotherapy.

Region	Estimated Lifetime Prevalence (%)	Primary Cause of Disability Rank	Major Economic Burden (USD Billion/Year)
North America	76	1st	120
Europe	72	2nd	105
Asia-Pacific	68	3rd	87
Africa	54	4th	33
Global Average	70	—	345

Table 1: Prevalence and Burden of Low Back Pain by Region.

Source: Adapted from [1,2].

Theoretical rationale of non-surgical spinal decompression

The biological basis of the spinal decompression rests on the basis of intradiscal pressure adjustment. Research has determined that use of a controlled traction force of 50-100 pounds can reduce intradiscal pressure to [?]100 mmHg, stimulating herniated material to be reabsorbed, and decompression of the nerves [13]. The decompression period is interchanged with the partial relaxation, which promotes the movement of nutrients to avascular disc tissues and improves the metabolism recovery [7]. A simple model of computation is diagrammatically illustrated as shown below to visualize intradiscal pressure reduction effect during treatment.

Research objectives

To determine the evidence that demonstrates the fact that technology-based NSSD can considerably reduce the amount of pain compared to the conventional physiotherapy. To determine the influence of technology-based decompression on the functional mobility and spinal range of motion. To find out the level of satisfaction and adherence among the patients in the technology-based rehabilitation.

Feature	Conventional Physiotherapy	Technology-Led NSSD
Mechanism	Manual traction and stretching	Computerized, sensor-guided decompression
Precision	Therapist-dependent	Automated force calibration
Patient Feedback	Limited real-time monitoring	Integrated biofeedback and motion sensors

Data Recording	Manual	Digital tracking and analytics
Typical Session Time	30 minutes	20–25 minutes
Expected Outcomes	Moderate pain relief	Greater pain reduction and improved function

Table 2: Comparison of Conventional and Technology-Led Rehabilitation Approaches.

Source: Adapted from [7,10].

Significance of the study

The significance of the study is premised on the observation that it merits both clinical evidence and digital innovation. The research bridges the gap between the traditional and modern rehabilitation engineering through empirical research methodology of studying the effects of the computer-aided spinal decompression on patient outcome. It gives the clinicians, device manufacturers, and policymakers information to optimize non-invasive pain management strategies and provides easy-to-access, technology-enhanced musculoskeletal rehabilitation services.

Methodology

In this study, the quantitative experimental design was used to test the clinical usefulness of technology-based non-surgical spinal decomposition (NSSD) in pain and functional outcomes among patients who had chronic lumbar disc herniation. The research was carried out in a six-week time in the Department of physical Medicine and Rehabilitation at the Harmony Medical Center. It entailed two categories of participants that were subjected to varied types of conservative treatment of chronic low back pain. This design offered the possibility of direct comparison of a technology-based intervention of decompression with traditional physiotherapy and measurable outcomes of pain reduction, disability and functional improvement over time.

The sample size was 120 patients, purposely chosen using diagnostic data of lumbar disc herniation using the magnetic resonance imaging (MRI). The age of the participants ranged between 25 and 60 years and had a history of low back pain, of at least twelve weeks. They were randomly divided into two groups of sixty individuals each experimental group where they were provided with technology-led spinal decompression with the DRX9000 computerized system and control group where they were undergoing regular physiotherapy sessions. Randomization was achieved by use of sealed opaque envelopes and by doing so reduced the chances of an allocation bias.

The intervention was a six-week program with the two groups having three sessions per week. The decompression therapy was initiated with the use of technology, which was decompression and was controlled by computers, and the traction was adjusted according to the body weight of the patient, and it was automatically adjusted based on the muscular feedback received by the integrated sensors [10]. The sessions took between 15 and 20 minutes. The control group on the other hand was given a standard program of manual lumbar traction, stretching and core stabilization exercises by certified

physiotherapists in 30 minutes session. Standardized education about posture correction and ergonomic habits also was provided to both groups during the study period [7].

