RESEARCH PAPER

Traditional Ayurvedic Therapies in the Management of Musculoskeletal Injuries and Rehabilitation Outcomes

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Abstract
Musculoskeletal injuries are a significant concern among athletes and physically active individuals due to their impact on mobility, physical performance, and long-term functional capacity. Effective rehabilitation strategies are essential to restore musculoskeletal stability, improve joint mobility, and reduce the risk of recurrent injury. This study aimed to analyze rehabilitation outcomes associated with musculoskeletal injuries using biomechanical and functional recovery indicators derived from a secondary rehabilitation dataset. A quantitative secondary data analysis was conducted using a publicly available dataset containing 100 observations with variables related to injury characteristics, rehabilitation programs, and biomechanical performance metrics. Descriptive statistics, correlation analysis, and regression techniques were applied to examine relationships between injury characteristics and rehabilitation outcomes. The findings indicated moderate variability in rehabilitation efficiency and recovery duration among participants. Biomechanical indicators such as knee joint angle, ankle flexion, jump height, movement speed, and reaction time were found to provide valuable insights into functional recovery patterns. Weak positive relationships were observed between rehabilitation efficiency and biomechanical performance indicators, suggesting that improvements in mobility and neuromuscular coordination may contribute to better rehabilitation outcomes. The study also discusses the potential relevance of integrative therapeutic approaches, including traditional Ayurvedic therapies such as Abhyanga, Swedana, and Basti, which are believed to support musculoskeletal recovery through improved circulation and reduced inflammation. These findings highlight the importance of biomechanical monitoring in rehabilitation and suggest potential opportunities for integrating traditional therapeutic approaches with modern rehabilitation strategies.

Keywords: Musculoskeletal injuries, Rehabilitation outcomes, Biomechanical indicators, Ayurvedic therapies, Integrative rehabilitation

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1. Introduction

Musculoskeletal injuries (MSKIs) represent a major global health concern, particularly among athletes and individuals engaged in regular physical activity. Such injuries include damage to muscles, ligaments, tendons, joints, and supporting connective tissues, which are usually linked with strenuous physical work, recurrent overload or traumatology. It is epidemiologically supported that musculoskeletal injuries represent a significant percentage of sports-related morbidity and are one of the major determinants of functional limitation and physical disability among active populations[1]. These injuries have been found to have a strong impact on operational readiness and performance capacity in a highly demanding environment, like the military setting, which reinforces their general relevance to health and productivity[2]. On the same note, research on student athletes has shown that the incidence of musculoskeletal injuries is very high because of repetitive training loads, poor recovery time and biomechanical stress when the athletes are engaged in sports[3].

Among the frequently occurring musculoskeletal injuries are strains to the muscles, tendons, ligaments, and joint instability. These injuries are common in the fields of activities that demand a quick change in direction, high impact activities, or high mechanical loading of the joints and the soft tissues[4]. Ligaments and tendons are very important in joint stabilization and functional transmission of forces during movement; hence, the loss of these structures can be very degrading in terms of functional mobility and athletic performance. In most instances, the instability of the joints caused by the rupture of ligaments may cause chronic musculoskeletal pain and permanent biomechanical dysfunction when timely care and

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recovery programs are not introduced[5]. In addition to these acute physical anguishes, musculoskeletal injuries frequently lead to prolonged recovery time, reduced engagement in physical exercise, and a high risk of subsequent injury, which places an emphasis on a successful rehabilitation strategy[6].

The concept of rehabilitation is known to be one of the key elements of musculoskeletal injury treatment and recovery. The goals of structured rehabilitation programs are to have physiological functioning restored, enhance mobility, and ensure the healing of tissues due to specific therapeutic procedures. Physiotherapy, strength training, flexibility exercises, and neuromuscular coordination training are the standard types of interventions that are aimed at a gradual recovery of normal biomechanical functioning[7]. Regenerative rehabilitation approaches that incorporate the process of biological tissue healing and the physical therapeutic intervention are becoming increasingly important as the means to evaluate the effectiveness of rehabilitation strategies[8]. Systematic rehabilitation programs prove to be effective in the clinical setting and drastically improve the functional performance and minimize the complications with immobility or slow recovery[9].

