PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL, BALANCE AND GAIT IMPAIRMENTS IN INDIVIDUALS WITH POST-COVID-19 INFECTION

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2026

DECLARATION

I, hereby declared that the presented work in the thesis entitled "**PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL, BALANCE AND GAIT IMPAIRMENTS IN INDIVIDUALS WITH POST-COVID-19 INFECTION**." in fulfilment of degree of Doctor of Philosophy (Ph. D.) is outcome of research work carried out by me under the supervision of **Dr. Zaki Anwer**, working as Professor, in the Department of Physiotherapy, Lovely School of Allied Medical Sciences of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here have been based on findings of another investigator. This work has not been submitted part or full to any other University or Institute for the award of any degree.

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DEDICATION

To my beloved family for their unconditional love and support,

I hope this achievement will fulfill the dreams they have envisioned for me.

-Vijayshree Singh-

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Date:

ABSTRACT

Background: The COVID-19 pandemic greatly affected healthcare access and posed a worldwide challenge. The appearance of new variants such as Delta, Omicron, and FLIRT reminds us of the ongoing threat. COVID-19 survivors often experience new or aggravated musculoskeletal discomfort, which can be linked to the virus's effects on the musculoskeletal system and the disruptions caused by the pandemic. However, due to the scarcity of data on post-COVID-19 infection complications, this study was conducted to examine the prevalence of musculoskeletal disorders, balance and gait abnormalities, and to develop a clear standard physiotherapy intervention for managing these issues.

Objective: The objective is to investigate the prevalence of musculoskeletal problems, balance, and gait impairments in individuals with post-COVID-19 infection, and to assess the effectiveness of Dynamic Neuromuscular Stabilization (DNS) exercises in managing these complications.

Research Methodology: The study was conducted in two phases. Phase 1 was a cross-sectional observational study conducted at the DAV Institute of Physiotherapy and Rehabilitation in Jalandhar, Punjab. 381 COVID-19 recovered patients were recruited for the survey, and responses were recorded by questionnaire. A short survey also included 50 physicians for recording their opinions. Phase 2 was an RCT intervention study in which 58 subjects were recruited based on inclusion and exclusion criteria and randomly assigned to two groups, each comprising 29 subjects. The control group A was given conventional treatment, and the experimental group B was given DNS exercises along with conventional treatment. Data collection involved demographic information, NPRS score for pain assessment, Tinetti balance and gait score for balance and gait assessment, and Borg PRE score for assessment of perceived exertion.

Results: The data analysis was conducted utilizing SPSS. Percentage and frequency distributions, and the non-parametric test Chi-Square, were used for survey analysis. For the intervention part, the second phase of the study data were initially assessed for normality using the Kolmogorov-Smirnov test; the results showed that the distribution

of residuals did not substantially deviate from normality. Although some minor deviations were observed, they fell within acceptable limits for repeated-measures ANOVA, which is considered a moderate violation. The sample size (n =58) is sufficiently large, and repeated-measures ANOVA is well-established to moderate violations of normality. Therefore, the distributions were considered appropriate for conducting RM ANOVA, supporting the continued use of parametric analysis without compromising the validity of the results.

Before conducting the repeated-measures ANOVA, the assumption of sphericity was examined using Mauchly's Test of Sphericity for all outcome measures. It was applied to each repeated-measure variable; when the sphericity assumption was violated, Greenhouse–Geisser corrections were used. The assumption of sphericity was violated for the NPRS scores, $\chi^2(2) = 28.04$, $p < .001$, $W = .61$. The corrected analyses yielded the same conclusion as the uncorrected model, showing a significant effect of treatment on NPRS scores, Greenhouse–Geisser: $F(1.43, 81.79) = 188.71$, $p < .001$, $\eta^2 = .77$; Huynh–Feldt: $F(1.46, 83.32) = 188.71$, $p < .001$, $\eta^2 = .77$. For Tinetti balance variable the assumption of sphericity was violated across the three time points. As a result, the Greenhouse–Geisser and Huynh–Feldt corrections were applied to adjust the degrees of freedom and provide a more conservative estimate of the F-value. However, even after applying these corrections, the repeated-measures ANOVA remained highly significant ($p < .001$), demonstrating a strong treatment effect over time. The repeated-measures ANOVA revealed a statistically significant effect of treatment on gait performance across time ($F = 116.10$, $p < .001$, $\eta^2 = 0.67$), which remained highly significant after applying both sphericity corrections. These results indicate a consistent and substantial improvement in gait function over time, demonstrating that the intervention had a meaningful impact, indicating that the effect is reliable. For Borg, rating statistically significant effect of time on perceived exertion was found, with consistent results across all correction methods ($F = 180.37$, $p < .001$, $\eta^2 = 0.76$). This indicates that participants showed a substantial improvement in BORG scores over the intervention period, and the corrected analyses confirm that these findings are consistent and reliable.

Descriptive statistics for all outcomes (NPRS pain scores, Tinetti balance and gait scores, and Borg rating of perceived exertion) were calculated as the mean scores (±SD) and standard errors (SE) of the outcome measure for both the Experimental Group (B) and Control Group (A) across the three assessment points (Day 1, Week 3, and Week 6). For NPRS at baseline (Day 1), the Experimental Group (6.07 ± 0.59, SE = 0.11) and the Control Group (5.86 ± 0.74, SE = 0.14) demonstrated comparable values. By Week 3, the Experimental Group B showed a marked reduction (4.66 ± 0.72, SE = 0.13), whereas the Control Group demonstrated only a modest decline (5.03 ± 1.02, SE = 0.19). At Week 6, the Experimental Group continued to show improvement, with mean scores decreasing further to 3.41 ± 0.78 (SE = 0.14), while the Control Group's mean decreased to 4.28 ± 1.39 (SE = 0.26). Overall, these descriptive results indicate that participants in the Experimental Group exhibited a greater and more consistent reduction of pain across the intervention period compared to the Control Group, suggesting a beneficial effect of the intervention. For Tinetti balance variable analysis at baseline (Day 1), the Experimental Group had a mean Score oof 9.97± 2.06 (SE = 0.38), while the Control Group scored slightly higher at 11.00 ± 3.22 (SE = 0.60). By Week 3, the Experimental Group improved to 12.31 ± 2.07 (SE = 0.38), whereas the Control Group showed only a modest increase to 11.90 ± 2.97 (SE = 0.55). At Week 6, the Experimental Group demonstrated a further increase to 14.14 ± 1.68 (SE = 0.31), compared with the Control Group's score of 13.07 ± 2.31 (SE = 0.43). The progressive increase in mean scores in the Experimental Group indicates that the intervention contributed positively to balance recovery, while the Control Group exhibited a smaller, less significant improvement.

Descriptive statistics for gait variable at baseline (Week 1), the Experimental Group recorded a mean gait score of 8.83 ± 1.00 (SE = 0.19), while the Control Group scored slightly higher at 9.00 ± 2.12 (SE = 0.39). By Week 3, the Experimental Group showed a notable improvement to 10.10 ± 0.86 (SE = 0.16), whereas the Control Group increased only modestly to 9.72 ± 0.61 (SE = 0.30). At Week 6, the Experimental Group demonstrated a further rise in gait performance, reaching 11.38 ± 0.73 (SE = 0.14), compared with the Control Group's score of 10.69 ± 1.39 (SE = 0.26). Overall, both groups exhibited progressive improvements in gait scores across the six weeks;

however, the Experimental Group demonstrated a greater and more consistent upward trajectory while for Borg rating at baseline (Day 1), the Experimental Group (B) reported a mean RPE of 15.72 ± 0.84, comparable to the Control Group (A) at 15.28 ± 1.22, reflecting a relatively high perception of exertion. By Week 3, both groups exhibited a reduction in perceived exertion, with Group B decreasing more substantially (14.07 ± 0.96) compared to Group A (14.00 ± 1.20). By Week 6, this downward trend continued, with the Experimental Group showing a sharper decline to 12.48 ± 1.12, while the Control Group reached 13.24 ± 1.50. The lower RPE scores in the experimental group suggest that participants experienced greater improvements in physical tolerance and efficiency.

Finally, Inferential statistics were applied to evaluate changes over time and differences between groups (DNS intervention vs. control). Separate two-way repeated-measures ANOVAs (Group × Time) were performed for each outcome measure. Significant main effects and Group × Time interactions were followed by Bonferroni-adjusted post-hoc comparisons. Effect sizes were reported using partial eta squared (ηp^2), and the significance level was set at $p < .05$. For the NPRS variable, analysis revealed a significant main effect of time ($F(2,112) = 234.90$, $p < .001$), indicating that NPRS scores decreased significantly across the three measurement points regardless of group. The effect size was large ($\eta p^2 = 0.81$), showing that a substantial proportion of the variance in NPRS scores was explained by time. The main effect of group was not statistically significant ($F(1,56) = 2.67$, $p = .108$), suggesting that, when averaged across all time points, there was no overall difference in NPRS scores between the Experimental and Control groups. However, the interaction between time and group was statistically significant ($F(2,112) = 14.95$, $p < .001$), with a moderate effect size ($\eta p^2 = 0.21$). This indicates that the pattern of change in NPRS scores over time differed between groups. Specifically, the experimental group demonstrated a greater and more consistent reduction in NPRS scores across the six weeks compared to the Control Group. Bonferroni-adjusted pairwise comparisons were conducted separately for the Experimental and Control groups to clarify the significant time × group interaction. In the Experimental Group (B), NPRS scores showed a significant decrease from Day 1 to Week 3 (mean difference ≈ 1.4, $p < .001$), from Day 1 to Week 6 (mean difference

≈ 2.7, p < .001), and from Week 3 to Week 6 (mean difference ≈ 1.3, p < .001). This demonstrates a steady and substantial decline across all measurement points. In the Control Group (A), scores also decreased over time, but the reductions were smaller. A modest change was observed from Day 1 to Week 3 (mean difference ≈ 0.8, p < .05) and from Day 1 to Week 6 (mean difference ≈ 1.6, p < .001). The reduction from Week 3 to Week 6 (mean difference ≈ 0.7, p < .05) was less pronounced compared to the Experimental Group. Overall, these post-hoc analyses confirm that both groups improved over time, but the Experimental Group experienced a greater and more consistent decrease in NPRS scores, supporting the intervention's effectiveness.

For the Tinetti balance, RM ANOVA revealed a significant main effect of time, $F(2,112) = 110.52$, $p < .001$, $\eta^2 = .21$, $\eta p^2 = .66$, indicating that Tinetti Balance Scores improved significantly across the three measurement points regardless of group. This represents a large effect size, suggesting that time accounted for a substantial proportion of variance in balance scores. The main effect of group was not significant, $F(1,56) = 0.06$, $p = .803$, $\eta^2 = .00$, $\eta p^2 = .00$, showing that there was no overall difference in balance scores between the Experimental and Control groups when averaged across time. The time × group interaction was statistically significant, $F(2,112) = 13.14$, $p < .001$, $\eta^2 = .03$, $\eta p^2 = .19$, with a moderate effect size. This indicates that the pattern of improvement differed between groups, with the Experimental Group showing a steeper and more consistent increase in balance scores across time compared with the Control Group. On Post hoc comparison, the Experimental Group demonstrated significant improvements across all time intervals (Day 1–Week 3, ≈ +2.34, $p < .001$; Day 1–Week 6 ≈ +4.17, $p < .001$; Week 3–Week 6, ≈ +1.83, $p < .001$). The Control Group also improved, but the changes were smaller (Day 1–Week 3 ≈ +0.90, $p < .05$; Day 1–Week 6 ≈ +2.07, $p < .001$; Week 3–Week 6 ≈ +1.17, $p < .05$). This indicates that while both groups benefitted over time, the Experimental Group experienced a larger and more consistent gain.

RM ANOVA for gait analysis revealed a significant main effect of time, $F(2,112) = 124.82$, $p < .001$, $\eta^2 = 0.29$, $\eta^2 p = 0.69$. This indicated that gait scores significantly improved over time in the overall sample, regardless of group. The large partial eta squared ($\eta^2 p = 0.69$) suggested that approximately 69% of the variance in gait scores

can be attributed to the repeated measures factor (time). The main effect of group was not statistically significant, $F(1,56) = 0.85$, $p = 0.362$, $\eta^2p = 0.01$. When averaged across all time points, the experimental and control groups did not significantly differ in overall gait scores. Thus, there was a significant interaction between time and group, $F(2,112) = 5.29$, $p = 0.006$, $\eta^2p = 0.09$. This indicates that the pattern of gait score improvement differed between groups, with the experimental group demonstrating greater improvements over time compared to the control group. In the Experimental Group (B), post hoc Bonferroni-adjusted comparisons showed a significant increase in gait scores from day 1 to week 3 (mean diff. ≈ -1.0, $p < .001$), with further improvement by Week 6 (Day 1 vs. Week 6 mean diff. ≈ -2.12, $p < .001$; Week 3 vs. Week 6 mean diff. ≈ -1.12, $p < .001$). This indicates a consistent and progressive enhancement in gait function throughout the intervention period.

For Borg rating analysis, the repeated-measures ANOVA revealed a highly significant main effect of time on Borg Rating scores across Day 1, Week 3, and Week 6 ($F(2,112) = 214.15$, $p < .001$, $\eta^2 = 0.46$, $\eta^2p = 0.79$) indicating that participants perceived exertion decreased significantly over the intervention period, with a very large effect size (partial $\eta^2 = 0.79$), suggesting that time alone accounted for a substantial proportion of the variance in Borg scores. In contrast, the main effect of group (experimental vs. control) was not statistically significant ($F(1,56) = 0.09$, $p = 0.764$, $\eta^2 = 0.00$, $\eta^2p = 0.00$), demonstrating that when collapsed across time points, both groups had comparable exertion levels. However, the interaction between time and group was significant ($F(2,112) = 11.67$, $p < .001$, $\eta^2 = 0.03$, $\eta^2p = 0.17$), indicating that the trajectory of exertion reduction differed between groups. However, Bonferroni-adjusted post-hoc comparisons revealed that Borg Ratings decreased significantly across all time intervals between Week 3 and Week 6 (mean difference = 1.17, $p < .001$, 95% CI [0.91, 1.43]), which suggested that the intervention had a cumulative effect over time, with progressive reductions in perceived exertion throughout the six-week program.

Conclusion: This study identified a high prevalence of post-COVID-19 musculoskeletal problems, most notably neck pain, lower back pain, knee pain, and fatigue, highlighting the significant functional burden experienced by survivors. The six-week Dynamic Neuromuscular Stabilization (DNS) intervention yielded consistent

and meaningful improvements across all clinical outcomes, including pain, balance, gait, and perceived exertion. Although both the experimental and control groups showed improvements over time, repeated-measures ANOVA demonstrated significant Group × Time interactions for all variables, indicating that participants who received DNS experienced greater and more sustained gains. The experimental group showed larger reductions in pain and perceived exertion, along with more pronounced improvements in balance and gait performance, supported by large effect sizes and robust post-hoc comparisons.