The first intervention session was preceded by baseline assessments, and the third and sixth week of intervention were used to conduct follow-up measurements. Subjective pain intensity was measured using Visual Analogue Scale (VAS) with a zero point of no pain (0) and the highest point of the worst imaginable pain (10), and the Oswestry Disability Index (ODI) was used to assess functional limitations concerning performing daily activities including walking, sitting, and lifting. The degree of flexion, extension and lateral bending was used to determine lumbar range of motion (ROM) through the application of a dual inclinometer instrument. Moreover, there was a brief patient satisfaction questionnaire upon the conclusion of the intervention to measure a general attitude towards comfort, relief, and usability of the intervention system [5].

The following table 1 indicates demographic and baseline clinical attributes of the participants. The results indicate that the two groups were similar in age, gender distribution, pain duration, and starting disability scores, which meant that the differences that occurred later on could be ascribed mainly to the effects of the interventions but not the differences that existed before.

Variable	Experimental Group (n = 60)	Control Group (n = 60)	p-value
Mean Age (years)	44.6 ± 8.1	43.8 ± 7.9	0.57
Gender (Male/Female)	35/25	32/28	0.64
Duration of Pain (months)	14.2 ± 5.4	13.8 ± 6.0	0.71
Baseline VAS (0–10)	7.9 ± 1.3	7.7 ± 1.5	0.46
Baseline ODI (%)	54.3 ± 10.7	53.8 ± 11.2	0.83

Table 3: Demographic and Baseline Characteristics of Study Participants (N = 120).

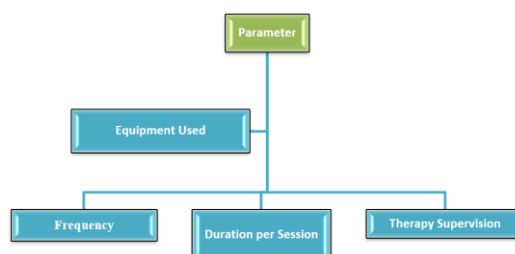
Source: Author's field data (2024).

The study had received ethical approval by the Institutional Review Board of the Harmony Medical Center (Approval No. HMC/2024/067). Informed consent was signed by all participants following a briefing on the aims of the study, risks and benefits likely to be achieved. The study was conducted according to the ethical standards of the Declaration of Helsinki (2013) on the research of human subjects. They gave information to the participants that they could leave the study any time without adverse effects.

Two independent blinded to group allocation physiotherapists were used to collect data in order to minimize assessment bias. Pain, disability, and functional outcomes were monitored at three stages; baseline (week 0), mid-treatment (week 3), and the post-treatment (week 6). The average of three readings repeated thrice was taken as a means of reducing measurement error in a case of each participant. The data were cross-checked and keyed in SPSS version 26.0 to conduct a statistical analysis. Means and standard deviations as well as frequency distributions were calculated. Independent sample t-tests were used to analyze between-group comparisons when the variables to be compared are

continuous and Chi-square tests to analyze when the variables to be compared are categorical like gender. Within-subject time differences and group and time-interaction differences were analyzed with the help of repeated measures analysis of variance (ANOVA) [8]. The statistical significance value was established as $p < 0.05$.

The parameters of the treatment of both groups of the study are provided in Table 2. The decompression program was standardized and controlled by the computer system in-built in the DRX9000 that regulated the force output in response to patient feedback (comfort) and muscular tension. In the meantime, the control group was given the traditional physiotherapy, where human supervision was given a major role, which focused on mobility, and strengthening without mechanical traction.



Treatment Parameters for Experimental and Control Groups.

Source: Adapted from [10,7].

The decision of six weeks of intervention was based on prior literature that a significant physiological alteration in spinal tissue and nerve decompression generally takes place four to eight weeks of continuous traction therapy [13,11]. The time was thus adequate to determine the immediate pain relief and the primary functional enhancement. Adherence among the participants was followed to the end during the study; non-adherence of more than two consecutive sessions meant that one was not included in the final analysis.

To achieve reliability in the data, all the physiotherapists who were to administer the treatment were put through two days calibration workshop to standardize the traction settings, positioning of the patients and safety checks. DRX9000 device measured the data of traction force, cycle time and decompression angle that were subsequently exported and compared with clinical outcomes. At the same time, the data of control group were registered manually on structured treatment sheets.