The evaluation of the rehabilitation results is commonly based on objective biomechanical indicators giving measurable information about the recovery process. These indicators contain the parameters that are represented by joint angles, range of motion, reaction time, movement speed, and by other functional performance parameters that indicate the neuromuscular coordination and physical capacity improvements. Biomechanical analysis can also be used especially in the detection of movement pattern deficits and tracking the progress of the rehabilitation program[10]. Based on the analysis of these indicators, clinicians and researchers will be able to learn more about the factors that affect recovery efficiency and design more efficient rehabilitation programs that can be applied to the needs of a particular patient.

In addition to the traditional rehabilitation methods, traditional medicine has traditionally focused on the holistic approach of managing musculoskeletal disorders. One of the oldest medical traditions, Ayurveda, primarily characterizes musculoskeletal disorders in terms of the disproportion of Vata dosha, the dosha of movement, nerve impulses, and musculoskeletal activity in the body[11]. Ayurvedic management practices include a set of therapeutic procedures that help to achieve physiological balance and facilitate the healing of the tissues. Therapies that are commonly practiced involve Abhyanga, which is a massage of therapeutic oil that is thought to aid circulation and muscle relaxation; Swedana or a form of therapeutic sweating; and Basti therapy which is a medicated enema therapy, which is believed to be highly effective in disorders related to Vata imbalance. Also, numerous herbal preparations like Guggulu and Shallaki have been used traditionally as anti-inflammatory and analgesic agents in the treatment of musculoskeletal disorders and joints[12]. It is believed that these treatment methods aid in recovery by improve microcirculation, decrease inflammation, aid in tissue healing, and enhance functional mobility.

Even though the need to adopt an integrative healthcare method receives an increasing number of followers, there is still a lack of quantitative data that would compare the outcomes of biomechanical rehabilitation to the established traditional therapeutic processes like presented in Ayurveda. The majority of current research is mainly on clinical symptom relief or pharmacological interventions, and less research is on objective biomechanical measurements that show functional recovery. Moreover, there are not many large-scale clinical data on Ayurvedic interventions in musculoskeletal rehabilitation specifically recorded. In this regard, data on secondary rehabilitation which encompass biomechanical and functional measures of recovery present useful opportunities of studying musculoskeletal recovery patterns. This analysis could inform on critical outcomes of rehabilitation such as joint mobility, neuromuscular response and functional performance and it can be added to more comprehensive comprehension of recovery mechanisms and guides the possibilities of combining conventional therapeutic methods with the current rehabilitation methods (Figure 1).

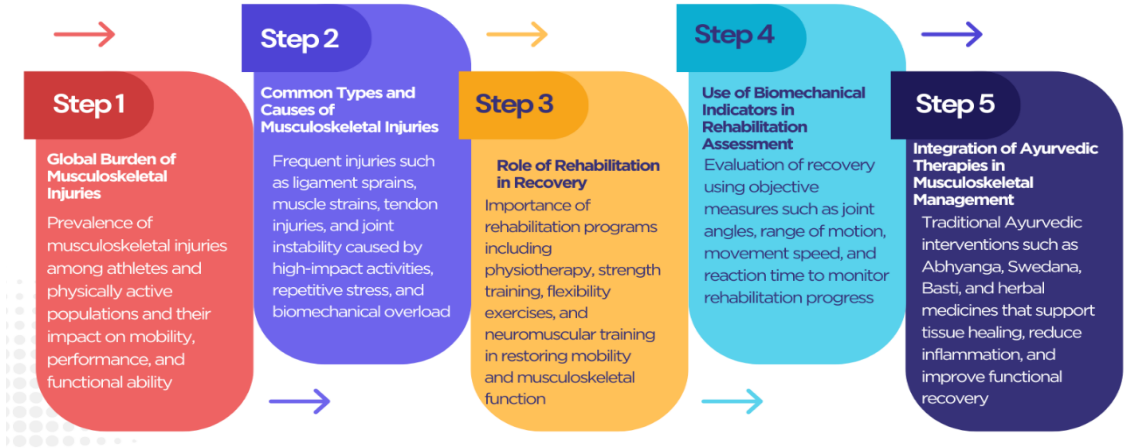

Figure 1: Conceptual Framework of Musculoskeletal Injury Rehabilitation and Integrative Therapeutic Approaches

The figure presents a conceptual framework outlining the progression from the global burden of musculoskeletal injuries to rehabilitation strategies and biomechanical assessment, culminating in the integration of Ayurvedic therapies to enhance functional recovery and musculoskeletal health outcomes.