Overall, the findings confirm that DNS is an effective rehabilitation strategy for addressing persistent musculoskeletal, balance, and gait impairments in post-COVID-19 individuals. The intervention not only accelerated recovery but also produced clinically meaningful functional improvements, supporting its integration into post-COVID physiotherapy rehabilitation programs.

Keywords: Post-COVID-19 infection, prevalence, physiotherapeutic management, Dynamic Neuromuscular Stabilization (DNS), musculoskeletal impairments, balance disorders, gait abnormalities, perceived exertion, rehabilitation.

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LIST OF ABBREVIATIONS

ACE	Angiotensin-converting enzyme
ADL's	Activities of daily living
APA's	Anticipatory postural adjustments
ANOVA	Analysis of variance
AROM	Active range of motion
BMI	Body mass index
COVID	Coronavirus disease
CDC	Centers for disease control and prevention
CNS	Central nervous system
CONSORT	Consolidated Standards of Reporting Trials
COREQ	Consolidated criteria for reporting qualitative research
CP	Cerebral palsy
DK	Developmental kinesiology
DNA	Deoxyribonucleic acid
DNS	Dynamic neuromuscular stabilization
IAP	Intra-abdominal pressure
IL	Interleukin
ISSS	Integrated spinal stabilization system
IEC	Institutional Ethical Committee
JBI	Joanna Briggs Institute
LLLT	Low-level Laser therapy
MBS	Modified Borg scale
MS	Multiple sclerosis
MCID	Minimal Clinically Important Difference.
NICE	National Institute for health and care excellence
NPRS	Numeric pain rating scale
PBM	Photo biomodulation

PCC	Post-COVID condition
PCS	Post COVID-19 syndrome
POMA	Performance-oriented mobility assessment
PRE	Perceived rate of exertion
QOL	Quality of life
RCT	Randomized clinical trial
RCGP	Royal college of general practitioners
RPE	Borg rating of perceived exertion
ROM	Range of motion
ROS	Reactive Oxygen species
SARS-CoV-2	Severe acute respiratory syndrome Coronavirus-2
TBGA	Tinetti balance and gait assessment
TENS	Transcutaneous electrical nerve stimulation
TMT	Tinetti mobility test
UST	Therapeutic ultrasound
US	United States
VAS	Visual analog scale
WHO	World Health Organization

OPERATIONAL DEFINITIONS

Term	Definition
Post-COVID-19 Infection:	A post-COVID-19 condition occurs three months after COVID-19 onset, with symptoms that last for at least two months and cannot be explained by another medical diagnosis in people with a history of probable or confirmed SARS-CoV-2 infection "(1).
Dynamic Neuromuscular Stabilization:	A rehabilitation approach that utilizes developmental kinesiology principles to activate the deep stabilizing system and restore optimal movement patterns**.** (2)
Numeric Pain Rating Scale:	The NPRS is an 11-point self-reported measure ranging from 0 ("no pain") to 10 ("worst imaginable pain"), widely used to assess pain intensity across various clinical conditions. It is recognized for its simplicity, ease of administration, and strong psychometric properties, including good-to-excellent test-retest reliability and responsiveness to clinical changes(3)

CHAPTER - I

1 INTRODUCTION

1.1 BACKGROUND

The severe acute respiratory syndrome coronavirus 2, or SARS-CoV-2, caused the global pandemic disease COVID-19, which primarily affected the respiratory system but also involved multiple other systems. It was first identified in Wuhan, China, on December 31, 2019. Millions of people worldwide have been impacted by the pandemic. Although many have recovered from the acute illness, concerns continue to rise about the potential long-term strain on healthcare services. Studies indicate that a significant number of individuals still experience symptoms even after the severe phase of recovery. The disease exhibits a vast clinical spectrum and can have long-lasting effects on various organ systems. In India alone, there have been 45.1 million confirmed cases of COVID-19 with 534,000 reported deaths in year 2025. The recovery rate stands at 81.2%, with 1,244,300 recoveries (4). The prevalence in India has varied from 30.34% - 37.3% with data collected among health care workers via different symptom checklists or patient health questionnaires using different methodologies and definitions. The study reported more than 1 symptom at 1 year after COVID-19, with a prevalence of MSD's 16.5% based on a study conducted in Western and Southern India (5).

According to the WHO report, 296,357 COVID-19 cases were reported by October 2024, reduced to 20,441 in April 2026. 10.2K cases in Southeast Asia in 2025, and in January 2026, 90 cases were reported. The infection first impacts the respiratory system. In the initial phase, patients experience fever, dry cough, and dyspnea. The severity of the infection can be classified into 3 groups: Mild, Moderate, and Severe. The prevalence of mild cases was nearly 80%, moderate cases were 14%, and only 6% of cases had a severe type of infection. After the acute infection stage, the symptoms that last long have been referred to as post-COVID-19 infection. The terms "long-COVID," "post-acute sequelae SARS-CoV-2," PCC, "post-COVID-19-syndrome," or

"long haul COVID" are synonyms used for the same condition. It is a multisystemic condition that arises after an infection attributed to the SARS-CoV-2 virus. Researchers have documented more than 200 symptoms affecting numerous organ systems, and global estimates suggest that it has affected at least 65 million people; the actual figure can be much higher due to numerous unrecorded cases (6).

WHO defined post-COVID-19 syndrome as a condition that occurs in individuals with a history of probable or confirmed SARS-CoV-2 infection, usually 3 months from the onset of COVID-19, with symptoms that last for at least 2 months and cannot be explained by an alternative diagnosis (7). Research on respiratory symptoms, cardiovascular, gastrointestinal, and neurological systems in patients' health is significant, but the prevalence of musculoskeletal disorders and symptoms related to balance and gait impairments still needs to be explored further. Its onset is possible no matter how severe the initial infection was, although risk factors include female sex, type of infection moderate or severe, and advanced age. Moreover, it is linked to reduced health-related quality of life in individuals, whether they had moderate to severe illness or only mild or no symptoms, although the number of vaccinations does not significantly affect the incidence of long COVID (8). Numerous other studies emphasized the mechanism of musculoskeletal involvement during and post-COVID-19 (9). Studies conducted on the prevalence of MSD in India till 2024 showed fatigue, arthralgia, myalgia, joint pain, muscle weakness, and low back pain as common prevailing symptoms, with joint pain as the most prevalent condition (10). Another prevalence study conducted in Andhra Pradesh , India reported fatigue (55%), shortness of breath(45.33%), headache (44.67%), and low energy (43.67%) as post-COVID symptoms during Delta wave (11). However, symptoms involving neurological complications, including balance and gait impairments, are still lacking, mainly in poor-resource countries like Asia and Australia. Recognizing these signs and prevalence will aid in improving the diagnosis, preventive measures, and treatment plan for infected patients (12).

A range of therapeutic approaches has been used in post-COVID-19 care, with several medications demonstrating positive outcomes in randomized controlled trials. Additionally, alternative methods, such as hyperbaric oxygen therapy, have

proven effective. Nevertheless, there are currently no officially approved treatments. A multidisciplinary approach includes continuous, long-term monitoring of symptoms and may involve physical and mental health rehabilitation and social support. Although the literature reports several treatment options, such as fatigue management, respiratory rehabilitation, anti-rheumatic drugs, and telerehabilitation, complete recovery has not been achieved with existing treatment protocols. Due to a lack of knowledge regarding the mechanisms underlying post-COVID-19 infection, few treatment options are currently available. A cross-sectional study published in 2026, being conducted in Delhi, reported that 72.22% of the population reported Long COVID-19 symptoms in PCI individuals. Their study suggested that the widespread impact of COVID-19 highlights the need for ongoing assessment and rehabilitation for all affected individuals, and that future studies with larger, representative samples of PwDs are needed. These findings emphasise the need for ongoing assessment and rehabilitation of all post-COVID-19 individuals (13). Thus, further long-term research is required to gain a deeper understanding of the prevalence. Clinical studies are critically needed to evaluate treatments that address the diverse manifestations and complications.

Post-COVID musculoskeletal problems have created a significant economic burden on healthcare systems worldwide. The increased demand for outpatient care, diagnostic procedures, medications, and surgical interventions, coupled with the need for long-term management, has intensified treatment costs. These complications have led to a decreased workforce, further impacting the economy. Mitigation strategies like early intervention or integrated care models are essential to address these challenges and effectively reduce the economic impact. Furthermore, the literature reported several treatments. A study highlighted the potential of a multidisciplinary rehabilitation program incorporating treadmill exercise, cycling, arm ergometry, stair climbing, and strength training. Results from 22 patients were collected, which showed significant improvement (14). An observational study published in March 2025, carried out at AIIMS, Jodhpur, reported that out of 1954 COVID-19 survivors, 1087 had MSK symptoms, the most common being fatigue (50.71%), followed by myalgia, backache, and joint pain. The study targeted the need to evaluate MSK symptoms over a longer period of time and to develop a comprehensive multidisciplinary management plan for the same. The physiotherapists

should place greater focus on recovered patients experiencing musculoskeletal symptoms by offering targeted exercises and enhancing their physical activity levels. (15).

A comprehensive review study discussed the application of Acu-TENS effective in patients with COPD; this can also be applied to COVID-19 patients to improve lung function, although further research is needed to provide clinical evidence to support this (16). Another review study promoted the importance of physiotherapists and multidisciplinary teams for managing musculoskeletal pain in individuals recovering from the acute infection phase(17). Various physiotherapy approaches—including soft tissue mobilization, myofascial release, massage, manual therapy, dry needling, heat application, electrotherapy modalities such as TENS, and therapeutic exercises—have shown effectiveness in alleviating both acute and chronic pain.

Clinical trials and research efforts are underway to address the management of long-term complications associated with COVID-19. However, the most effective treatment for this chronic condition continues to be a topic of discussion, and a definitive treatment intervention has not yet been established. Consequently, there is an urgent requirement for efficient intervention approaches capable of facilitating the prompt recovery of individuals experiencing post-COVID infection condition (PCS). There is growing clinical evidence that Dynamic Neuromuscular Stabilization (DNS) exercises are beneficial in the management of various musculoskeletal disorders and neurological complications causing balance and gait abnormalities. Dynamic Neuromuscular Stabilization (DNS) is a new emerging concept in rehabilitation. The concept was proposed by Professor Pavel Kolar. It is based on the principle of developmental kinesiology, which is the study of human movement based on mechanics and anatomy. It focuses on optimal breathing exercise patterns by diaphragm stabilization and integrated mechanical activation of the stabilization system of the spine before initiating movements in the extremities. It promotes the development of the motor nervous system by engaging neurodevelopmental locomotor patterns derived from the motor positions of healthy newborns. The treatment approach evaluates stability, quality, or movements to regain the spine's integrated stabilizing system through special exercises based on the child's motor position (18). A study proposed

the effects of DNS on balance and trunk function in people with multiple sclerosis (19). Another study highlighted the sustained effective application of Dynamic Neuromuscular Stabilization in managing chronic musculoskeletal pain and discomfort (20). DNS activates the Integrated Spinal Stabilization system and restores ideal intra-abdominal pressure regulation, which optimizes the movements and reduces overload on joints and spine. By strengthening the core muscles, the technique can prove to be effective in improving gait and balance abnormalities.

DNS has gained attention in sports and neurological rehabilitation, but the concept still needs to be explored for musculoskeletal rehabilitation. A regimen of DNS exercises lasting eight weeks in multiple sclerosis patients has been found to improve quality of life, endurance, and physical functions (21). The principle of DNS is based on two concepts: (a)" every developmental position is an exercise position" and (b) provides stable and effective support to facilitate dynamic movement of the extremities. The concept given can be applied to the rehabilitation of COVID-19 recovered patients having musculoskeletal problems like joint pain, including pain at the lower back and knee joint pain, and having impaired balance and gait parameters.

Affected individuals usually have dysfunctional breathing patterns due to lung inflammation, ventilator use, or reduced respiratory capacity. The DNS exercises can help improve breathing patterns, including oxygen delivery and motor control during walking. When endorsed with conventional exercise, it shows improvement in functional capacity in overweight and obese individuals (22). 6 weeks of DNS enhances muscular strength, flexibility, joint range of motion, and overall physical fitness, along with improvement in balance and gait function in the elderly when measured by assessment tools, including the Berg Balance Scale for dynamic balance, the Modified Stork Stand Test for static balance, and measurements of temporal and spatial gait parameters."(23). The technique can lack poor posture or compensatory patterns. By reducing energy expenditure and improving endurance, fatigue can be reduced, although the application of DNS to address post-COVID-19 complications needs to be tested. The clinical effectiveness of DNS exercise in the recovery of individuals with persistent symptoms following COVID-19 infection is not well documented in the literature. The purpose of this study is to assess the effectiveness of DNS combined

with conventional physiotherapy for individuals with musculoskeletal problems and balance and gait impairments after COVID-19.

The pandemic has endured for more than four years, impacting a vast number of individuals worldwide. As a result of the virus's continual mutation, evolution of infectivity, and immunity evasion, the number of cases continues to grow worldwide. Some studies have reported that symptoms of musculoskeletal pain, balance, or gait variations persist for 24 months after COVID-19. Thus, it is necessary to establish an evidence-based treatment plan for the same. Currently, there is no established treatment protocol specifically designed for addressing the needs of the affected population. Although exercises are important in treating neuromuscular complications of COVID-19, limited evidence is available to support this concept (24). The most significant research has appropriately concentrated on preventing and treating the acute stage of the illness. Additionally, viral variants may have differing impacts on persisting conditions, and the effects of emerging variants on transmission rates, immune evasion, and the incidence of post-acute sequelae remain to be fully understood (25).

Therefore, the present study aims to focus on the prevalence and evidence-based physiotherapy management for musculoskeletal problems, balance, and gait impairment in individuals with post-COVID-19 infection.