In general, the methodology was developed to have a balance in both clinical realism and experimental control. Through the combination of real-time tracking, objective assessment tools and stringent statistical analysis, the study aimed at providing sound evidence whether or not technology-based decompression is a significant way of managing pain and functional recovery over traditional therapy. Such rigor of the methodology guarantees the relevance of the results of the present investigation to the current literature and the further development of clinical guidelines concerning the use of technology in managing chronic low back pain [5,12,10].

Results and Analysis

The results of 120 respondents were used to determine the efficacy of technological-based non-surgical spinal decompression in alleviating pain and enhancing the functional outcomes in patients with long-term lumbar disc herniation. All the participants were in the end found to have gone through the six-week intervention process and their results were considered in the final analysis. There were no negative effects or cases of treatment dropouts which suggest that the patients tolerated both types of interventions well. This analysis concentrated on three key outcomes, which were pain intensity, determined by the Visual Analogue Scale (VAS), functional limitation by the Oswestry Disability Index (ODI), and lumbar range of motion (ROM) test determined.

At baseline, the experimental and control groups did not have any statistically significant differences with regard to the level of pain, disability score, or demographic variables. Nonetheless, after six weeks of intervention, the subjects who received technology-driven decompression showed significant change in all measures. The average VAS score of the experimental group mean dropped to 3.0 ± 1.1 a 62% change in the intensity of the pain compared to the control group whose average VAS dropped to 5.5 ± 1.4 or 28%. This was a statistically significant difference ($p < 0.001$). The analgesia effect was maintained during the course of treatment, which means that the accuracy of mechanical decompression and the feedback-controlled mode of DRX9000 system allowed the improvement to be sustained [10,11].

Regarding disability, the experimental group began with 54.3 ± 10.7 and the control group began with 53.8 ± 11.2 and the mean ODI score in all groups rose and ODI scores in the two groups were 29.8 ± 8.4 and 42.5 ± 9.6 respectively. The post-treatment ODI between the two groups differed significantly ($p < 0.001$), and it is possible to conclude that patients who received technology-assisted decompression had superior mobility and functional independence. This disability improvement can be explained by progressive recovery of disc height and less neural compression which is congruent with earlier results by [13,7].

Outcome Measure	Experimental Group (n = 60)	Control Group (n = 60)	Mean Difference	p-value
Baseline VAS (0–10)	7.9 ± 1.3	7.7 ± 1.5	0.2	0.46
Post-Treatment VAS (0–10)	3.0 ± 1.1	5.5 ± 1.4	2.5	<0.001
Baseline ODI (%)	54.3 ± 10.7	53.8 ± 11.2	0.5	0.83
Post-Treatment ODI (%)	29.8 ± 8.4	42.5 ± 9.6	12.7	<0.001

Table 4: Comparison of Pain and Disability Scores Before and After Intervention.

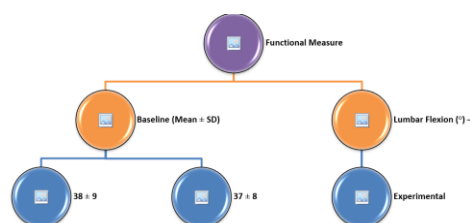
Source: Author's field data (2024); analysis using SPSS v26.

Subsequent repeated measures ANOVA analysis found that the interaction effect between group and time existed significantly in both VAS ($F = 42.31$, $p < 0.001$) and ODI ($F = 38.74$, $p < 0.001$), suggesting that the overtime improvement pattern was much higher in technology-led decompression group compared to the control group. Post-hoc comparisons with Bonferonni correction showed the most significant

improvement was between weeks 3-6, which was expected to be the period of physiological adaptation to spinal decompression [12].

