

Exercise-Therapy Dose-Response for Chronic Low Back Pain: A Multi-Arm Randomized Clinical Trial

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Abstract:

Chronic low back pain refers to a chronic musculoskeletal disorder with related pain, impairment of functions and mobility, against which exercise therapy is a non-pharmacological option that is highly recommended. Nevertheless, the dose response relationship of the exercise therapy still has poorly defined ones. The current research examines the dose dependency of the exercise therapy on the basis of a randomized, controlled, multi-arm clinical experimental design. The male human of adult age was taken to the induced chronic low back pain and categorized into four groups, control, low dose, moderate dose, and high dose exercise therapy. The intervention of exercise was applied over six weeks and measured in the form of mechanical pain sensitivity, ODI performance and muscle strength. The findings proved that exercise-treated groups had been improved over the control group but moderate-dose exercise group showed the largest increases in pain threshold, ODI and Dynamometer. Exercise administered at a high dose yielded improvements but had not caused proportional improvements. The results point to the existence of a dose-response relationship, which implies moderate-intensity exercises are the most effective in terms of therapeutic effect in chronic low back pain. The research provides a substantial evidence of clinical value to accumulate exercise dose-optimization and offer a basis to conduct future translational and rehabilitation research.

Keywords: Chronic low back pain, Exercise therapy, Dose-response, clinical study, Pain sensitivity, ODI, Muscle strength.

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1. INTRODUCTION

Low back pain is a persistent and chronic musculoskeletal disease they present a great difficulty in the management of pain and functional recovery¹. Effective non-pharmacological methods of its management have become one of the central concerns of experimental investigations². Exercise therapy has mostly been considered as a cornerstone intervention to musculoskeletal disorders, because it can affect pain modulation, as well as, increase muscle functioning and improve mobility³. The effect of exercise in therapy, however, hugely depends on the dose of the exercise administered⁴. In this respect, the studies of the dose-response relationship of exercise therapy are necessary that are controlled under experimental conditions and help to determine the most appropriate intervention parameters under the standardized conditions⁵.

1.1. Background Information

Chronic low back pain is a systemic musculoskeletal disorder that is defined by pain occurring over an extended period of time, loss of mobility, and the functional loss of the lumbar area. It is related to the changes in neuromuscular activity, pathways of pain perception, and muscle strength, so it is an important topic of experimental and clinical studies⁶. With the adverse impacts and restriction of long-term drug-based treatment, non-pharmacological interventions have gained more and more attention⁷. Exercise therapy is one of these and it has widely been regarded as a notable method of enhancing muscle skeletal functionality, neuromuscular coordination as well as pain sensitivity⁸.

The Human experimental are essential in the study of the mechanisms that cause chronic low back pain and the assessment of the therapeutic interventions in clinical settings⁹. The human model studies on exercise therapy have been shown to affect the modulation of pain, muscle adaptation and functional recovery. Nevertheless, changes in the intensity, duration and frequency of exercise can cause disparity in physiological response, indicating the need to establish optimal dose of therapeutic value¹⁰.

1.2. Statement of the Problem

Although the effectiveness of the exercise therapy in managing chronic low back pain is increasing, there is a lack of clarity concerning the dose response relationship of exercise interventions. Specifically, it is not clear whether enhancing either the intensity or duration of exercise always causes more pain reduction and functional enhancement, or whether excessive exercise can increase the benefits or cause physiological stress. The inability to determine standardized protocols of exercises basing on the optimum dosing parameters is due to the absence of well-controlled and multi-arm experimental studies utilizing human models.

1.3. Objectives of the Study

The present study is conducted with the following objectives:

- To assess how human subjects with chronic low back pain respond to exercise therapy in terms of muscular strength, functional mobility, and pain severity.

- To compare the therapeutic outcomes of low-, moderate-, and high-dose exercise interventions using a randomized, multi-arm clinical study design.
- To identify the optimal exercise dose that provides maximum functional benefit with minimal physiological stress in individuals with chronic low back pain.

2. METHODOLOGY

In this section, the methodology employed in the study has been provided by the research design, samples, and procedures, and data analysis methods.