1.2 RESEARCH PROBLEM

Although COVID-19 infection was known to primarily affect the respiratory system, it was later found to have a wide range of clinical manifestations. Around 65 million people globally are thought to be living with long-COVID, and the number of cases is rising every day, as reported by the WHO in 2021. A multicentric study done in western and southern India reported 16.5% prevalence of long COVID with symptoms lasting up to 1 year(5). According to the latest statistics reported in AIIMS India 2026, 72.22% of the population reported Long COVID-19 symptoms in PCI individuals, and in 2025 more than 50% of patients presented with MSK symptoms after recovery, with the most prevalent symptoms being fatigue

(50.71%), myalgia (13.92%), joint pain (3.73%), and backache (3.63%), with an overall 88.78% post-COVID functional limitations (13)(15). Some individuals continue to experience a variety of symptoms for months or even years following infection, and evidence of damage to multiple organs has been widely reported. Evidence from a review article conducted in Western India in 2026 demonstrated that symptoms may persist or fluctuate up to four years post-infection, with fatigue and respiratory complaints, indicating an urgent need to integrate LC management into national health programs and develop multidisciplinary post-COVID clinics (26). Despite the increasing evidence regarding the acute management of this disease, a significant gap remains in understanding the long-term musculoskeletal and functional effects of the virus. The rising number of individuals reporting ongoing symptoms after recovery has contributed to increased musculoskeletal involvement over the past two years. Moreover, insufficient data focus on the potential positive outcomes of exercise for COVID-19-recovered patients, emphasizing tailored exercises in rehabilitation. One review study has been conducted to explain the benefits of exercise in the rehabilitation of the targeted population (27). The extent to which COVID-19–related neuromuscular dysfunction affects gait patterns and functional mobility remains unclear. No clear consensus has been reported on the prevalence of gait deviations, particularly in resource-limited regions such as Asia and Africa (28). The impact of the pandemic remains unresolved, even with global vaccination efforts. Addressing these research gaps is essential for several reasons. Firstly, there is a need to study the prevalence of post-pandemic musculoskeletal disorders, balance, and gait abnormalities. The findings can contribute to the enhanced understanding of long-term health impacts and physical sequelae of the disease. Secondly, the benefits of rehabilitation interventions for these patients are not yet well developed, and there is a scarcity of evidence-based tailored physiotherapy exercise protocols. Investigating the role of Dynamic neuromuscular stabilization (DNS) exercises may contribute meaningful evidence regarding their potential benefits in the management of long-term post-COVID musculoskeletal, balance, and gait complications.

Identifying the critical gaps, this study focuses on contributing both to the scientific understanding of post-COVID infection musculoskeletal problems and to the practical application of targeted physiotherapy interventions for the affected population.

1.3 RATIONALE

According to the WHO report, 296,357 COVID-19 cases were reported by October 2024, 1.2K of which were in Southeast Asia. A meta-analysis reported a pooled global prevalence of post-COVID-19 syndrome (PCS) of 41.79%, with the highest prevalence in Asia (49.79%) (31). The sustained impact of the COVID-19 pandemic has brought clarity to the long-term effects that many individuals experience, collectively known as post-COVID-19 syndrome (PCS). These conditions hinder an individual's physical abilities and affect their independent functional activities and overall quality of life. Thus, the rationale for conducting this study is as follows:

- **Global Health Concern:** COVID-19 has appeared as a major global health crisis challenge, with long-term effects persisting well beyond the acute phase of infection. Among these, musculoskeletal, balance, and gait abnormalities are increasingly reported but still not understood. This prevalence study is essential for addressing the ongoing health burden in these populations.
- **Understanding Long-Term Effects for patient care:** Despite numerous extensive studies on the acute management, there is limited evidence on the ongoing effects in recovered individuals. Findings of these long-term impairments will contribute to a more comprehensive view of post-COVID syndrome.
- **Evidence-Based Rehabilitation:** This rehabilitation approach facilitates holistic improvement, supporting improved life quality and mental health outcomes in recovered populations.
- **Contribution to physiotherapy rehabilitation and community health:** The research outcomes will contribute to the development of practical guidelines for

physiotherapists, supporting management of post-COVID functional impairments.

- **Gap in Existing Research:** There is a lack of comprehensive studies integrating both prevalence assessment and physiotherapeutic intervention for post-COVID musculoskeletal, balance, and gait abnormalities. This study aims to fill this gap, thereby enriching the existing body of knowledge and guiding future research.

1.4 RESEARCH SIGNIFICANCE

The present study is highly important for society and public health as it examines the prevalence and physiotherapeutic management of musculoskeletal complications, balance, and gait problems in people who have had COVID-19. The results will help improve quality of life by supporting physical recovery, functional independence, and reintegration into the community. Physiotherapy rehabilitation aims to reduce long-term issues, hospital readmissions, and the overall healthcare burden caused by post-COVID-19 symptoms. By providing specialized rehabilitation exercises, the research supports work productivity and economic stability by helping individuals return to their jobs and daily activities more effectively. Additionally, the findings will serve as a basis for creating evidence-based rehabilitation protocols and standardized physiotherapy practices tailored to post-COVID-19 conditions. On a larger scale, the study encourages low-cost, community-based rehabilitation, ensuring fair healthcare access across different socioeconomic groups. The evidence generated can also inform public health planning and resource distribution for community physiotherapy and rehabilitation programs. Ultimately, this research strengthens public health resilience by highlighting the importance of physiotherapy in restoring function, preventing secondary complications, and improving the overall physical and mental well-being of individuals and communities after the pandemic.

1.5 RESEARCH QUESTIONS

- What is the prevalence of musculoskeletal problems, balance, and gait abnormalities among subjects with post-COVID-19 syndrome?

- Is the Dynamic Neuromuscular Stabilization (DNS) exercise protocol effective in improving musculoskeletal pain, balance, and gait abnormalities among subjects with post-COVID-19 syndrome?

1.6 RESEARCH OBJECTIVES

1.6.1 General Objectives

- To study the prevalence of musculoskeletal problems, balance, and gait impairments in individuals with post-COVID-19.
- To study the effects of physiotherapeutic exercise training protocol on pain, balance, and gait abnormalities in individuals after COVID-19 infection, manifested with musculoskeletal problems.

1.6.2 Specific Objectives

- To study the prevalence of musculoskeletal problems in individuals with post-COVID-19 infection.
- To study the prevalence of balance and gait impairments in individuals with post-COVID-19 infections.
- To study the effectiveness of dynamic neuromuscular stabilization (DNS) exercises for musculoskeletal, balance, and gait impairments in individuals with post-COVID-19 infections.

1.7 RESEARCH HYPOTHESIS

Null Hypothesis: There is a statistically non-significant difference in the efficacy of Dynamic neuromuscular stabilization exercises on pain, balance, gait, and perceived exertion in subjects with post-COVID-19 infections.

Alternate Hypothesis: There is a statistically significant difference in the efficacy of Dynamic neuromuscular stabilization exercises on pain, balance, gait, and perceived exertion in subjects with post-COVID-19 infections.

CHAPTER - II

2 LITERATURE REVIEW

This chapter examines the existing published research and highlights the gaps in knowledge regarding post-COVID-19 syndrome and how it is managed.

2.1 POST-COVID-19 SYNDROME

2.1.1 Definition:

The term "post-COVID-19 Syndrome"(PCS) pertains to a broad category of clinical symptoms, manifestations, indicators, and health problems that may appear weeks after the first stage of viral infection caused by SARS-CoV-2. As mentioned by the UK National Health Service (NHS), it is characterized by inexplicable, enduring indications or symptoms that appear 12 weeks after initial COVID-19 infection. This term is often used to refer to the symptoms and signs that persist or emerge after the initial phase of infection (≥12 weeks) (29)**.** Some patients show little to no symptoms at all and recover completely during the acute infection phase (i.e., the first 28 days). However, after an initial SARS-CoV-2 infection, some patients developed additional problems or continued to have symptoms.

The phrase "post-COVID-19 conditions" (PCC), as used by the US Centers for Disease Control and Prevention (CDC), referred to a wide variety of symptoms, indicators, and diseases that persisted for at least four weeks subsequent to infection. It also included conditions that first appeared during the initial phase and continued beyond the expected healing period**.** Some illnesses may worsen or improve gradually, while others may relapse and remit. The World Health Organization (WHO) coined the term "post-COVID-19 condition" as occurring three months or more after the start of infection, or confined to people having a history of suspected or diagnostically confirmed instances who continue experiencing symptoms three months post-infection and are not consistent with any other diagnosis (7). The higher levels of disability reported in this population indicate a persisting need for rehabilitation and recovery.

Commonly observed symptoms encompass fatigue, breathlessness, and cognitive impairment, among others, which collectively affect daily functioning. These symptoms might arise again following the initial recuperation or may appear after the initial sickness. Symptoms may also aggravate or subside over time (32).

Moreover, according to guidelines from the Royal College of General Practitioners and the Scottish Intercollegiate Guidelines Network, post-COVID-19 infection is defined as "post-COVID-19 syndrome," and ongoing symptomatic COVID-19 is defined as clinical manifestations persisting 4–12 weeks after the initial infection (33). According to recent data from the UK Office for National Statistics, 1.5 million people's daily activities have been negatively impacted by this condition(34). Two years later, 30% of people who had contracted the SARS-CoV-2 virus showed presentation of post-COVID-19 infection; the most prevailing symptoms were discomfort, persistent fatigue, and cognitive deficits.

Furthermore, up to 15% - 25% of survivors reported anxiety, depression, and sleep issues or reported one or more newly developed symptoms three months following the initial infection, enduring for at least two months, with no other explanation (35). The post-COVID-19-infection situation is defined as follows, despite variations in definitions:

"Condition occurs three months after COVID-19 onset with symptoms that last for at least two months and cannot be explained by another medical diagnosis in people with a history of probable or confirmed SARS-CoV-2 infection."(1)

Twenty percent of patients have mid and long-term sequelae, even though a large majority of them fully recovered from their original sickness. The terms "long COVID," "post-COVID-19 condition," and "post-acute COVID-19 syndrome (PACS)" are synonyms to describe. It occurs frequently in those with a prior severe infection and persists for weeks, months, or an extended period in some cases. It can also affect those with minimal or no symptoms of illness. Epidemiological studies have linked it to several general, digestive, respiratory, cardiac, and neurological symptoms commonly observed, were fatigue, post-exertional malaise, fever, gastrointestinal discomfort, diarrhea, cough, dyspnea, migraines, depression, and joint or muscle pain (36). A

systematic literature review identified and summarized a sizable worldwide body of evidence for both adult and pediatric populations, highlighting the abundance of data being produced for PCC in real-world contexts. It describes a range of numerous clinical features and health complications that prevail or emerge after the acute phase of the illness has resolved. While many individuals recovered fully within a few weeks, others experienced issues such as tiredness, dyspnoea, chest/ribs pain, cognitive difficulties ("brain fog"), sleep disturbances, and musculoskeletal discomfort lasting for a prolonged duration of time. The severity and duration of these symptoms vary widely and can affect individuals irrespective of the severity of initial infections, with even mild cases leading to long-term consequences.

According to the SLR, there was substantial variation across studies in terms of definitions, methodologies, follow-up periods, symptom or condition domains evaluated, and data sources. It has been acknowledged that COVID-19 infection can affect many systems over the long run due to its wide clinical spectrum. Given the ongoing uncertainty in the medical and scientific community regarding a standardized PCC definition suitable for both clinical practice and research, real-world studies must continue to address this gap across multiple organs and systems (34)

The available literature search defining post-COVID-19 infection is shown below in table 2.1

Table 2.1: Published/available literature on post-COVID-19 infection

The Original Source citation	**Content**
The Wellcome	When symptoms last longer than four weeks after they first appeared, then it can be named as a condition post-COVID-19 infection (37)
The Lancet	A greater number of patients had reported multiorgan problems following COVID-19. People of all ages were impacted by them, and symptoms included coughing, dyspnoea, exhaustion, headaches, palpitations, chest and joint pain, limited physical capacities, depression, and insomnia. Some discharged patients may experience dysfunctions and complications for up to six months. The extended COVID is a growing health issue that requires immediate attention (38).
NICE	Clinical symptoms that develop during or post-infection consistent with COVID-19, continue beyond 12 weeks, and are not explained by any other diagnosis (29).
Royal Society of London	One or more of the following symptoms may appear in recurring or persistent episodes within weeks of SARS-CoV-2 infection and last for weeks or longer: extreme exhaustion, diminished capacity for exercise, palpitations, fever, anosmia or ageusia, headache, peripheral neuropathy, tinnitus and vertigo, bitter or loss of taste, skin allergy, joint discomfort, or swelling, and cognitive impairment (40).
French National Authority for Health.	Three specifications: Four weeks after the onset of the illness, exhibiting one or more first signs of a symptomatic form of COVID-19, with no other diagnosis being able to account for any of these symptoms (41)
Centers for Disease Control and Prevention	The majority of COVID-19-infected patients healed and resumed their regular lives; however, some patients may experience symptoms that last for weeks or even months following their acute illness recovery. Even those without a hospital stay and with minor illnesses may have delayed or chronic effects (42).

The Original Source citation	Content
Journal of Medical Virology	Condition identified by long-term consequences – persisted after the normal convalescence phase – of coronavirus disease 2019 (COVID-19*)*(43)
Nature Reviews Journal	Post-acute COVID-19 refers to the ongoing / persistence of symptoms or the emergence of delayed health issues that persist beyond four weeks after the initial onset of SARS-CoV-2 infection (44).

Across leading health and scientific institutions, definitions of post-COVID-19 converge on the recognition that a subset of individuals experience persistent, multisystem symptoms well beyond the acute infection phase, although differ in the time thresholds and emphasis placed on symptom characteristics. Most bodies—including the Wellcome Trust, CDC, and Nature Reviews—identify symptoms lasting beyond four weeks as indicative of a prolonged phase, while NICE adopts a threshold of more than twelve weeks (29). Several sources, such as The Lancet and the Royal Society, highlight the multisystem and heterogeneous nature of post-COVID manifestations, ranging from respiratory and neurological to psychological and functional impairments, emphasizing its impact across all age groups. Others, such as the French National Authority for Health, stress the need for symptoms to be unexplained by alternative diagnoses, underscoring diagnostic complexity. Collectively, these definitions reflect an evolving understanding of post-COVID-19 as a multifaceted condition with variable duration, diverse symptoms, and significant implications for long-term patient management.

2.1.2 History of COVID-19

The global pandemic stems from infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). As a beta coronavirus, it is responsible for atypical pneumonia and a novel form of respiratory infection that can potentially

progress into a more serious condition known as severe acute respiratory syndrome (SARS). On December 31, 2019, the virus was first discovered in Wuhan, China. Approximately 160 million SARS-CoV-2 cases have been reported globally by the year 2021, resulting in 5.1 million deaths (30). The symptoms of SARS-CoV-2 infection include fever, cough, sore throat, anorexia, myalgias, nausea, diarrhea, anosmia, and ageusia. Although instances of COVID-19 in children and adolescents were initially recognized as early as January 2020, these cases are considerably less prevalent and less severe than those in adults.

In 2020, the Coronavirus Study Group of the International Committee on Taxonomy of Viruses officially named the virus severe acute respiratory syndrome coronavirus, identifying it as the cause of an outbreak of atypical pneumonia reported by the Municipal Health Commission of Wuhan, the capital of Hubei Province, China.