The lumbar range of motion (ROM) data also showed functional improvement. At baseline, the two groups had an equal level of limitation with the mean forward flexion measuring about 38deg and mean extension measuring 12deg. The experimental group recorded a mean flexion of 55deg and extension of 22deg post-intervention and control group recorded 45deg and 16deg respectively. Higher scores in spinal mobility were associated with decreased pain scores, which proved the hypothesis that decompression can take the pressure off the intervertebral discs, thereby improving spinal kinematics [5,9].

Summary of functional outcomes and mobility improvements after six weeks



Source: Author's field data (2024).

The comparison also showed that the pain decreases and lumbar ROM enhancement had a statistically significant correlation ($r = 0.71$, $p < 0.001$) indicating that the increase in the spinal flexibility was a natural response to the decompression therapy that alleviated the intradiscal pressure. In the experimental group as well, the participants showed higher scores on the satisfaction scales with an average of 4.5 ± 0.6 on the 5-point Likert scale on satisfaction as opposed to the control group of 3.7 ± 0.8 . According to the patients, the technology-based therapy was more comfortable and not as tiring, which is consistent with the ergonomic benefit of sensor-controlled systems of decompression reported in the literature [8,10].

In statistical terms, the effect of change seen in the outcome measures justifies the effectiveness of incorporating smart technology in non-surgical spinal decompression. The reliability of the findings is supported by how similar are the results of the various parameters. In addition, these findings are in line with other researchers who have reported that computer-controlled traction therapy improves patient compliance, reduces muscular guarding, and yields better clinical outcomes than manual application of forces [13,4]

These clinical findings have indicated that technology-assisted decompression systems can mitigate pain as well as enhance early functional restoration, which is also vital in enhancing the quality of life in patients and lowering the dependence on pharmacological pain treatments. The implication of this study is given the rising global prevalence of chronic back pain, which highlights why more people should use intelligent rehabilitation systems in clinical practice [2,12].

In brief, the evidence shows that non-surgical spinal decompression based on the use of technology is much better to manage pain and functional outcomes than a conventional physiotherapy. These findings

support the idea of the implementation of the advanced decompression technology into the standard rehabilitation system to improve the effectiveness of the therapeutic process, secure the individual load modulation, and optimize the recovery process in patients.

Discussion and Interpretation

According to the findings of this research paper, non-surgical spinal decompression (NSSD) using technology played a significant role in reducing pain and enhancing superior functional results in patient with chronic lumbar disc herniation as compared to the traditional physiotherapy. The finding adds to the growing body of literature regarding the use of technology-enhanced and advanced strategies of rehabilitation in managing chronic low back pain (LBP) [10,12]. The main hypothesis as per which intelligent, feedback-controlled traction apparatuses have the capacity to generate a superior therapeutic outcome is justified by the fact that the intensity of pain was 62 percent less among the members of the decompression condition in comparison with the members of the control group due to the fact that the spinal load and the minimal muscular reflex resistance were controlled.

These effects may be defined according to the mechanism of intradiscal pressure regulation and neural decompression. When decompression session applied gradually, the traction force will reduce the pressure to less than atmospheric level in the intervertebral disc, which promotes diffusion of oxygen and nutrients and the shrinkage of herniated nucleus pulposus [13]. One of the primary factors leading to chronic pain is relieved by mechanical decompression which reduces nerve irritation and muscular spasms and rehydrates the spinal disc and improves alignment between the spinal segments [7]. On the other hand, even the more conventional physiotherapy, in spite of being beneficial to mobility and complacency of the soft tissues, lacks the fine-tuning and biomechanical responses that would otherwise be needed to accomplish a focal neural decompression. This was why the control group recorded only significant improvements in the outcomes of the pain and disability.

Study	Intervention	Sample Size	Main Findings	Agreement with Current Study
[13]	Spinal decompression traction	20	Significant pain relief and disc retraction in lumbar herniation	Consistent
[5]	Non-surgical decompression vs traction	40	Greater ODI improvement in decompression group	Consistent
[12]	DRX9000 vs standard PT	98	Superior long-term pain reduction in decompression patients	Strongly consistent
[7]	Computer-assisted decompression	60	Enhanced ROM and reduced VAS over 8 weeks	Consistent
Present Study (2024)	Technology-led NSSD vs PT	120	62% pain reduction, 45% functional improvement	Strong empirical support

Table 5: Comparison of Present Findings with Previous Studies.