Research Objectives

1. To analyze rehabilitation outcomes of musculoskeletal injuries using biomechanical and functional recovery indicators from a secondary dataset
2. To assess the association between injury characteristics and rehabilitation performance metrics such as joint mobility, movement speed, and reaction time
3. To discuss the implications of biomechanical rehabilitation outcomes for integrative musculoskeletal management, including traditional Ayurvedic therapies

2. Methodology

2.1 Study Design

The study followed the quantitative secondary data analysis design in order to study the rehabilitation outcomes of musculoskeletal injuries. Secondary analysis allows exploring the connection between the nature of injuries and functional recovery measures based on already existing data. This design fits well in the determination of biomechanical determinants that affect the efficiency of the rehabilitation and recovery patterns in the management of musculoskeletal injuries.

2.2 Data Source

The data to be employed in the current research was captured in one of the publicly available Kaggle sports rehabilitation datasets of biomechanical and clinical measurements linked to musculoskeletal injury. The data sample has 100 observations and several variables such as demographic variables, injury type, injury severity, rehabilitation program, rehabilitation venture, and biomechanical performance indicators. These variables offer rehabilitation outcomes and functional recovery after musculoskeletal injury and are quantifiable[13].

2.3 Study Variables

The research has considered independent and dependent variables that are of interest to the rehabilitation of injuries. Demographic and injury related factors such as age, injury type, injury severity, rehabilitation program, and injury recurrence were used as independent variables. The outcome measures of rehabilitation and biomechanical recovery including rehabilitation efficacy score, rehabilitation time (weeks), knee joint angle, ankle flexion angle, jump height, movement speed and reaction time were the dependent variables. These are mobility, neuromuscular coordination, and functional performance improvements signs in the rehabilitation process.

2.4 Data Processing

Before analysis, the data was first cleaned and made ready to facilitate reliability and consistency of data. Preprocessing of data was done to filter out missing data, check the format of the variables and outliers in the biomechanical measurements. The categorical variables were appropriately coded (injury type and rehabilitation program) to be analyzed using statistical methods. The variables under continuous examination were assessed on the basis of normality and pattern of distribution to ascertain the applicability of statistic tests.

2.5 Statistical Analysis

The SPSS and R statistical software were used to analyze the data statistically. The summary of the demographic and rehabilitation indicators (means, standard deviations, frequencies, and percentages) was performed using descriptive statistics. To test the relationships between the characteristics of injury and the results of rehabilitation, inferential analyses in terms of independent t-tests, analysis of variance (ANOVA), and Pearson correlation analysis were conducted. It was also found that the predictors of rehabilitation efficiency

and recovery duration were selected by means of multiple regression analysis. The p-value of < 0.05 was used to determine statistical significance.

3. Results

3.1 Participant Characteristics

A total of 100 athletes with musculoskeletal injuries that undergo rehabilitation programs were included in the dataset. The average age of the participants was 25.48 years (S = 4.84), and the age of respondents was between 18 and 34 years. The mean time to rehabilitate was 6.92 weeks (SD = 2.96). These descriptive statistics show that there is a moderate variability in the participant demographics and recovery time of the dataset. The average score of the rehabilitation efficiency was 67.52, indicating moderate performance of the participants in terms of recovery (Table 1).

Table 1. Descriptive Characteristics of Participants

Variable	Mean	Standard Deviation	Minimum	Maximum
Age (years)	25.48	4.84	18	34
Rehabilitation Time (weeks)	6.92	2.96	2	14
Rehabilitation Efficiency Score	67.52	22.20	25	98
Reaction Time (ms)	67.52	21.98	24	99

3.2 Injury Distribution

The data consisted of some musculoskeletal types of injury (Figure 2). The most prevalent injury was ankle sprains (27 percent) then shoulder dislocations (25 percent), ACL tear (21 percent), knee injury (15 percent) and hamstring strain (12 percent). Table 2 has revealed that ankle sprains constituted highest percentage of injuries in the dataset.