The World Health Organization (WHO) recognized this entity as coronavirus disease 2019 (COVID-19) on February 11, 2020, and the form of pneumonia as novel coronavirus pneumonia. As of July 26, 2021, the disease had spread to 215 countries or territories, leading to 180 million cases and 3.97 million deaths have been recorded (33). By December 3, 2021, more than 263 million confirmed cases and more than 5.2 million deaths had been reported by the WHO dashboard (WHO, 2020). Following other prevalent infections like Middle East respiratory syndrome coronavirus (MERS-CoV) and severe acute respiratory syndrome coronavirus (SARS-CoV), SARS-CoV-2 is the third most highly infectious human coronavirus that has evolved in the past twenty years (45).

However, in India, the first case was reported on January 27, 2020, in Kerala. However, its recognition as a distinct clinical condition remains unclear. In one case from Italy, reactive arthritis was documented 25 days following the onset of severe respiratory symptoms(46). In 2020, the second case of reactive arthritis associated with COVID-19 was reported in a patient who exhibited no symptoms of respiratory illness (47). While the third case reported in Thailand in 2020 in which patient who experienced fever and arthritis before the development of any respiratory symptoms, which delayed the diagnosis of COVID-19 infection. Viral arthralgia could be an uncommon, yet unrecognized, novel clinical entity. Although it affects multiple organs,

the respiratory tract is the primary target. Fifteen to thirty-six percent of cases have been reported to have musculoskeletal problems(48).

2.1.3 Prevalence: The Global Burden

It is estimated that 400 million people globally suffer from post-COVID-19 infection symptoms till year 2024, which have an annual economic impact of $1 trillion, or nearly 1% of the global economy. A point prevalence of the burden in the general population is estimated to be 6% to 7% in adults and ~1% in children, respectively. However, the differences in study designs and populations, follow-up times, control group selection, pre-evaluation, and standard definitions of “Post COVID-19 Syndrome" make it difficult to estimate the global burden of long COVID. Few countries have implemented surveillance mechanisms for determining the population-level burden.

According to data from the National Health Interview Survey conducted by the US Centres for Disease Control and Prevention (CDC), 1.3% of children51 and 6.9% of adults in the US had a long-term effect of COVID-19 infection in 2022. As of early 2023, 6.9% of adults in the United States have experienced a prolonged episode, according to data from the Medical Expenditure Panel Survey report. As reported by the CDC's Household Pulse Survey, approximately 6.7% of adults in the United States were experiencing ongoing symptoms as of March 2024. According to cross-sectional prevalence estimates from the Office for National Statistics, 2.9% of people in the UK, including children, self-reported having symptoms in March 2023(49). Figure 2.1 shows the global incidence of post-COVID-19 infection from 2020-2023 (31)

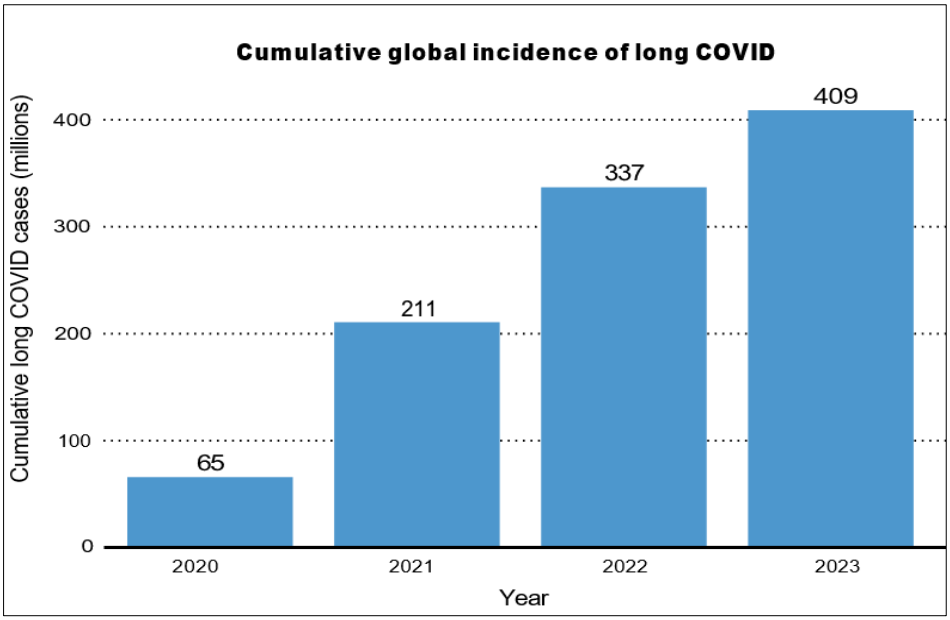


Figure 2.1: Estimated global cumulative incidence of long COVID (50).

The chart shows a steep rise in cumulative global long COVID cases from 2020 to 2023. The large jumps between years suggest substantial variability in estimation methods, testing capacity, and reporting practices. The figures may simplify a complex and heterogeneous global burden, useful for illustrating a trend of an increasing number of cases of post-COVID-19 infection

2.1.4 Prevalence in the South Asian Region

Across South Asia, more people are still experiencing conditions known as Post-COVID-19 infection, a variety of symptoms that last for weeks or even months after the initial infection. Common symptoms include tiredness, breathlessness, bone/joint pain, brain fog, and emotional distress, all of which greatly affect daily life. Research from countries like India and Bangladesh showed that a significant percentage—up to one-third—of COVID survivors reported ongoing health issues even after recovery. A 2024 review and meta-analysis reported that PCS affected 47.23% of men (95% CI: 44.03–50.42%) and 52.77% of women (95% CI: 49.58–55.97%). When analyzed by continent, pooled prevalence was 46.28% (95% CI: 39.53–53.03%) in Europe, 46.29% (95% CI: 35.82–56.77%) in the Americas, **49.79% (95% CI: 30.05–**

69.54%) in Asia, and 42.41% (95% CI: 0.00–90.06%) in Australia (31). In 2024, another review conducted in China(2024) concluded that the disease notably elevated the chances of developing various symptoms, with no significant variation based on gender, age, or the duration beyond three months after infection.. An analysis of 51 studies identified 25 symptoms associated with a higher risk, among which the 10 most common were fatigue (18.0%), post-exertional malaise (14.6%), sleep disturbances (12.2%), low back pain (12.1%), loss of smell (11.4%), headaches (11.1%), muscle aches (8.1%), altered taste (7.7%), and joint pain (7.7%). The study highlighted the need for services and interventions for the management of the long-term consequences of post-COVID-19 infection conditions(51).

A prospective study explores the inflammatory pathways involved in arthritis. The prevalence of joint and muscle pain is less than 10% cases, with arthralgia occurring in 15% and myalgia in 44% cases. Studies have shown a positive association between COVID-19 exposure and persistent symptomatic complaints, indicating that long COVID remains a significant post-infection health concern(52). In a rheumatology case report, musculoskeletal symptoms, fatigue, and arthralgia/myalgia are among the most common symptoms. They highlighted an emerging spectrum of musculoskeletal complications and found the prevalence of Reactive Arthritis, classified within a group of diseases called Spondyloarthropathies (62).

2.1.5 Prevalence in India

In India, the prevalence has emerged as a growing health concern in the aftermath of the pandemic. Understanding how it varies across different regions, age groups, and socioeconomic backgrounds is critical for identifying vulnerable populations and tailoring interventions accordingly. Moreover, limited national-level data in India may affect policy-making, clinical management, and resource utilization. A focused effort to study prevalence will support the development of comprehensive goal-oriented rehabilitation services, improve patient outcomes, and formulate long-term public health planning. A survey based on population was carried out in Haryana (Rohtak, Gurugram, and Jhajjar)in September 2021. The study was conducted on 2205 adult individuals. A structured questionnaire was distributed in a cross-sectional study.

The results of the study showed a positive correlation between symptomatic complaints and exposure in regression models, indicating that COVID-19 may still have an impact on this population. The study is among the first in India to look at the long-term impacts of COVID-19 using a sizable population-based sample. Both the occurrence of new cases and the total physical morbidity index were higher among those who were positively tested. The study addresses the research gap, suggesting that the burden of disease should primarily be addressed in clinical settings, where specialized treatment for individual cases should continue to evolve(52).

There is limited availability of data related to the Omicron variant. To address this gap, in 2024, a prospective study was carried out across 11 districts in Delhi, India, involving individuals who had recovered from COVID-19. The average age group of participants was 42.07 years, and a significant proportion of 79.7% reported experiencing post-COVID-19 symptoms. The most frequently reported clinical presentations were joint pain (36.0%), ongoing cough/sore throat (35.7%), anxiety (28.4%), difficulty breathing (27.1%), fatigue (21.6%), recurring headaches (20.0%), and limb weakness (18.6%). Among these, anxiety had the longest reported duration (138.75 ± 54.14 days), followed by fatigue (137.57 ± 48.33 days), breathing difficulties (131.89 ± 60.21 days), and joint pain or swelling (131.59 ± 58.76 days)(53).

In India, over the past 2 years, research has been focused on numerous institutes on post-COVID-19 infection long-term complications. A retrospective cohort study conducted at Hind Institute of Medical Sciences, Sitapur, India, examined the musculoskeletal problems among 100 COVID-19 patients who tested positive and found that a minimum of one orthopedic impairment was found in approximately 27% of individuals. According to the study, patients with diabetes, obesity, or young age were at risk. Further research is needed to clarify whether muscle pain serves as a marker of ongoing poor prognosis and risk factors for orthopedic injuries. The study highlighted an important gap, noting that examining medical comorbidities and their impact on other diseases could guide the development of alternative COVID-19 treatments for vulnerable patients (54).

Another review study on post-COVID-19 syndrome was conducted at the Sri Venkateshwara Institute of Medical Sciences, Tirupati, India (2024). Anxiety or sadness, nausea, abdominal pain, skin rashes, sore throats, tinnitus, ear pain, headaches,

peripheral neuropathy, and joint and muscle pain were among the often-reported long-term clinical signs. The study highlighted the lack of systematically structured and properly designed research on post-COVID that includes sufficient control groups. Most existing studies are descriptive and observational, often relying on convenience sampling. Additionally, the majority of this research has been conducted in high-income countries. Therefore, further studies should be conducted to understand the effects of post-COVID-19 infection, particularly in developing countries such as India. This will help develop an intervention plan for managing these complications(55).

A cross-sectional study performed at NIMS University on persistence of neuropsychiatric manifestations of long COVID in India after 2.5 year 2025 reported that nearly 69.6%% of patients experience persistent neurological symptoms including myalgia (18.5%), dizziness (17.3%), headache (16.6%), pain (15.7%), anosmia (13.3%), brain fog (9.4%), numbness (6.0%), tinnitus (5.5%), and dysgeusia (3.7%), with only dizziness being more frequent in the post-hospitalization than the non-hospitalized group (20.3% vs. 14.5%; $p = 0.012$). It highlighted a research gap that the neurological manifestations of Long COVID in the Indian population remain limited. Future studies should focus on developing targeted interventions to reduce cognitive decline and enhance quality of life(4). Another Indian AIIMS study published in 2026 reported long COVID-19 symptoms in 72.22% of the patients(13).

The prevalence of post-COVID-19 musculoskeletal problems in India has appeared as a significant community health concern after the pandemic. Contributing factors may be age,viral-induced inflammation, immobilization, or psychological stress. Prevalence studies are needed to understand the true burden of these conditions in the population, especially in a diverse and densely populated country like India. In the absence of reliable prevalence data, the scope of the problem remains underestimated and unresolved. With this taken into consideration, data from prevalence studies have been critically analysed.

The prevalence of post-COVID was reported as 29.2% of subjects at the four-week and six-month follow-up points in a study done in Bhubaneshwar in 2022. In the four-week follow-up, the incidence was 23.4% in individuals with mild to moderate illness and 62.5% in severe cases. The incidence of mild to moderate cases was low at

six months. i.e, 7.2%, as compared to 23.1% in severe cases. Fatigue was the most prevalent symptom. Those with pre-existing medical issues had significant symptoms at 4 weeks. They had a greater number of symptoms during the acute phase, had completed two doses of COVID-19 vaccination, and were being admitted to the hospital. The study identified a significant gap, emphasizing the need for further long-term COVID research to objectively assess symptoms, monitor them over extended periods, and examine biological and radiological markers, ultimately supporting the development of improved treatment guidelines and comprehensive management strategies(56). Jogdand et al. (2023) conducted a study in a rural region of Maharashtra to assess the prevalence of post-COVID-19 conditions and the associated risk factors. Data were gathered through participant interviews using a pre-formulated, semi-structured questionnaire. The prevalence was found to be 17.5%. Determinants were the elderly age group, male sex, severe presentation, and those who were intubated(57). Poor general health, smoking, and low physical activity level were found to be strongly linked to musculoskeletal pain(58).

Compared to men, women are at higher risk. Another risk factor is age, with older adults at higher risk. According to a prevalence study conducted in Banglore highest prevalence of musculoskeletal disorders is in the lower back region, i.e., 54%, as reported in a study (2022), followed by neck pain, arthralgia, fatigue, and myalgia. Females (61%) are more affected than males (39%). Additionally, individuals who had been hospitalized showed a greater prevalence (52.9%) than those who had undergone home isolation (47.1%). Among vaccinated individuals, those who had received both doses exhibited a slightly higher prevalence (52%) than those who had received only one dose (48%). Furthermore, more symptoms were reported in those treated with steroids (51.1%) than in those who had not received steroid treatment (48.9%)(12).

2.1.6 Risk Factors

A wide range of demographic, clinical, and lifestyle-related variables may contribute to the persistence of post-COVID-19 complications, particularly musculoskeletal symptoms such as myalgia, joint pain, fatigue, and reduced physical function. It can influence both the severity and duration of symptoms, often interacting

in complex ways. Numerous studies help in the identification of these risk factors for further understanding of the topic.