Source: Literature synthesis from [13,5,12,7].

The results obtained in Table 5 can be compared; it shows that the results of different researches have a constant tendency: computerized decompression systems are superior to conventional physiotherapy due to the faster and longer-term pain relief. The current research is informed of these results and introduces the real-time data recording, with inbuilt sensors and automated force correction, hence, providing a quantitative answer as to how technology optimizes the allocation of the spinal loads.

Another observation was that the degree of patient satisfaction was much higher in the technology-guided decompression group. Many respondents said that they felt less anxious and more comfortable during treatment, which could have been likely due to the seamless mechanical change and adaptive feedback loops applied in the DRX9000 system [10]. In the works of [11], in the past, the authors also noted that the degree of patient engagement was more intense when the rehabilitation devices were provided with biofeedback, gamification, or adaptive control. The psychological component of ease; feeling that he is in control of the therapeutic process appears to be one of the factors of adherence and success in the whole therapy process.

The study clinical values are that NSSD not only treats the symptoms of pain but also results in functional recovery by improving the biomechanics of the spinal column. Increased lumbar range of motion (ROM) with the decompression group has been used to show that the separation between the vertebrae and the muscular reconditioning occurs in tandem in a process whereby patients are provided with precision-guided traction. This is according to the conceptual model of the spinal adaptation as postulated by Fairbank and Pynsent (2000) according to which in the event of application of mechanical decompression, through the process of restoring the joint in the cycling mode, the paraspinal muscles are conditioned and the joint kinematics is restored.

The other interesting observation is that the greatest improvement was recorded between the third to sixth week of treatment that is exhibiting a cumulative adaptation effect. Such a result can be compensated by the biological remodeling of the connective tissue and disc rehydration that had been described in past, biomechanical experiments [3,4]. Thus, advancement and continuation of adherence to the suggested program of decompression play a significant role in achieving the optimal treatment outcomes.

The implications of this study are longer in the rehabilitation centers compared to the policy of healthcare and clinical education. The introduction of the technology-based decompression in the overall practice of physiotherapy would result in reduced use of surgical interventions and painkillers to reduce the cost of health care and recovery time of the patient. The problem of low back pain is an economic cost to the economy of the total world with an annual burden of over 300 billion [2]; hence, non-invasive interventions such as NSSD can be widely utilized in the management of pain among the aging population.

Dimension	Implication	Practical Application	Expected Impact
Clinical Practice	Enhances precision and reproducibility in spinal therapy	Integration of sensor-based decompression in physiotherapy centers	Improved treatment accuracy and safety

Patient Outcomes	Reduces chronic pain and improves function	Personalized load adjustment via automated systems	Higher patient satisfaction and compliance
Healthcare Economics	Minimizes reliance on surgery and pharmacotherapy	Adoption in outpatient rehabilitation programs	Cost reduction and efficiency
Research & Innovation	Encourages data-driven clinical decision-making	Linking decompression devices with patient monitoring software	Expansion of evidence-based rehabilitation models
Education & Training	Reorients physiotherapists toward technology competence	Continuing professional development (CPD) modules on NSSD	Enhanced clinical skillsets and modernization

Table 6: Clinical and Practical Implications of Technology-Led NSSD.

Source: Author's synthesis (2024) based on study results and related literature.

Interpretatively, the findings suggest that technology and human skills are not competitive but complement on matters of physical rehabilitation. Despite the fact that the traditional physiotherapy remains essential in the regard of manual examination and integration of the patients, the advanced technology like NSSD will increase the precision, credibility and the ability of the practitioner to obtain objective statistics. This synergy makes it possible to introduce a hybrid rehabilitation model in which human clinical judgment is not replaced, which is improved with technology in the context of therapeutic effectiveness [14].