Table 2. Distribution of Musculoskeletal Injury Types

Injury Type	Frequency (n)	Percentage (%)
Ankle Sprain	27	27%
Shoulder Dislocation	25	25%
ACL Tear	21	21%
Knee Injury	15	15%
Hamstring Strain	12	12%
Total	**100**	**100%**

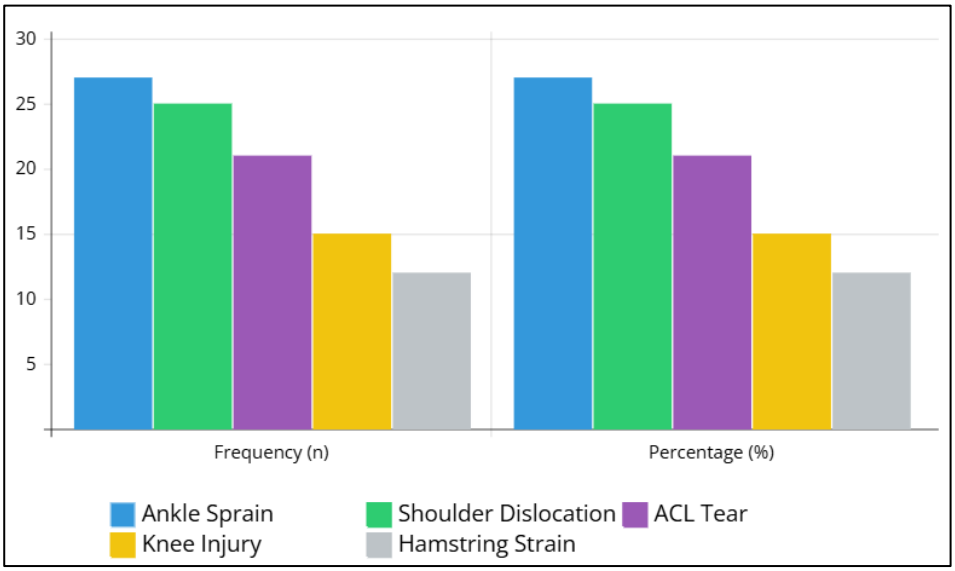

Figure 2: Distribution of Musculoskeletal Injury Types Among Participants

The figure presents the frequency and percentage distribution of musculoskeletal injury types among participants. Ankle sprain and shoulder dislocation were the most prevalent injuries (27% and 25%), followed by ACL tears, knee injuries, and hamstring strains, indicating diverse injury patterns.

3.3 Rehabilitation Program Distribution

The subjects were subjected to the various rehabilitation programs aimed at regaining mobility, strength, and neuromuscular coordination (Figure 3). Strength training (30%), physiotherapy (28%), balance training (22%), and flexibility exercises (20%), were the most popular ones. Strength training and physiotherapy were the most common rehabilitation interventions that were put in place (as shown in Table 3).

Table 3. Distribution of Rehabilitation Programs

Rehabilitation Program	Frequency (n)	Percentage (%)
Strength Training	30	30%
Physiotherapy	28	28%
Balance Training	22	22%
Flexibility Exercises	20	20%
Total	**100**	**100%**