Increased BMI results in fatigue being the most common musculoskeletal symptom. Figure 2.2 shows the major symptoms evaluated after 4-12 weeks following diagnosis in hospitalized or outpatient patients. More prevalence was found in the lumber region, followed by cervical pain and arthralgia due to the online mode of education, poor/faulty posture, or prolonged screen time. Prevalence might help provide measures and exercises to the affected population(12). Lower back MSDs accounted for 42.44% of all MSDs reported in the previous 12 months. Even more people have lower back pain than the 38% found in a global systematic analysis of 165 populations in Saudi Arabia. Despite having a complex etiology, obesity and occupational variables are key contributors to the development of lumbar pain symptoms, according to the Global Burden of Disease research conducted in 2016 (59)

Several risk factors, such as the intensity of primary symptoms, advanced age, poor general health, poor lifestyle including smoking, and low physical activity level, were found to be strongly linked to musculoskeletal pain (58). Compared to men, women are at higher risk. Another risk factor is age, with older adults at higher risk. Children are likewise affected by this, with older kids being more vulnerable than younger ones. The majority of long-term COVID diagnoses occur in people aged 36-50 years. People who earn a lower income, have less education, or belong to underprivileged ethnic groups are also more likely to acquire post-COVID-19 infection (60)

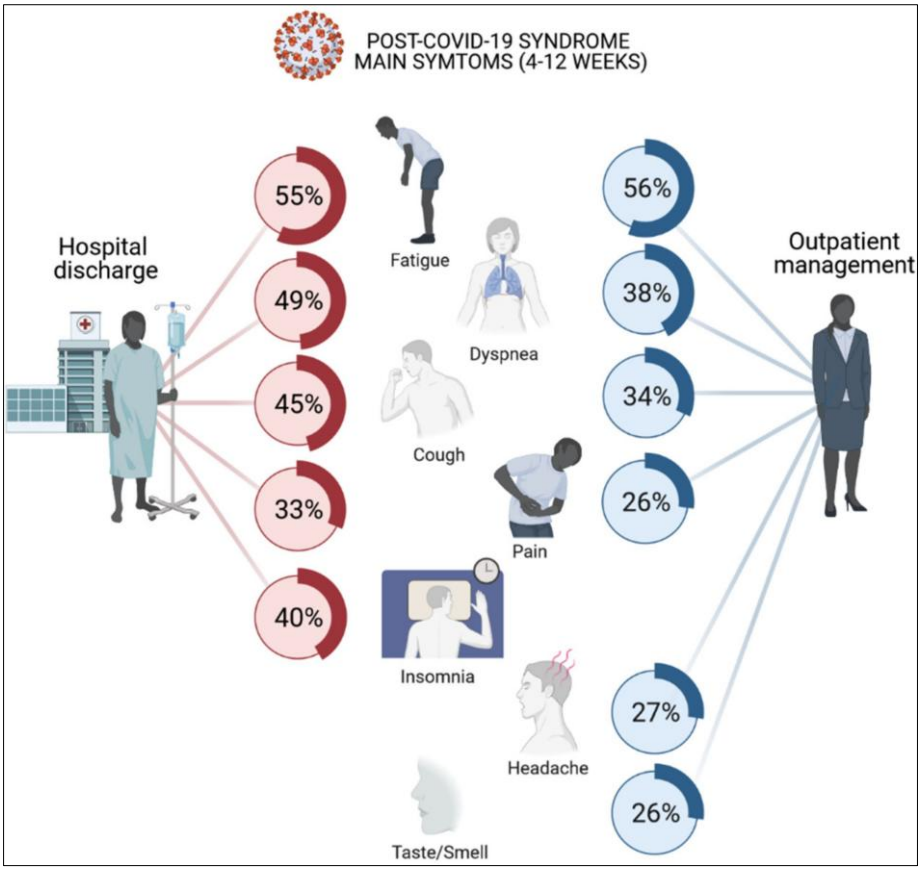


Figure 2.2: Prevalence of Post-COVID-19 syndrome (12)

2.1.7 Clinical Manifestation of Post-COVID-19 Infection

The clinical presentation of musculoskeletal complications varies greatly, reflecting the multifactorial nature of the condition. In many cases, these issues are accompanied by neuromuscular impairments, which lead to balance disturbances or gait abnormalities. 80% of patients experience more than one symptom, usually more than two, but sometimes up to ten (28). The RNA virus known as SARS-CoV-2 is a causative agent for COVID-19 infection, which has devastated the world for four years. Due to mutations, there are now COVID-19 variants that continuously pose a threat to global health because they are highly transmissible despite worsening the disease (64).

Twenty percent of patients had long-term sequelae, even though a majority of them fully recovered from their original sickness(61). "long COVID," "post-COVID-19 condition," and "post-acute COVID-19 syndrome (PACS)" are synonymous terms

for post-COVID-19 infection given by different world agencies. High prevalence is found in individuals with a history of severe infection that lasts for weeks or months. Asymptomatic individuals are also at risk. Epidemiological studies have linked it to several general, digestive, respiratory, cardiac, and neurological symptoms, which include fatigue, post-exertional malaise, fever, abdominal pain, GIT disturbances, coughing, breathlessness, migraines, depression, and joint pain or muscle cramps (36).

The clinical spectrum ranges from asymptomatic infection to fatal disease, such as the absence of symptoms to severe pneumonia. Many times, it is influenced by socio-geographical factors. A study involving 430 COVID-19 recovered patients reported common symptoms including myalgia (60%), arthralgia or pain in joints (57.2%), difficulties in ADLs (57%), anorexia (42.6%), chest/ribs pain (32.6%), gastritis (32.3%), cough (29.3%), and dyspnea (29.1%)(72). Ten days after infection, a 34-year-old man was diagnosed with reactive arthritis in his right knee (62). Additionally, numerous meta-analyses and systematic reviews have been published on the after-effects. Common symptoms included dyspnea, persistent taste and smell problems, exhaustion, and cognitive issues such as headaches, memory and thinking difficulties, anxiety, depression, and sleep disturbances. Musculoskeletal symptoms were also frequent. About 80% of patients experience more than one symptom, often more than two, but sometimes up to ten (63)(64)

- Compared to men, women tend to be affected more significantly (65). The correlation between myalgias and fatigue is significantly stronger in females than in males (66). The occurrence has been linked to symptoms that include anxiety, depression, sleep disturbance, lack of concentration, memory impairment, attention deficit disorder, and cognitive impairment (67).
- Both the severity of presentation and advancing age are linked to a higher chance of ongoing symptoms. ICU patients more often experienced fatigue, dyspnoea, and neuropsychological issues after discharge. However, there is debate among studies about their connection to previous factors and comorbidities (68)(69)
- The symptoms are recurring and change over time in appearance. Patients' perceptions are generally flexible regarding both the form and timing of

symptoms. The progression of symptoms does not follow a consistent pattern, often triggered by physical exertion or mental stress. Although ongoing changes in timing and intensity have been reported, some patients are more affected as the condition worsens; however, many improve gradually over time (70)

- The most severe aspect and feature that significantly affects the quality of life of individuals with post-COVID-19 syndrome is fatigue, along with neurocognitive problems. According to patients, these symptoms severely inhibit the development of daily working activities (71).
- It is important to note that multiple studies have found no meaningful differences in symptom presentation or progression between individuals with confirmed diagnostic testing and those who were unable to be tested but were considered probable/suspected cases (72).

Clinical symptoms in recovered patients exhibit diverse patterns, influenced by risk factors, age, phase of immobilization, pre-existing comorbidities, and various other predisposing factors. These symptoms can be discussed under separate headings depending on their presentation.

2.1.7.1 Musculoskeletal Symptoms Post-COVID-19 infection

Many people experience chronic musculoskeletal symptoms, such as joint pain, myalgia, fatigue, and muscle weakness, after contracting the initial infection. These symptoms can last for a number of days and have a major impact on day-to-day activities and overall well-being. It is believed that deconditioning, neurological, and inflammatory processes are among the underlying factors. Comprehending and resolving these complications is essential for successful post-COVID recovery. Many evidences support these findings.

A systematic review of musculoskeletal and neurological features reported the prevalence of myalgia and lumbar pain as 19% and 10%, respectively (73). Sahin et al., (2021) also provided evidence for pain in the upper limb, lower limbs, and head (74) .

Fatigue and back pain emerged as the most frequently reported musculoskeletal complaint. Myalgia is primarily driven by ischemia resulting from hypoxia, and the characteristic triad of muscle pain, weakness, and fatigue helps illustrate the pattern of

muscular involvement. Low levels of physical activity (PA) during the quarantine phase contribute to the occurrence of musculoskeletal pain, including neck(33.5%) and low back pain(43.5%)(75). Lockdown adversely affected the musculoskeletal health of participants. Although the musculoskeletal pain may initially be temporary, it has the potential to become a chronic condition and a significant health burden if appropriate interventions are not implemented (76).

A higher BMI has been linked to an increased risk of persistent musculoskeletal symptoms. In a cohort of 300 post-COVID-19 patients assessed one month after hospital discharge, complaints such as fatigue, myalgia, arthralgia, knee pain, low-back pain, and neck pain were reported, with their prevalence correlating with higher BMI levels (77).

Research has indicated that even after complete recovery, people with a history of acute infection might have imbalanced gait patterns. The severity of the asymmetric gait pattern may be influenced by post-COVID symptoms, such as peripheral nerve system abnormalities, dizziness, balance issues, and muscle weakness, mainly quadriceps weakness 80% and bicep weakness 73% (78). Fibromyalgia has been reported in one-third of patients as a part of the complex spectrum of pulmonary, cardiovascular, hematological, renal, gastroenteric, dermatological, endocrine, and neuropsychiatric sequelae (79). A study on 85 recovered patients, when conducted, concluded that 30 patients reported having musculoskeletal problems prior to infection, while 55 acquired them afterwards, supporting the evidence of the prevalence of MSDs in COVID-19 recovered patients. The most affected region was the lower back and shoulder (15). Another evidence was reported in a (2022) systematic review study, which reported that headache or cervical pain, hip pain, and back pain were less prevalent, whereas myalgia, arthralgia, and fatigue were the most common features. Figure 2.3 shows the mean percentage of fatigue (49.12%) in 4 studies, muscle pain (34.75%) in 8 studies, bone/joint pain (33%) in 6 studies, headache(28.4%) in 3 studies, and lumbar pain (30.58%) in 5 studies (80)

Numerous research studies are being conducted in India to find the frequency of musculoskeletal disorders among the Indian population. According to the findings,

as shown in Figure 2.4 high prevalence was found in the lumbar region (54%), while prevalence of other regions of the body was also noted in the shoulder joint, cervical region, hip and knee joint, including thoracic area, arm, forearm, & wrist (12).

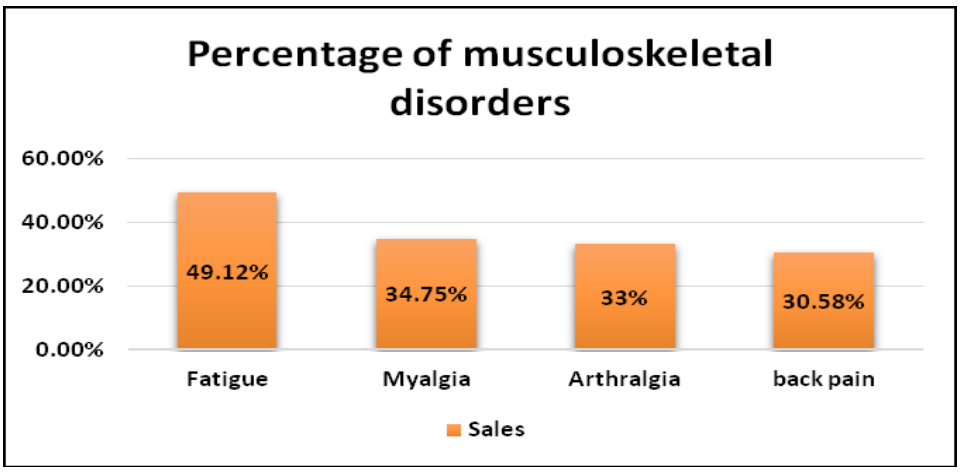


Figure 2.3: Prevalence of Musculoskeletal disorder(80)

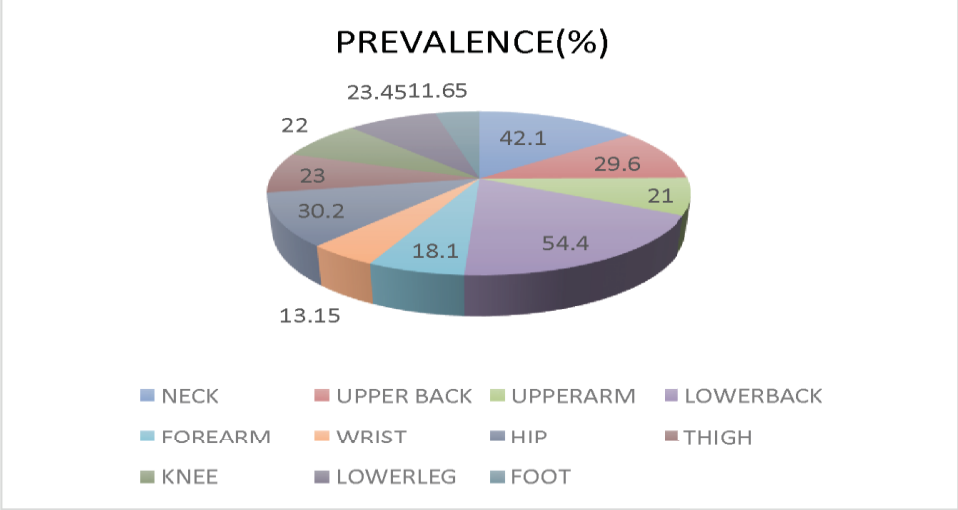


Figure 2.4: Prevalence of body region affected in COVID-19 patients(12)

2.1.7.2 Neurological Complications of Post-COVID-19 Syndrome

After a viral infection, numerous damages occur in multiple organs, mainly in the brain. In addition, neuroinflammation, central and peripheral responses are triggered by the

infection and lead to cognitive impairment, psychological stress, anxiety, depression, and sleep disorders. The neurotropic characteristics of this virus, which permit it to infect specific brain regions, might be indicative of neurocognitive impairment. There are several hypothesized avenues for this, including immune-mediated pathways (immune cells that transfer the pathogen into the brain), blood (beyond the blood-brain barrier, or BBB), and neural retrograde invasion through the olfactory bulb and/or trigeminal nerve. Figure 2.5 shows various mechanisms responsible for neurological complications of post-COVID-19 syndrome. Additional indirect causes of brain lesions could include increased BBB permeability, endothelial damage from a local or systemic aberrant inflammatory response, or access to pro-inflammatory cytokines, which would disrupt brain homeostasis and eventually result in neuronal death. Disruption of the autonomic nervous system (dysautonomia) can lead to orthostatic intolerance, commonly known as postural orthostatic tachycardia syndrome (POTS). This condition may present with palpitations, gastrointestinal disturbances, or recurrent loss of consciousness and can contribute to the development of additional neurological symptoms (29).