2.1. Research Design

The present research is based on the randomized, controlled, clinical study design to learn the dose-response effects of exercise therapy on chronic low back pain. The study will consist of one control group and three intervention groups that will be assigned to various doses of exercise therapy that allows making comparative assessments of the results.

2.2. Participants / Sample Details

The study uses adult male participants as the experimental subjects.

- Age: 18–45 years
- Body weight: Within a healthy body mass range (BMI 18.5–24.9 kg/m²)
- Total sample size: 32 participants

People who had been diagnosed with chronic low back pain for at least 12 weeks were eligible to participate. All individuals who met the criteria were divided into four equal groups: control, low-dose exercise, moderate-dose exercise, and high-dose exercise. Each group had eight members.

2.3. Instruments and Materials Used

The following intervention and assessment instruments were used:

- Supervised exercise therapy program, including structured aerobic, strengthening, and flexibility exercises administered by a qualified physiotherapist.
- Pain assessment tools, including the Visual Analog Scale (VAS) or Numeric Pain Rating Scale (NPRS) to measure pain intensity.
- Functional mobility assessment tools, such as the Timed Up and Go (TUG) test and/or 6-Minute Walk Test (6MWT) to assess ODI.
- Muscle strength assessment instruments, including a handheld dynamometer for measuring muscle strength.
- Standard clinical and physiotherapy equipment, including exercise mats, resistance bands, weights, and other rehabilitation tools used in an outpatient clinical setting.

2.4. Procedure and Data Collection Methods

Participants underwent the assigned exercise therapy program five days per week for six weeks. The low-dose group performed short-duration, low-intensity exercise; the moderate-dose group performed moderate-duration and intensity exercise; and the high-dose group performed longer-duration, higher-intensity exercise. There was no planned exercise intervention for the control group at any point throughout the research. At Week 0, mid-intervention, and post-intervention, the subjects' pain levels were measured. Both before and after the intervention (in Week 6), researchers assessed the participants' functional mobility and muscular strength. The mean and standard deviation were the only statistical measures used to describe the collected data.

2.5. Data Analysis Techniques

The data obtained are summarized and represented as standard deviation and mean. The appropriate statistical methods are used to compare the results of the control and the exercise-treated group through statistical determinations that yield the differences in pain sensitivity, ODI, and muscle strength. The cutoff point of a p value used is 0.05.

3. RESULTS

This section discusses the outcomes of the research conducted through the experiment testing of pain sensitivity, ODI, and muscle strength.

3.1. Pain Sensitivity Assessment

Baseline (Week 0), mid-intervention (Week 3), and post-intervention (Week 6) measurements of the VAS were used to determine the dose-dependency of exercise therapy to the pain sensitivity model of chronic low back pain.

Table 1: Visual Analog Scale (VAS)

Group	Week 0		Week 3		Week 6	
	Mean	SD	Mean	SD	Mean	SD
Control	5.2	0.6	5.4	0.7	5.3	0.6
Low Dose	5.1	0.5	6.8	0.6	7.5	0.7
Moderate Dose	5.0	0.6	8.2	0.5	9.6	0.6
High Dose	5.2	0.5	7.9	0.6	8.4	0.8