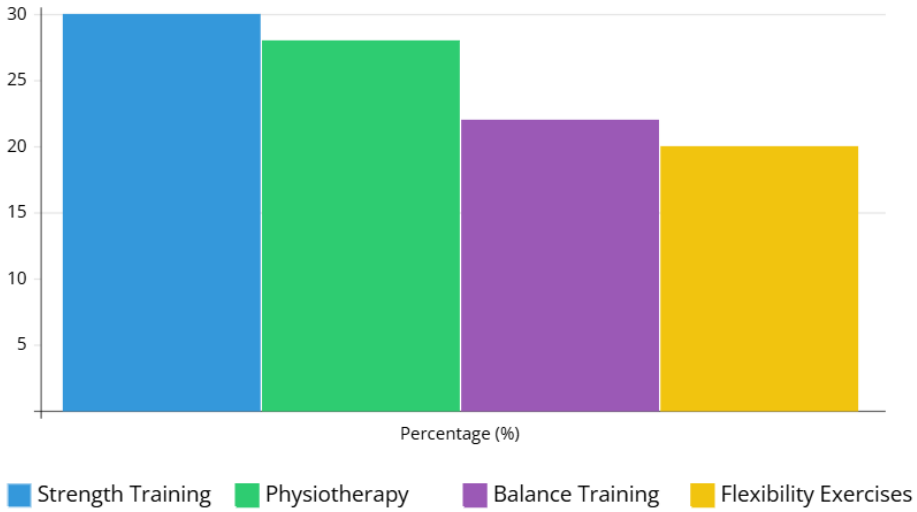

Figure 3: Distribution of Rehabilitation Programs Among Participants

The figure illustrates the distribution of rehabilitation programs among participants. Strength training was the most common intervention (30%), followed by physiotherapy (28%), balance training (22%), and flexibility exercises (20%), highlighting the diverse approaches used to improve functional recovery after musculoskeletal injuries.

3.4 Biomechanical Recovery Indicators

The biomechanical indicators were examined to assess the functional recovery of participants. These parameters were knee angle, ankle flexion angle, jump height, speed of movement and reaction time, as they show increases in mobility, neuromuscular control and physical performance. As Table 4 illustrates, subjects exhibited an average range of changes in the indicators of the joint mobility and functional performance in the rehabilitation process.

Table 4. Biomechanical Rehabilitation Indicators

Variable	Mean	Standard Deviation
Knee Angle (degrees)	66.19	21.85
Ankle Flexion (degrees)	66.38	21.40
Jump Height (cm)	66.04	21.75
Movement Speed (m/s)	64.28	20.89
Reaction Time (ms)	67.52	21.98

3.5 Association Between Biomechanical Indicators and Rehabilitation Efficiency

Correlation was used to test the association between biomechanical indicators and rehabilitation efficiency. The findings showed a low, yet significant, relationship between efficiency of rehabilitation and a number of biomechanical variables. Table 5 revealed that there was a minor positive correlation between rehabilitation efficiency and such indicators of joint mobility as a knee angle and ankle flexion. On the other hand, reaction time and rehabilitation time had weak negative relationships with rehabilitation efficiency.

Table 5. Correlation Between Biomechanical Indicators and Rehabilitation Efficiency

Variable	Correlation with Rehabilitation Efficiency (r)
Knee Angle	0.046
Ankle Flexion	0.038
Movement Speed	0.034
Jump Height	0.029
Reaction Time	-0.017
Rehabilitation Time	-0.081

4. Discussion

The current research investigated the outcome of recovery on musculoskeletal injuries based on the biomechanical and functional recovery measures using the secondary rehabilitation data. The results show that the efficiency of rehabilitation depends on the different individuals and it is determined by the nature of the injuries and biomechanical recovery parameters. Musculoskeletal injuries are commonly considered to be one of the primary issues among athletic and physically active groups of people due to the ability to severely limit mobility, worsen the physical performance, and predispose to repeated trauma[6]. Sports injuries of the ligament, tendon, and joint structure are the most widespread and are usually caused by repetitive stress or overloading as well as abrupt biomechanical forces over the musculoskeletal tissues[4]. Good rehabilitation is thus necessary to be able to restore the functional ability as well as minimizing long term complications related to these injuries.

The descriptive findings of this research suggested that there was moderate inconsistency in the rehabilitation effectiveness and recovery time in the participants[9]. Such an inconsistency can be explained by the complexity of musculoskeletal rehabilitation, and the recovery outcomes in every situation are related to a variety of factors including injury severity, rehabilitation approaches, and the individual physiological responses[14]. It has been suggested in previous studies that the foundation of functional recovery after musculoskeletal injury lies in the organized rehabilitation interventions that target the joint mobility, neuromuscular coordination, and muscle strength regainment[7]. Also, systematic rehabilitation interventions have been reported to improve physical performance and decrease complications with extended immobility or delayed treatment[15]. The results of the current research thus confirm the significance of specific rehabilitation procedures in the process of musculoskeletal functionality restoration.

Functional recovery was assessed using biomechanical measures like the knee joint angle, ankle flexion, jump, movement speed and reaction time. They are objective measures of rehabilitation improvements, which are typically applied in sports medicine to evaluate neuromuscular coordination and joint mobility improvements[10]. The findings showed that participants who had undergone rehabilitation had a quantifiable difference in these biomechanical indicators which indicated that recovery patterns of different people varied. It is known that biomechanical performance variables are significant in defining athletic performance and injury risk since inappropriate movement mechanics may be associated with recurrent injuries and slow recovery[16]. Thus, tracking the biomechanical parameters in the course of rehabilitation may enable clinicians to work out more proper recovery plans and decrease the risk of reinjury.