Encephalopathy and Encephalitis: Confusion, disorientation, agitation, and somnolence—all of which are referred to as encephalopathy—have been regularly recorded in a variety of COVID-19 cohorts. Although altered mental status affects most critically ill COVID-19 patients with ARDS, it happens infrequently (<5%), even in patients who require hospitalization for respiratory illness. Multiple cases have been reported in which COVID-19 patients met the recognized diagnostic criteria for infectious encephalitis, such as elevated body temperature, seizures, changes in mental status, presence of WBC in CSF, and localized abnormalities on brain radiological scanning. Only two studies reported detecting SARS-CoV-2 in the CSF; however, only modest amounts of viral RNA were detected (82). SARS-CoV-2 has not been detected in the majority of CSF samples. Delirium, confusion, and coma appear to be the most common symptoms of critical illness, which is often marked by decreased oxygen saturation, hypotension, renal failure, the need for heavy doses of sedatives, and prolonged immobility and isolation all factors responsible for causing encephalopathy. There is currently no targeted antiviral therapy for SARS-

CoV-2, and treatment remains primarily supportive and aimed at relieving symptoms. Ongoing surveillance and studies are required to understand whether SARS-CoV-2 will eventually stop causing illness in humans—as occurred with the SARS-CoV outbreak—or if it will persist as a significant infectious threat(84)

Ischemic Stroke: Stroke occurs with notable frequency in hospitalized patients, with incidence estimates ranging from 1%–3% among general inpatients and reaching up to 6% in those who are critically ill. Although it is more frequent in older patients and those who have numerous vascular comorbidities. Cardioembolic stroke may be a danger for patients with COVID-19. According to reports, 20% to 40% of patients requiring intensive care and 10% of hospitalized patients have acute cardiac damage and clinically severe arrhythmias(85),(86)

Post-infectious Neurological Complications: The nervous system may be affected by the dysregulated systemic immune response caused by SARS-CoV-2 in later stages. These immune-mediated symptoms, which typically appeared after the infection's acute phase has passed, affect both the central and peripheral nerve systems. Acute disseminated encephalomyelitis and other classic post-infectious inflammatory conditions are identical to COVID-19 cases in the CNS(87). Patients with recent SARS-CoV-2 infection have been noted to have several cases of Guillain-Barré syndrome, a motor neuron disease (88). The majority of documented instances outline the typical symptoms of this illness, including widespread weakness, demyelination on nerve conduction tests, and increased proteins in CSF devoid of white blood cells. Long-term consequences may be associated with neurological and psychological problems, including Parkinsonism, dementia, and post-traumatic stress disorder, respectively.

Post-COVID-19 syndrome describes a range of persistent symptoms that arise during or after a confirmed or suspected COVID-19 infection, commonly even after mild illness. These lingering effects may include anosmia, ageusia, cognitive difficulties, as well as psychological conditions such as depression and anxiety, representing both acute and long-term neurological and neuropsychiatric

manifestations. COVID-19 "brain fog," a syndrome of chronic cognitive impairment characterized by lack of attention, concentration, memory, processing speed, and executive function, is one of the most prominent long-lasting neurological consequences.

Common neurological signs include neuropathies, autonomic dysfunction, headaches, sleep disturbances, and cognitive problems. Ataxia, motor abnormalities, and dysexecutive syndrome are further, less common neurological consequences. In addition to the viral persistence of SARS-CoV-2, long-term COVID patients have also been shown to reactivate viruses of the herpesviridae family, such as Epstein-Barr virus (EBV) and Varicella-zoster virus (89). SARS-CoV-2 RNA is reported in cerebrospinal fluid (CSF) of patients with acute neurologic symptoms, including seizures(90). In contrast, meningitis and encephalitic pathology were also reported in severe patients, although the virus was not detected in cerebrospinal fluid (CSF)(91). A case of mild respiratory sickness that progressed to akinetic mutism due to encephalitis (92). A 60-year-old patient with multifocal transverse myelitis was found after infection(93). Due to baseline inflammation, metabolic disruption, and a high body mass index, people with PCC may experience disruptions in objective cognitive function. Research indicates that between 10 and 20 percent of people who have had COVID-19 fit the criteria for PCC, with immune-inflammatory and vascular dysfunction.

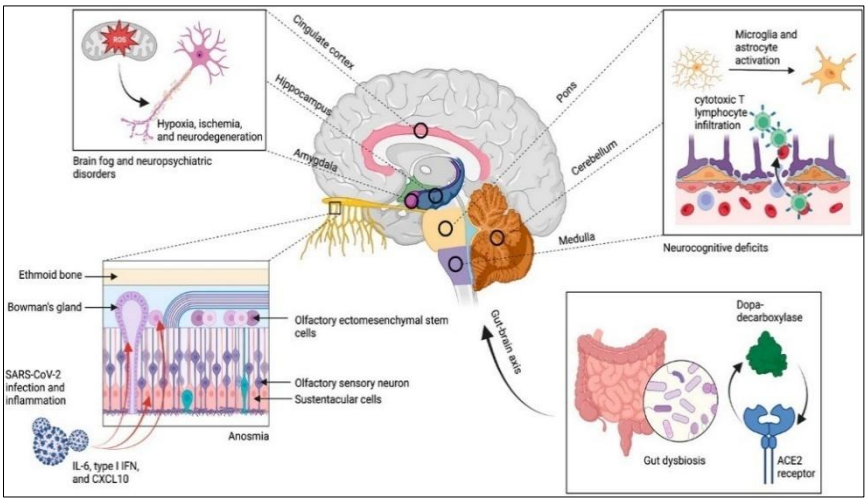


Figure 2.5: Neurological Complications of Post COVID-19 Syndrome, (27)

2.1.7.3 Post-COVID-19 Balance and Gait Abnormalities

Post-COVID manifestations affecting the musculoskeletal system include joint and muscle pain, along with structural and tissue abnormalities that arise either directly or indirectly from SARS-CoV-2 infection, as stated by numerous studies (94)(95). People who have been hospitalised for long periods developed muscle weakness, affecting balance and increasing the frequency of falls. The cognitive state can be affected in post-ICU patients due to the use of medications and/or the presence of delirium irium(96)(97). Additionally, the condition might result in peripheral and central nervous system difficulties, such as balance impairment and dizziness(98)(99). Human gait can be described through three fundamental elements: patterns of motion, the distribution of load, and rhythmic cycles. This encompasses alterations in speed, gait width, spatial and temporal metrics, kinematic factors, or ground reaction forces (GRF). Asymmetrical gait patterns were more prevalent in people with a history of mild-to-moderate infection than in people without any history.A cross-sectional study was conducted on 12 subjects with mild-to-moderate COVID-19 history and 20 sedentary controls. Inertial sensors on a motorized treadmill were used to measure gait. Each participant's spatial-temporal characteristics and gait symmetry were computed using a minimum of 512 consecutive steps. In terms of gait parameters like loading response, pre-swing, double support, duration symmetry, and single support, the COVID group displayed more asymmetrical gait patterns than the CONTROL group. More asymmetrical patterns were displayed with a history of mild-to-moderate infection than by those without (100). Patients who recovered had different kinetics and muscular activity than the healthy control group individuals(101).

Furthermore, gait abnormalities and sit-to-stand activities are impacted by post-COVID-19 symptoms, including depression or dizziness affecting dual-task performance, which may be due to impairments related to post-intensive care syndrome (PISU) (102). The COVID-19 pandemic, along with related social restrictions, resulted in a significant decrease in physical activity levels among individuals. Reduced mobility and limited exercise participation may worsen pre-existing health conditions and increase the risk of developing new functional impairments (103). A study was carried out on gait using the Timed Up and Go (TUG) test score. A total of 30 subjects

were recruited for the study. The hospitalized subjects infected with the virus but had no chronic diseases or other conditions affecting the musculoskeletal system before COVID-19 were taken in the study group, while the other group included non-infected subjects. A wireless motion analyser based on sensors (inertial measurement units, or IMUs) was employed in the investigation. The spine, upper limb, lower limb, head, and shoulder were fitted with special IMU sensors. MyoRESEARCH 3.10 was used to develop movement task reports based on the recording. The study group's participants were required to complete the Timed-Up and Go Test (TUG). The participants who were infected with took 46% longer to finish the entire mobility challenge than the participants who were not infected. The infected group had a higher Sit-to-Stand Time [s], measuring 2.1 ± 0.7. The mean walking speed [m/s] was 0.26 ± 0.07, which was less than that of the group not infected with COVID-19. Steps per minute, or walking cadence, was lower at 21.2 ± 1.2. Participants with COVID-19 had lower hip flexion angles ($p = 0.025$) and anterior pelvic tilt angles ($p < 0.001$), whereas their knee ($p < 0.001$) and ankle ($p < 0.001$) flexion angles were higher. Thus, the findings of the study proved that infected individuals presented variation in the ranges of motion and the time to complete the TUG task compared to those who were not infected(78).

In a review study on movement disorders associated with COVID-19, myoclonus and ataxia were the most common movement disorders found, along with a few instances of tremor, chorea, and hypokinetic-rigid(104).

However, some researchers have stated that the results of multidisciplinary rehabilitation in post-COVID are effective for parameters like fatigue, dyspnoea, and functional disabilities, but found not effective in the case of balance, gait, and cognitive functions, thus, lack of high-quality research, particularly randomized controlled trials, remains a significant research problem in confirming these findings and understanding the effectiveness of multidisciplinary therapies including aerobic exercise, resistance training or neurodevelopmental approach for post-COVID-19 conditions(231).

2.1.7.4 Cardiopulmonary Sequelae of Post-COVID-19 Infection

The more prevalent functional deficits observed in long-term COVID-19 pneumonia survivors include restrictive patterns and diffusion capacity of lungs for

carbon monoxide (DLCO). The patients often complained about headaches, fatigue, muscle cramps, and dyspnea. 518 children and their families were evaluated by clinicians on symptoms that lingered for months following COVID-19 infection. There were reports of palpitations in 7/472 (1.5%) and heart rate variations in 10/494 (2.0%), respectively (105). Similarly, in a case series involving 129 children, between 3.1% and 6.2% experienced palpitations, chest pain and discomfort (106). Patients are also at higher risk of cardiac complications like congestive cardiac failure, myocardial infarction, and arrhythmia in the mid-and long-term (107). Additionally, viral variants may differently affect the conditions, with the effect of new variants on transmission rate, immune evasion, and incidence of post-acute sequelae still to be understood (25)

2.1.7.5 The reproductive system

Long-term COVID may interfere with ovarian sufficiency, gonadal function, menstrual cycle, menopause, and fertility in females. There have also been reports of other protracted COVID symptoms getting worse around menstruation(108). Males have been reported with reduced sperm count.

2.1.7.6 The Immune System

A report of the European Academy of Allergy and Clinical Immunology (EAACI) by Sokolowska, M. et al., (2020) on Immunology of COVID-19: Mechanisms, clinical outcome, diagnostics, and perspective provided evidence that innate pathogenic immune activation and an excessive and poorly directed host immune response are characteristics of severe forms of presentation of COVID-19 (109). (Many problems, primarily thromboembolic, are caused by immune response dysregulation, which also impacts the physiological activities of the vascular endothelium (endothelium). Chronic symptoms may arise as a result of these endothelial inflammatory processes (110).

2.1.7.7 Miscellaneous Effects

Long-haul or long-term COVID-19, after an initial period of COVID-19 infection, may arise or persist as a sequelae of viral infection. Symptoms can last weeks, months, or years and are often debilitating(6). Symptoms may include abdominal pain,

nausea, diarrhea, anorexia, orthostatic hypotension, syncope, dysautonomia, and taste and smell alterations, along with psychological disturbances like anxiety, depression, insomnia, and post-traumatic stress disorder(27).

2.1.8 Pathophysiological Changes in Post-COVID-19 Infection

A study analyzed biomarkers in two groups matched for age and gender: individuals with post-COVID-19 condition (PCC) and those who had recovered within three months of acute COVID-19 in 2020, with 85 participants in each group. Biomarker assessments were conducted between 12 and 24 months after the initial diagnosis, focusing on numerous parameters such as biochemical markers, complete blood counts, coagulation profiles, antibody responses, lymphocyte subsets, and cytokine concentrations. Among individuals with post-COVID condition (PCC), significant differences were observed in 49 out of 167 biomarkers. Significant alterations were observed in potassium levels, anti-glutamic acid decarboxylase (aGAD) antibodies, antithrombin III, insulin-like growth factor-binding protein 3 (IGFBP3), and interleukin-10 (IL-10). A combination of aGAD antibodies, IL-10, potassium concentrations, and CD16^bright^CD56 cell counts effectively distinguished PCC patients from those who had fully recovered, with an accuracy exceeding 88% and precision of 92%. The study further linked specific biomarkers to persistent symptoms: elevated IL-10 was associated with post-exertional malaise, fatigue, neurological issues, and muscle pain, while imbalances in sodium and potassium were related to headaches, fatigue, muscle aches, and cardiac arrhythmias; high aGAD antibody levels were associated with neurological issues, cognitive impairment, and fatigue due to disrupted GABA neurotransmission; and sustained elevation of NT-ProBNP was related to symptoms of dysautonomia. In addition, the study pointed to potential underlying mechanisms of PCC, such as changes in antithrombin levels associated with prolonged coagulation activity, microvascular injury, and thrombotic processes. The body's primary transporter of insulin growth factor 1 (IGF-1) is IGFBP3. Chronic inflammatory disorders are said to change the production of IGFBP3 in the lining as well as its circulating levels (111).

Viral proteins or DNA were discovered even after a long period, like months to years, after an acute infection. They suggested in "SARS-CoV-2 reservoir in post-acute sequelae of COVID-19" that in individuals with long-lasting COVID, the RNA virus may be present up to almost two years after initial infection. Although less frequently, persistent viruses have also been discovered in those without long-term COVID-19. A persistent virus may cause symptoms through changes in the microbiome and neuroimmune system, as well as potential effects on coagulation(112). Evidence suggests that SARS-CoV-2 persists in the body after acute infection in certain individuals experiencing long-term symptoms (113).

SARS-CoV-2 is a respiratory virus that can cause long-term impairment of the respiratory system. After initially infecting the alveolar epithelium, SARS-CoV-2 triggers chronic inflammatory responses that result in the prolonged production of reactive oxygen species (ROS) and inflammatory cytokines. Furthermore, fibroblasts are activated to deposit collagen and fibronectin when cellular integrity is disrupted, resulting in fibrotic alterations in lung tissue. Long-term inflammation and a hypercoagulable state are encouraged by virus-induced complement activation and the coagulant pathways that are disrupted as a result, which puts the patient at risk for thrombosis.

Figure 2.6 shows 4 possible pathophysiological mechanisms for post-COVID-19 syndrome signs and symptoms.