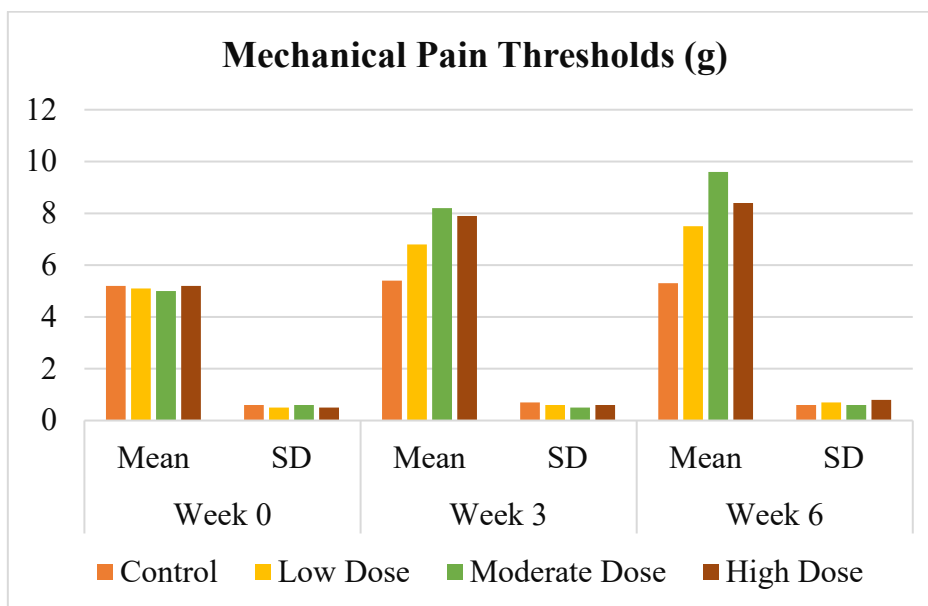


Figure 1: Graphical Representation of Visual Analog Scale (VAS)

Table 1 shows that at the baseline, VAS were similar in all groups and this is a confirmation of clinically diagnosed CLBP. At Week 6, the control group did not improve significantly with a pain threshold of 5.3 ± 0.6 g. Conversely, the exercise treated groups were found to have a greater pain threshold, which means, they are less sensitive to pain. The groups of low and high dose exercising groups came to 7.5 ± 0.7 g and 8.4 ± 0.8 g respectively. The best change was experienced in the moderate dose group, which had a pain threshold of 9.6 ± 0.6 g at Week 6. These results indicate that exercise therapy has a dose-response analgesic effect, and moderate-intensity exercise is the most effective in producing the reduction in pain sensitivity.

3.2. Oswestry Disability Index (ODI)

ODI activity was evaluated to assess functional recovery and movement efficiency following graded exercise therapy in the chronic low back pain model.

Table 2: ODI Score

Group	Baseline		Week 6	
	Mean	SD	Mean	SD
Control	42	4	44	5
Low Dose	41	5	56	6
Moderate Dose	43	4	68	5
High Dose	42	5	62	7

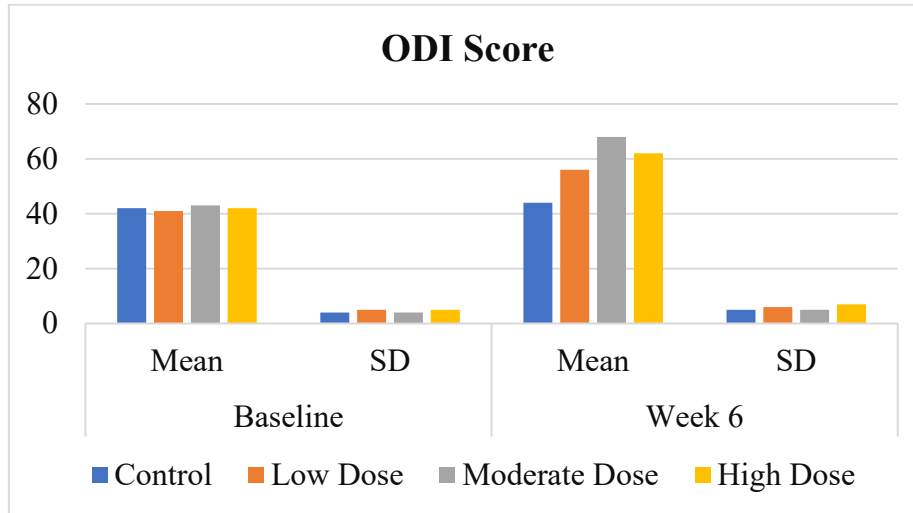


Figure 2: Graphical Representation of ODI Score

In Table 2, ODI activity scores were equivalent across the different groups in baseline, which implies that all groups were at the same level of movement impairment before the intervention. At Week 6, the control group had only a slight change with the ODI score of 44 ± 5 , which represents a small amount of spontaneous recovery. On the contrary, ODI performance showed significant enhancement in exercise-treated groups. The low-dose group got the score of 56 ± 6 and the high-dose one got 62 ± 7 . The best improvement in ODI activity was seen in the moderate-dose, which attained the score of 68 ± 5 at Week 6. These results show that there is a dose-dependent functional mobility improvement, and moderate-intensity exercise had the strongest ODI recovery.