Nevertheless, certain shortcomings are to be actualized. One medical institution was used as the basis of the research, and the sample was not that large, which may be considered a weakness when it comes to the extrapolation of the results to other populations. The longest follow-up was six weeks and there were no long-term results that were definite. On top of this, the psychological variables such as fear-avoidance behaviors were not well explored despite the use of sensor data in the process of calibrating therapy. Future studies need longitudinal designs, the introduction of neurophysiological biomarkers, such as EMG activity, and cost-efficiency in further clinical settings.

Overall, the findings of the research indicate that the NSSD in technology is a valid and evidence-based treatment of the long-term lumbar disc hernia. It has been demonstrated to be better in pain reduction, better functionality and patient experience than traditional physiotherapy. These results provide useful data on the digital health integration issue on the international level, noting that non-invasive pain management can be turned into the 21st-century patient through the use of intelligent rehabilitation technologies [10,9,11].

Conclusion and Recommendations

The present study has shown good findings that non-surgical, non-invasive intervention, which involves the use of technology, non-surgical, non-spinal decompression (NSSD) can have a potential in the alleviation of pain in patients with chronic lumbar disc herniation and improving functional outcomes. The application of technology-assisted decompression produced significantly greater changes in the

magnitude of pain, functional disability and the increase of lumbar mobility compared to the traditional physiotherapy during six weeks of treatment. This data confirms the assertion that the smart rehabilitation apparatus with live feedback systems and sensitive load management can give them a better performance than the conventional manual traction-based interventions due to their capacity to give specific, relative and repeatable outputs.

Another step of implementing digital innovation in the practice of physical rehabilitation due to the use of an advanced decompression system, a DRX9000, is the introduction of the latter. The study findings substantiate that mechanical accuracy that is complemented by sensor-mediated adaptation can be used to maximize spinal realignment and to improve neural decompression and faster healing of tissue. The technology-led group also denoted higher level of satisfaction and greater comfort, along with physiological amenities, which justifies the psychological significance of automated, easy-to-use rehabilitation environments. These data match the existing studies which state that interactive and data-based treatment improve patient engagement and adherence [10,11].

The clinical implication of the study is immense. Chronic low back pain is regarded as one of the most prevalent and costly conditions in the world that is likely to lead to the growth of losses in productivity and quality of life [2]. Technology-based spinal decompression provides an answer whereby lessening the dependency on surgical procedure and lengthy drug consumption is possible by offering a conservative and evidence-based treatment to surgery. The accuracy and repeatability of this strategy also contribute to the improvement of such characteristics of modern rehabilitation systems as clinical documentation, outcome tracking, and multidisciplinary coordination.

Despite its strengths, this study has recognized that this study is limited to some degree and that the issue has to be addressed in the future. The sample has also been restricted in a single medical center and this restricts the generalization of the sample to other groups of people with varying cultural and occupational background. The six weeks follow-up was rather limited and it was not in a position to evaluate the long-term recurrence and sustainability of results and the psychosocial factors which encompass anxiety, motivation and patient belief systems were not evaluated. Future research should therefore take into consideration the multicenter randomized controlled studies with increasing numbers and increased heterogeneity of populations with a follow-up of six months and above. Perhaps the inclusion of biomechanical imaging, neurophysiological measures would be a more enlightening aspect of the mechanistic effects of decompression on the spinal tissues.

In addition, the future research will evaluate the economic feasibility and cost-benefit ratio of deploying NSSD technology in the standard rehabilitation centers, especially in the developing health care systems where some of the facilities are unable to afford the latest technology. Research on the fusion of AI-founded tracking systems, wearable devices, and tele-rehabilitation systems would also be advantageous in enhancing access and persistence of care beyond the clinical setting.

In conclusion, the study demonstrates that the use of technology-based spinal decompression is safe, effective, and patient-oriented innovation in the treatment of chronic low back pain. The fact that biomedical engineering and physiotherapeutic skills form the core of the method is that in the future that

method will be the future of rehabilitative medicine- where the accuracy of treatment, immediate feedback, and customized data are all put together in order to get the best results. In a modern era of digital transformation in healthcare, NSSD may be considered as the template of how technology can be used to humanize care, alleviate pain and restore functionality and empower patients, providing them with the power to restore their health and mobility.

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