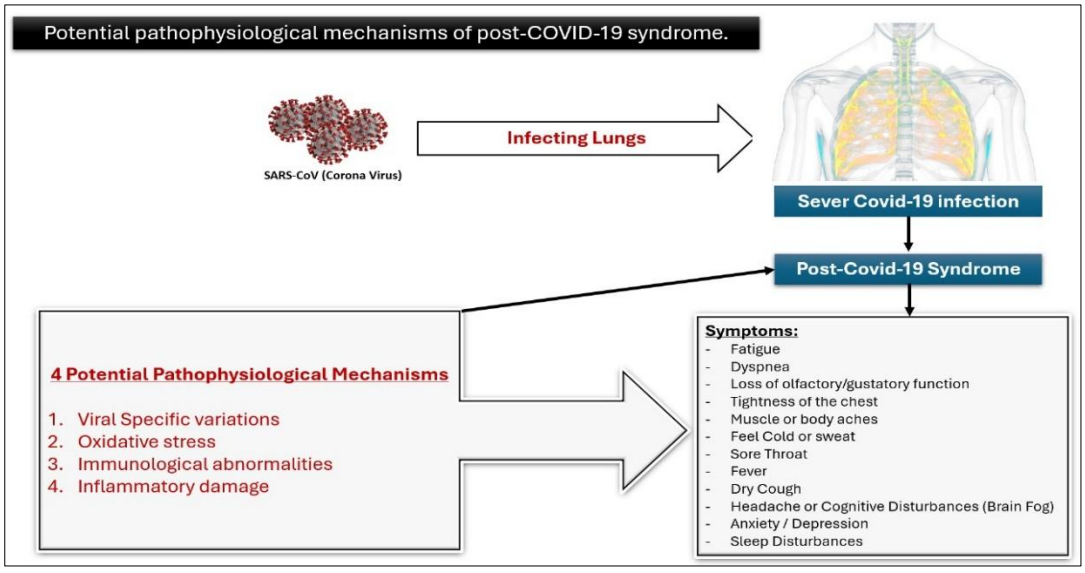


Figure 2.6: Pathophysiological mechanisms of post–COVID–19(113)

The musculoskeletal complications in post-COVID-19 infection can be explained by the following mechanism(15):

- Elevated levels of lactate dehydrogenase (LDH) and creatine kinase have been reported in response to tissue injury, in individuals with COVID-19 musculoskeletal symptoms (82)
- Musculoskeletal pain results from a COVID-19 inflammatory cytokine storm, which is characterized by a sudden rise of pro-inflammatory cytokines like interleukin-6(114), (115)
- In certain cases, COVID-19-associated thromboses lead to poor muscle vascularization, causing muscular pain (116)
- Coronavirus spike proteins interact with the muscle's ACE2 (angiotensin-converting enzyme 2) to mediate the formation of COVID-19. Nevertheless, it is still unknown how important this link is for the progression and symptoms of COVID-19(117).

Thrombocytopenia was a frequent hematological alteration noted in SARS patients, according to a review by although the precise etiology was unclear (110). In severe lung disease, thrombocytopenia can arise from increased platelet destruction and/or reduced platelet production within damaged pulmonary tissue. A case series of three patients with diverse neurological, muscular, and joint symptoms suggested that SARS-CoV-2 infection may provoke heightened levels of proinflammatory cytokines, platelet-activating factor, arachidonic acid metabolites, reactive oxygen species, and proteolytic enzymes. These elements may produce a neurotoxic environment that results in neuropathy(118).

2.1.9 Evaluation of post-COVID-19 infection

Evaluation of post-COVID-19 condition begins with a thorough history-taking, focusing on the onset, severity, and duration of initial infection, pre-existing conditions, and ongoing symptoms such as fatigue, breathlessness, brain fog, or palpitations. A detailed symptom timeline helps differentiate post-viral sequelae from other conditions. Physical examination should assess vital signs, respiratory function, and neurological

status. Musculoskeletal pain assessment is focused on the onset, duration, severity, and nature of the pain, as well as any exacerbating or relieving factors. It is essential to assess prior musculoskeletal conditions, severity, hospitalization history, and any prolonged immobility or steroid use. A physical examination evaluation of joint pain and tenderness, muscle strength, range of motion, and signs of inflammation or neuropathic involvement. Laboratory tests (e.g., inflammatory markers, muscle enzymes, vitamin D levels) and imaging (e.g., X-ray, MRI) can be done to rule out secondary conditions like myositis or arthritis.

Balance and gait assessment includes evaluation of symptom onset, progression, dizziness, vertigo, falls, weakness, neuropathic symptoms, and prior COVID-19 severity or hospitalization. A review of medications, pre-existing neurological or musculoskeletal disorders, and post-viral fatigue should be emphasized. The physical examination should include a gait assessment by tandem walking or a timed up-and-go test, and balance tests include the Romberg test or Berg Balance Scale. Neurological evaluation for proprioceptive deficits, ataxia, or vestibular dysfunction can be conducted. Functional assessments like the Chalder Fatigue Scale or 6-minute walk test can help quantify fatigue severity along with an assessment of impact on daily activities, cognitive dysfunction, sleep disturbances, or orthostatic intolerance.

2.1.10 Outcome measures used in study

2.1.10.1 Tinetti balance and gait Assessment Scale

The Tinetti Test, or Performance-Oriented Mobility Assessment (POMA), is a commonly used clinical measure designed to assess both static and dynamic aspects of balance. Developed by Mary Tinetti (1986), they described performance-oriented mobility evaluation, including balance and gait evaluation in detail. The assessment is divided into two phases: one section focuses on assessing balance in sitting and standing positions with eyes open and closed, while the second phase evaluates gait pattern and symmetry. The two sections are sometimes used as separate tests(119). The Tinetti assessment can be widely used in the elderly to evaluate mobility, balance, and gait with different available versions of the scale. Individuals experiencing post-COVID-19 conditions may develop both short-term and long-term neuromuscular impairments,

including difficulties with postural balance. Nevertheless, there is still limited evidence regarding the relationship between balance impairments and reduced functional status in post-COVID-19 patients. A cross-sectional study done on 60 individuals for postural balance assessment concluded that the Tinetti Balance and gait Test appears to be a valuable method for evaluating functional status in individuals recovering from COVID-19, as it effectively identifies postural balance impairments and may assist in postural control assessment and rehabilitation planning (39).

The 16-item Tinetti balance and gait assessment scale is a standard evaluation tool for balance and gait assessment. The total score is the sum of the scores of each section. A total Tinetti score of 22 or below (out of 28) suggests an increased risk of falling. An article published in the MMWR Morbidity and Mortality Weekly Report examined symptom duration and factors associated with delayed recovery in outpatients with COVID-19 across multiple U.S. health care networks (March–June 2020). The study found that many individuals experienced extended recovery times, commonly reporting persistent fatigue, muscle weakness, and respiratory difficulties. It provides valuable context for understanding the need for functional assessments like the Tinetti Scale to monitor post-COVID-19 symptoms affecting balance and mobility(120).

The Tinetti Performance-Oriented Mobility Assessment (POMA) is a valuable tool for evaluating balance and gait, particularly in elderly individuals and individuals at risk of falls. In the context of evaluation of post-COVID-19 recovery, the Tinetti Scale is relevant, as many patients experience persistent fatigue, muscle weakness, balance and gait impairments like dizziness and impaired coordination. These factors can increase the risk of instability and falls, even in patients with no pre-existing comorbidities. By using the Tinetti Scale, one can objectively assess mobility limitations and design appropriate rehabilitation programs to improve functional independence and reduce fall risk. The scale has been used for evaluation of balance and gait abnormalities in COVID-19 infected patients, eg, Halpin et al. (2021), in their cross-sectional study examined post-discharge symptoms and rehabilitation needs among COVID-19 survivors, and evaluated ongoing health concerns in hospitalized individuals. Their findings emphasized frequent problems such as persistent fatigue,

muscle weakness, and neurological impairments, all of which can adversely affect balance and gait. It emphasized the importance of tools like the Tinetti Scale in rehabilitation settings to evaluate and address these post-COVID-19 functional impairments(121). Another research done on" Persistent Symptoms in Patients After Acute COVID-19" identified a range of lingering symptoms in post-COVID-19 patients, from fatigue to cognitive disturbances. The study underscores the role of rehabilitation tools like the Tinetti Scale in assessing and monitoring functional mobility impairments, as many patients report difficulties that can impact balance and increase fall risk(63).

Similarly, the use of scale has also been supported in the article on Long COVID: An overview offered overview of post-COVID symptoms, including physical and neurological symptoms that persist long after the initial infection. The study discussed how functional tools, like the Tinetti Scale can support rehabilitation efforts by identifying and tracking balance and gait issues common among post-COVID patients who experience muscle weakness, fatigue, and reduced physical capacity(122).

Being easy, accurate, valid, and less costly effective the scale has been used in previous research, providing evidence for use in future studies. Some of which are discussed below:

- Zaldivar et al.,(2022) performed a study evaluating the effects of MEP on enhancing frailty and physical performance in hospitalized post-COVID-19 older people. The included patients' functioning, strength, balance, gait, coordination, and capacity to perform fundamental daily living tasks were evaluated both at the beginning and end of the protocol. Statistically significant improvements were found for trunk control as evaluated by Tinetti–POMA, including the balance, gait subscales (123).
- Greenhalgh, T., Knight, M., A, Court, C., Buxton, M., & Husain, L. (2020), emphasized the importance of balance and gait assessments in post-COVID recovery, suggesting that physical assessments by Tinetti Scale can help clinicians understand the extent of functional impairments and tailor rehabilitation programs accordingly in their study on management of primary care in post acute condition (124).

- Punt, L., Ridout, A., Bhuva, A., & Sander, J. W. (2021) highlighted the neurological complications, such as dizziness and coordination issues, which can impair gait and balance. It underscored the need for tools like the Tinetti Scale in evaluating the impact of these symptoms on mobility and safety, as well as in tracking patients' progress throughout rehabilitation(125).
- Kosel. I., (2024) evaluated gait and physical performance sections between the long COVID-19 syndrome group and the Control group who were not diagnosed with COVID-19 using the Tinetti balance and gait Assessment (TBGA) scale and found the outcome as non-significant for the level of balance(126).

The Tinetti Scale has demonstrated good reliability and validity in evaluating balance and gait, particularly in older individuals and populations with mobility/balance impairments. It shows high inter-rater and test-retest reliability, making it a consistent tool for clinical use. Strong correlations with fall risk and functional mobility outcomes support its validity. Jinse. P. et al., (2018) studied interrater reliability for Parkinson's disease. For concurrent validation, various scales were utilized, including the Berg Balance Scale, Timed-Up and Go test, 10-minute walk test, and gait analysis using a 3-D motion analyzer. For the Korean version of the Tinetti scale, reliability was high: inter-rater and intra-rater reliability were 0.97 and 0.98 for the balance component, and 0.94 and 0.96 for the gait component, respectively. Tinetti Mobility test(TMT) showed excellent validity and reliability for balance and gait, and has high sensitivity and specificity (127). Yang *et al.,* (2023) evaluated the reliability and validity of the POMA in Chinese community-dwelling older adults and found it as a reliable and valid measurement (128).

2.1.10.2 Numeric Pain Rating Scale

The Numeric Pain Rating Scale (NPRS) is a widely used subjective tool for assessing pain intensity, where pain is rated on a scale from 0 to 10, where 0 indicates no pain and 10 represents the maximum intensity pain. It is simple, easy to administer, and helps track pain levels over time, making it useful in clinical settings and research. While effective, it is subjective and may not be ideal for young children or individuals with cognitive impairments. Despite its limitations, NPRS is a valid and reliable method

for pain assessment in healthcare settings. NPRS (ICC: 0.86; 95 %CI, 0.33–0.96) exhibited good reliability and excellent responsiveness (NPRS: a0.96, 95 %CI 0.92–0.99 in a shoulder pain patient (129). It shows good reliability, both in terms of consistency across repeated tests and agreement between different evaluators, ensuring consistent pain assessment across time and evaluators. It shows strong construct and criterion validity, correlating with other standardized pain assessment tools. It is sensitive to changes in pain levels, making it a valid tool for monitoring treatment effectiveness in both acute and chronic conditions.

Test-retest reliability of the numerical rating scale for pain intensity assessment is applied in patients with upper or lower limb impairments. Validity was evaluated with the Pearson or Spearman correlation coefficient. Excellent reliability, ICC = 0.92-0.95, is reported for lower limb pathologies. Also, no differences were observed in reliability or validity between the verbal or written format of NRS for musculoskeletal pain assessment. A very good to excellent test-retest reliability of the numeric pain rating scale was found in patients with musculoskeletal disorders. Correlations with the visual analog scale and verbal rating scale were very good to excellent, which confirms the construct validity. An MCID of 2 points was noted; thus, the numerical rating scale is a reliable and valid tool for pain outcome evaluation in patients with musculoskeletal impairments of the limbs(130)

In comparison of four methods on the measurement, namely verbal rating scale, face scale, visual analogy scale, and numeric scale to evaluate the reliability of the following scales of pain intensity measurement in patients with musculoskeletal disorders and low educational level, Numerical scale has the highest reliability value (r = 0,99), and verbal rating scale, had the lowest reliability value (r = 0,88). The numerical scale was considered the easiest to interpret, understand, and complete, even by subjects with low educational backgrounds, while the visual analogy scale was most difficult.

Thus, the NPRS scale is easy to administer and score, takes <1min to complete, requires minimal language translation, and is more reliable than the VAS, particularly for older patients or those with poor literacy, with no further procedure for scoring.

2.1.10.3 Borg Rating of Perceived Exertion

The Borg Rating of Perceived Exertion (RPE) Scale is a tool used to measure the rate of fatigue during physical activity. The scale was given by Swedish researcher named Gunnar Borg and is widely used in sports, rehabilitation, and exercise science. The Borg scale is based on a subjective assessment of exertion, meaning it relies on how the person feels, rather than on physiological measures like heart rate. The original scale ranges from 6 to 20 where 6 is No Exertion and 20 is Max Exertion. This scale roughly correlates with heart rate. If we multiply the RPE score by 10, we get an estimate of heart rate (bpm) (for example, an RPE of 15 corresponds to about 150 bpm). Gerez, G., (2021) conducted a pilot study on the effectiveness of the Respiratory Telerehabilitation Programme, and the results showed that a week-long telerehabilitation program basedon respiratory exercise is effective (ACBT tech) as measured by the Borg scale(131).

Modified Borg scale (MBS) is a quick, easy, valid, and reliable assessment tool for dyspnea. It correlated well with other clinical parameters and could be useful in patients with acute bronchospasm for assessing and monitoring outcomes of treatment (132). Zhao. H, Nishioka, T, and Okada. J.(2023) assessed the validity of using the Borg CR-10 scale and velocity to predict muscle fatigue assessed by surface EMG during single joint resistance exercises and recommended RPE as a useful tool for assessing rate of perceived exertion when resistance exercise is performed (133).

The Perceived Rate of Exertion (PRE) scale correlates with physiological markers such as heart rate, especially during aerobic and resistance exercise. As exertion increases, higher PRE scores is recorded along with elevated heart rate. This makes PRE a useful, non-invasive tool for estimating cardiovascular effort and guiding exercise intensity.

The scale has indicated strong validity, evidenced by its close correlation with physiological indicators of exercise intensity, such as:

- Heart rate (HR): RPE often correlates with heart rate at approximately 10 times the RPE value (e.g., an RPE of 12 corresponds to about 120 bpm).