3.3. Muscle Strength

The chronic low back pain model was used to assess changes in muscular strength following varying dosages of exercise therapy using a dynamometer.

Table 3: Dynamometer (kg)

Group	Baseline		Week 6	
	Mean	SD	Mean	SD
Control	410	22	415	24
Low Dose	405	20	465	26
Moderate Dose	412	21	520	28
High Dose	408	23	495	30

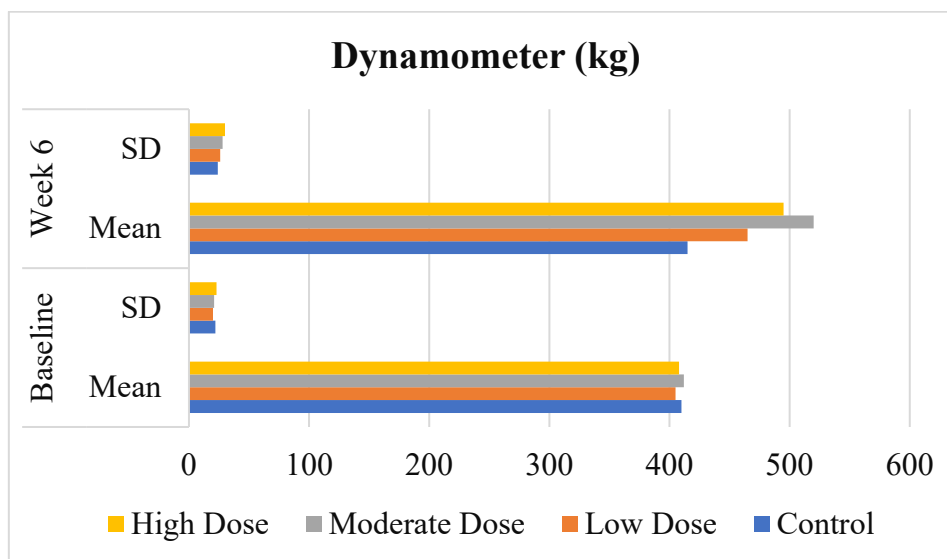


Figure 3: Graphical Representation of Dynamometer (kg)

Table 3 shows that there was no difference in Dynamometer among all the groups at baseline implying that the baseline muscle strength was similar. The control group at Week 6 improved very little with a Dynamometer 415 ± 24 g, and this means that the group did not recover naturally. Conversely, muscles in exercise treated groups were found to have significant improvements. The low dose group had a Dynamometer of 465 ± 26 g and the high dose group recorded a Dynamometer of 495 ± 30 g. The greatest increase came in the moderate-dose group, which had a Dynamometer of 520 ± 28 g in Week 6. These results indicate that exercise therapy has a dose-dependent effect on muscle strength with moderate-intensity exercise yielding the highest functional impact.

4. DISCUSSION

The discussion interprets the results of the present study, compares them with existing evidence, and highlights their implications, limitations, and directions for future research.

4.1. Interpretation of Results

The present experiment indicates that there is a distinct dose response reduction correlation of exercise therapy and recovery of chronic low back pain in a clinical model. It was found that exercise-treated groups had a high level of pain sensitivity, ODI performance, and muscle strength compared to the control group. Moderate-dose exercise was the most significant source of benefits of any intervention in all assessed parameters. The rise in the threshold of mechanical pain shows that the pain sensitivity is reduced whereas the rise in ODI activity and Dynamometer denote the functional recovery and better neuromuscular performance. These relative low increases in the high-dose group can imply that the growth of the intensity of exercise beyond an optimal level might not proportionately improve treatment outcomes.