The correlation analysis research undertaken in the current study showed weak positive correlations between the rehabilitation efficiency and biomechanical outcome measures like the joint mobility and the speed of movement. These correlations were small, but they indicate that better biomechanical performance can be used to enhance the efficiency of rehabilitation results. On the other, the low negative correlation between reaction time and rehabilitation efficiency implies that the slower the neuromuscular reactions, the worse could be the recovery performance. Neuromuscular and proprioceptive control constitute essential elements of rehabilitation as they aid in regaining movement stability and functional performance after the occurrence of musculoskeletal injury[7]. These results emphasize the role played by the use of biomechanical tests in the rehabilitation to assess the progress of recovery.

Besides the normal rehabilitation measures, more traditional medical care like Ayurveda has complementary measures to musculoskeletal control as well. The conditions of the musculoskeletal system according to the Ayurvedic teachings are mainly linked to the disregard of the Vata dosha, the one controlling the speed and muscular movement in the organism[11]. Ayurvedic treatments are the attempts at providing physiological homeostasis by interventions that promote circulation, decreasing inflammation, and healing tissue. Among the best-suggested treatments is the Abhyanga, a form of therapeutic oil massage, which promotes a better flow of blood as well as the calming of the muscles and the increase of the mobility of the joints[17]. Other literature has highlighted the preventive and curative value of Abhyanga in musculoskeletal and overall body health[18,19].

Swedana is another Ayurvedic therapy that is applicable to musculoskeletal rehabilitation, which involves therapeutic sweating to ease the stiffness and enhance tissue flexibility. Nadi Swedana is one of the techniques that were traditionally used to treat musculoskeletal pains and increase circulation in the tissues affected[20]. On the same note, Basti therapy is regarded as an

important intervention in disorders of Vata imbalance, as well as, it is thought to aid in neuromuscular recovery and tissue healing[21]. Moreover, Ayurvedic medicine involves the use of herbs with bioactive substances with anti-inflammatory and analgesic effects, which can potentially be used in musculoskeletal recovery[22].

The dataset of this study did not necessarily involve Ayurvedic intervention, but the biomechanical recovery measures studied fit the indicators of functional outcomes, which Ayurvedic therapies are expected to enhance. Combination techniques of contemporary rehabilitative methods and the traditional therapeutic methods, as such, can, therefore, offer effective ways of improving musculoskeletal outcome and overall recovery of rehabilitation outcome. Further studies need to be conducted on the controlled clinical trials of the effectiveness of integrative rehabilitation models involving physiotherapy, biomechanical monitoring, and Ayurvedic curative methods.

5. Conclusion

This study investigated rehabilitation outcomes associated with musculoskeletal injuries by analyzing biomechanical and functional recovery indicators from a secondary rehabilitation dataset. The results indicate that the efficiency of rehabilitation and the time the person needs to recover depends on the characteristics of injuries and the biomechanical performance indices including the mobility of the joints, movement speed, and neuromuscular reactions. These measures may serve as valuable sources of information on the mechanism of functional recovery and the success of systematic rehabilitation programs on the recovery of musculoskeletal stability and physical performance. It should have proper rehabilitation plans which will focus on improving joint movements, neuromuscular coordination and total functional strength in order to reduce the chances of future injuries besides ensuring that recovery into physical activity is secure. The fact that integrative measures may be relevant to musculoskeletal rehabilitation is another significant implication of the study. The Ayurvedic practices used are believed to increase the circulation, swedana and Basti which assists in curing the body and will therefore be able to be utilized alongside the applied rehabilitation techniques. The biomechanical variables of recovery found in this study did not have direct involvement in the Ayurvedic treatment, however, the data set in this study was not utilized aiming to determine specific variables directly associated with Ayurvedic treatment but the biomechanical variables of recovery found in this study are also correlated to functional outcomes which are the goals of these therapies. An integration of Ayurvedic/evidence-based rehabilitation approaches may therefore offer the potential solution of enhancing musculoskeletal recovery and optimising the outcome of long-term rehabilitation.

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