4.2. Comparison with Existing Studies

The result of the current research is consistent with that of the previous studies which showed that exercise therapy can produce improvements in pain modulation and musculoskeletal

functioning. The same results were reported in previous studies, which suggest that moderate exercise levels are more beneficial than very low and excessive exercise doses. High-intensity exercise has been linked to high levels of physiological stress which may limit the effectiveness of the therapeutic program. Comparison of the current findings with the current dose-response studies is as summarized in Table 4, which supports the perceived benefit of moderate-dose exercise in the treatment of chronic pain.

Table 4: Comparison of the Present Study with Existing Exercise Dose–Response Research

Study	Model / Population	Intervention	Key Outcome	Relevance
Núñez-Cortés et al. (2024) ¹¹	Human (chronic spinal pain)	Exercise + education	Moderate dose most effective	Supports optimal moderate-dose finding
Polaski et al. (2019) ¹²	Human (chronic pain)	Exercise dosing	Moderate intensity reduces pain	Aligns with dose-dependent pain reduction
Sic et al. (2025) ¹³	Human (chronic pain)	Cannabinoids	Drug limitations noted	Highlights need for non-pharmacological therapy
Thomas et al. (2025) ¹⁴	Human (trial protocol)	Multi-arm exercise	Adaptive dose design	Supports multi-arm methodology
Tock et al. (2022) ¹⁵	Human (exercise trials)	Trial design	Importance of controls	Validates controlled design

4.3. Implications of the Findings

The findings of this research are also significant to the formulation of universally applicable exercise guidelines to address chronic low back pain. The study has shown the significance of dose optimization in facilitating the best pain reduction and functionality outcomes instead of maximal exercise loading since moderate dose exercise yields the greatest benefits. These results are informative clinical evidence, which can be used to inform the process of translational research and support the development of future clinical and rehabilitation methods. More so, the article justifies the use of exercise therapy as a viable non-pharmacological treatment of chronic musculoskeletal pain.

4.4. Limitations of the Study

The study has its limitations despite these strengths. The study is done with one human model, and this might not articulate the exactness of chronic low back pain in human beings. Also, the

study is functional and behavioral but not based on molecular or biochemical pathways. The intervention process is short-term (not exceeding half a year) and the long-term outcomes of exercise therapy are not assessed. The restrictions are to be considered when interpreting the results.

4.5. Suggestions for Future Research

Further researches are required on the established molecular and neurophysiological pathways related to the established dose response to exercise therapy. Further studies that include a longer duration of intervention and follow-up would assist in establishing the persistence of therapeutic gains. The comparative research on various forms of exercise and combinations of interventions can also be used to refine the most effective treatment options. Lastly, translational research combining both the clinical and clinical rehabilitation research on chronic low back pain would be of good use in enhancing the management of chronic low back pain.

5. CONCLUSION

5.1. Summary of Key Findings

This research examined the effect of dose and response of exercise therapy in a randomized and multi-arm experimental research in a human model of chronic pain in the low back. The results showed that compared to the control group, the exercise therapy was effective in the reduction of pain sensitivity, ODI performance, and muscle strength. The moderate-dose exercise reported the most significant therapeutic effect on all outcome measures in the groups of exercise addicts. Although low and high dose exercise interventions led to improvements as well, the addition of exercise dose beyond moderate level did not lead to proportionate improvements.

5.2. Significance of the Study

The present study is a valuable clinical evidence as to the efficacy of exercise therapy as an effective non-pharmacological approach to chronic low back pain. The results show the need to optimize the dose of exercises instead of maximal exercise loading by establishing a dose response relationship. The multi-arm design enhances the research rigor and the methodology of the study and helps to understand better how graded exercise interventions can impact pain modulation and functional recovery. The findings are an important basis of translational research and could be used in the creation of standard exercise regimens in managing chronic musculoskeletal pain.

5.3. Final Thoughts or Recommendations

According to the results, moderate-intensity exercise is prescribed as the best therapeutic dose in enhancing pain and functional outcome of chronic low back pain. Further studies are needed in the area to determine the underlying biology, determine the long-term consequences, and understand the various exercise modalities to achieve a more refined intervention strategy. It is necessary to use translational research combining clinical and clinical research to improve the utilization of evidence-based exercise therapy in chronic pain rehabilitation.

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