- Oxygen consumption (VO_2): A strong correlation r = 0.80–0.90 exists between RPE and VO_2 during exercise.
- Blood lactate levels: RPE increases in rating with rising lactate accumulation, particularly at higher intensities.
- Power output and workload: Studies show a linear relationship between RPE and work rate during cycling, running, and resistance training.
- Test-retest reliability is high, with correlations above 0.80 in a controlled exercise setting(134). A study published in *JAMA Network Open* highlighted that patients with post-COVID-19 conditions often experience exercise intolerance, with perceived exertion levels correlating with physiological markers such as heart rate and oxygen consumption, suggesting that the Borg RPE Scale may be a useful tool in assessing perceived exertion in post-COVID-19 patients(135). A chapter on physiotherapy management for patients with COVID-19 mentioned the application of the Borg Scale CR10 (6/10 scale) for assessment of dyspnea 6 weeks post-hospital discharge (136).The extended periods of immobility and the severity of the illness can result in muscle weakness, decreased cardiovascular endurance, and compromised respiratory function. Incorporating physical exercise during and after hospitalization may help reduce these complications and promote functional improvement. An RCT conducted on 30 patients to study the effect of exercise-based rehabilitation on balance and physical activity measured by the perceived exertion scale for resistance training, ranging from 0 to 10, showed that pulmonary rehabilitation reduces dyspnea, improves exercise capacity, and alleviates fatigue(83).

2.2 Management of post-COVID-19 Syndrome

Long COVID-19 may be fatal as of 2023 because there are currently no proven, viable treatments for it. However, several countries and healthcare organizations have set up public and physician guidelines for managing long COVID. Due to limited knowledge of the underlying pathophysiological mechanisms, therapeutic interventions remain scarce and require further exploration. Patients require multidisciplinary rehabilitation followed by long-term monitoring of persistent clinical symptoms.

However, most PCC cases in primary care settings are managed conservatively by medications, symptom-based treatment, physiotherapy, which includes electrotherapy, exercises, and manual therapy, lifestyle modification, psychological support, patient education, and self-management. Surgery is mainly done to manage complications of PCC, like cardiovascular or pulmonary complications.

2.2.1 Medical Management

Pharmacotherapy: Antiviral agents targeted to act directly against SARS-CoV-2 are categorized into several classes, including fusion inhibitors, protease inhibitors, transcription inhibitors, nucleoside reverse transcriptase inhibitors, and drugs that act on the M2 channel protein. Various antiviral agents have been considered for COVID-19 management through the drug repurposing process, like remdesivir, favipiravir, ribavirin, umifenovir, lopinavir, ritonavir, and molnupiravir, which involves identifying new therapeutic applications for medications that have already been approved for other indications, including drug screening and analysis. The NIH guideline identifies remdesivir and ritonavir-boosted nirmatrelvir (Paxlovid®) as the preferred therapeutic options for non-hospitalized COVID-19 patients. Remdesivir, an adenosine analog antiviral agent, interferes with RNA-dependent RNA-polymerase (RdRp), which in turn interferes with the viral replication process. Molnupiravir, a synthetic nucleoside analog, has received FDA approval as an anti-COVID-19 agent in mild to moderate COVID-19 infection. Nirmatrelvir/ritonavir (Paxlovid®) is the first FDA-approved oral treatment (nirmatrelvir 300 mg/ritonavir 100 mg) for emergency use and got final approval in May 2023. The recommended dose of Paxlovid is 300 mg of nirmatrelvir and 100 mg of ritonavir, which should be administered orally twice daily. According to NIH COVID-19 Treatment Guidelines, symptom therapy was primarily considered in quarantine/non-hospitalized patients. It is recommended against the use of dexamethasone or other systemic corticosteroids in these patients. However, in those patients who are at high risk of developing infection, Paxlovid and Remdesivir were preferred therapeutic agents, whereas bebtelovimab and molnupiravir are considered alternative therapeutic drugs. Therapeutic or

prophylactic doses of anticoagulation with heparin were administered based on the specific conditions of the patients. In patients receiving systemic corticosteroids and on oxygen supply, and those with systemic inflammation, baricitinib or tocilizumab could be added to the therapeutic regimen (226). During the pandemic, emphasis was given to varied aspects of pharmacotherapy and therapeutic options, pharmacokinetic aspects of drugs, potential drug-drug interactions (PDDI) among anti-COVID-19 drugs with other drugs, and adverse drug reactions (ADRs) management.

- Effects of Anti-Inflammatory Drugs on PCC:

Cavalli E. (2019) discussed current treatment and future therapeutic approaches to neuropathic pain: Anti-inflammatory drugs have several modes of action. Even though inflammation is the primary cause of pain, pathophysiology and COX inhibitors are the main drugs used to treat it. The central nervous system plays a critical role once pain becomes chronic. Neuropathic pain may be brought on by the sensory center surrounding the brain and spine. Thus, a sufficient anti-inflammatory medication, along with morphine-like drugs, like Ultracet (acetaminophen/tramadol), helps in musculoskeletal pain reduction. Tricyclic antidepressants are recommended to lessen pain that is aggravated by the brain if the pain becomes more neuropathic, such as by producing numbness and paresthesia. To reduce pain and swelling during the acute phase, anti-inflammatory medications and muscle relaxants, such as nonsteroidal anti-inflammatory medicines, are recommended (137)(138). During an acute infection phase, immunological abnormalities due to molecular mimicry cause the formation of autoantibodies, which activate T cells and cause tissue destruction(110). Therefore, controlling inflammatory responses is essential for controlling SARS-CoV-2 clinical sequelae and viral manifestation. In individuals with acute COVID-19, dexamethasone is frequently used to alleviate inflammation. In an observational study, individuals with COVID-19 treated with dexamethasone had a lower likelihood of experiencing prolonged COVID symptoms at an 8-month follow-up(139).

- Effects of Steroid Therapy on PCC:

Studies have reported numerous drugs like azithromycin, remdesivir, favipiravir, infliximab, tocilizumab, siltuximab, hydrocortisone, rituximab, rintatolimod, and intravenous immunoglobulin found to be effective for managing post-COVID-19 complications. Non-steroidal anti-inflammatory drugs (NSAIDs) are commonly used to manage musculoskeletal pain, including in patients recovering from COVID-19. Acetaminophen, an alternative drug to NSAIDs, has been linked to a worsening of symptoms. Concerns have been expressed about the safety application of NSAIDs during the pandemic; however, current evidence does not indicate that NSAIDs worsen symptoms or increase susceptibility to the virus. Therefore, for post-COVID-19 patients experiencing musculoskeletal pain, NSAIDs remain a viable option for analgesia, provided they are used judiciously and under medical supervision to monitor for potential adverse effects (140)

Table 2.2: Common therapeutic drugs in COVID-19 treatment

Pharmacologic category	**Drug name**	**Recommendations**
Antiviral drugs	Remdesivir	➢ Received FDA approval for COVID-19 treatment. ➢ Recommended for both hospitalized and home quarantine positive patients. ➢ It can be administered without dose adjustment in COVID-19 patients with renal dysfunction (eGFR < 30 mL/min) and those who are on dialysis.
	Ritonavir-boosted nirmatrelvir (Paxlovid)	➢ Received Emergency Use Authorizations (EUA) from the FDA for the COVID-19 treatment. ➢ Recommended for the treatment of non-hospitalized.
	Molnupiravir	➢ should be used only in quarantine patients when Remdesivir and Paxlovid are not available.

Pharmacologic category	Drug name	Recommendations
Anti-SARS-CoV-2 Monoclonal antibodies	Bebtelovimab	➢ Recommended for mild-moderate cases only when remdesivir and Paxlovid are not available.
	Vilobelimab	➢ Emergency Use Authorization (EUA) by Food and Drug Administration (FDA) to administer within 48 h of mechanical ventilation or extracorporeal membrane oxygenation (ECMO) in hospitalized adult COVID-19 patients.
	Bamlanivimab plus Etesevimab	➢ Recommended against the use for the treatment of COVID-19 or post-exposure prophylaxis.
	Casirivimab plus Imdevimab	➢ Recommended against the use for the treatment of COVID-19 or post-exposure prophylaxis. ➢ Casirivimab plus Imdevimab are not effective against the Omicron variant and should not be used as prophylactic agents.
	Sotrovimab	➢ Recommended against the use for the treatment of COVID-19 or post-exposure prophylaxis.
COVID-19 convales-cent plasma		➢ Recommended against the use for COVID-19 treatment.
Cell-Based Therapy	Mesenchymal stem cells	➢ Recommended against the use for COVID-19 treatment except in clinical trials.
Immunomodulators	Colchicine	➢ Recommended against the use for hospitalized and non-hospitalized COVID-19 patients.
	Intravenous immuno-globulin (IVIG)	➢ Recommended against the use for the treatment of patients with acute COVID-19 except in clinical trials.

Pharmacologic category	Drug name	Recommendations
	Inhaled corticosteroids	➢ Insufficient data available for recommendation or avoid the use in COVID-19 treatment.
	Fluvoxamine	➢ Insufficient data available to recommend for or against the use in COVID-19 treatment.
	Granulocyte-Macrophage-phage Colony-Stimulating Factor Inhibitors	➢ Insufficient data available to recommend for or against the use in COVID-19 treatment.
	Systemic corticosteroids: Dexamethasone	➢ Recommended for hospitalized patients based on severity of infection.
	Inhaled corticosteroids: •Inhaled budesonide plus fluvoxamine •Inhaled fluticasone	➢ Insufficient data available to recommend for or against the use in COVID-19 treatment.
	IL-1 inhibitors: Anakinra	
	IL-6 inhibitors:	
	Janus Kinase Inhibitors: Baricitinib (or Tofacitinib)	• Insufficient data available to recommend for or against the use in COVID-19 treatment. • Recommended for use in hospitalized COVID-19 patients based on disease severity.
	Bruton's Tyrosine Kinase (BTK) Inhibitors (ibrutinib or acalabrutinib)	• Recommended for use in hospitalized COVID-19 patients based on disease severity. • Recommended against the use of baricitinib plus tocilizumab except in clinical trials.

Pharmacologic category	Drug name	Recommendations
	Siltuximab	Recommended against the use for COVID-19 treatment except in clinical trials.
	Canakinumab	Recommended against the use for COVID-19 treatment except in clinical trials.
		Recommended against the use for COVID-19 treatment except in clinical trials.
Antithrombotic Therapy	Anticoagulant therapy	➢ Recommended against non-hospitalized patients or after discharge from the hospital. ➢ Unfractionated heparin (UFH) and low molecular weight heparin (LMWH) are preferred over oral anticoagulants in hospitalized patients. ➢ Consider the therapeutic doses of heparin in hospitalized with mild-moderate infection who receive low-flow oxygen. ➢ Recommended the prophylactic doses of heparin in severely infected patients. ➢ Recommended against the therapeutic dose of rivaroxaban for venous thromboembolism (VTE) prophylaxis or for prevention of disease progression. ➢ Insufficient data available regarding the administration of the therapeutic dose of apixaban for VTE prophylaxis or for prevention of disease progression. ➢ Recommended against the continuation of VTE prophylaxis in patients after hospital discharge
	Antiplatelet therapy	

Pharmacologic category	Drug name	Recommendations
		➢ Recommended against the use in non-hospitalized patients. ➢ Those who are receiving antiplatelet or anticoagulant therapy for an underlying disease can use it during infection.
Supplements	Vitamin C Zinc Vitamin D	➢ Insufficient data available for recommendation or not. ➢ data not available to recommend or against the use ➢ Recommended against the administration of zinc over the recommended dietary allowance (RDA) for COVID-19 prophylaxis. ➢ data not sufficiently available to recommend or against the use in COVID-19 treatment.

2.2.2 Surgical Intervention Procedure

Chronic musculoskeletal pain can be effectively managed with US-guided treatments. It can be significantly reduced using platelet-rich plasma or a regenerative dextrose solution (prolotherapy) with US-guided procedures (142). However, there is no established surgical management. Surgery is primarily aimed at managing complications such as pulmonary issues. In rare cases of severe post-COVID-19 pulmonary fibrosis, lung transplantation has been considered. For cardiovascular complications, options include Coronary Artery Bypass Grafting (CABG), stenting, or pacemaker placement. Cervical spinal decompression is performed for patients with worsening pre-existing conditions like Chiari malformation. Endoscopic or surgical procedures are used for persistent gastrointestinal symptoms such as gastroparesis or bowel dysmotility. Replacement surgeries are necessary in cases of AVN in the hip or joint destruction due to prolonged, excessive steroid use.

2.2.3 Rehabilitation

Research highlighted the potential of a Multidisciplinary Rehabilitation program (including treadmill exercise, cycle or arm ergometer, stair climbing, and strength training). Results of 22 patients with COVID-19, of whom 15 had required intensive care, were analyzed, which showed significant improvement with physical, mental, and cognitive therapy(14). A review study explained the management of post-COVID complications under four headings:

- long-term monitoring
- mental health support
- social support and
- Rehabilitation.

Patients' respiration and exercise capacity, muscle power, quality of life, and functional activity results can be improved by pulmonary rehabilitation(141) Early mobilization enhances cognitive, functional, and respiratory functions

Another study proposed the effectiveness of short-term breathing exercises on the respiratory rehabilitation of patients with COVID-19. A randomized controlled trial was done on elderly patients with COVID-19, and the result showed significant improvement in SpO2, respiratory rate, and heart rate who received breathing exercises and the respiratory rehabilitation protocol(142).A review article discussed the use of telemedicine, pain management, physical therapy, and the use of drugs like opioids, steroids, and non-steroidal anti-inflammatory drugs for the management of musculoskeletal pain after COVID-19 (17). Myofascial release techniques, soft tissue mobilizations, modalities, exercises, and other methods are used in physical therapy to alleviate musculoskeletal discomfort. Exercise is a key component of recovering from COVID-19; it improves physical condition, improves fatigue, increases muscle strength, enhances coordination and balance. Additionally, in hospitalized patients, strength training with mild to moderate resistance and a moderate number of repetitions should be added as the patient improves, and progressions can be done by overload and variations in exercise. Beginning with simpler open kinetic chain exercises

(monoarticular) and moving on to more intricate closed kinetic chain exercises (multiarticular).

A home exercise program, such as stretching and strengthening exercises, can be recommended to improve stability. Strengthened muscles and improvement in static and dynamic stability can help reduce pain due to instability and asymmetry. Application of protected technique has also been encouraged to protect the affected site through orthosis or kinesiology taping. Reports have increasingly indicated that kinesiology taping can provide stability to injured joints and reduce pain and swelling through its lymph and fascia function(143).

Rehabilitation plays a crucial role in the recovery of COVID-19 patients by improving physical deconditioning, respiratory dysfunction, and musculoskeletal complications. It helps restore mobility, improve lung capacity, and functional independence. Early and structured rehabilitation programs can significantly reduce long-term disability and improve quality of life in post-COVID individuals. Numerous studies have been done on rehabilitation of individuals after acute infection, highlighting the effectiveness of various rehabilitation programs like respiratory rehabilitation, which is an important component in the management of post-COVID-19 infected individuals, In a quasi-experimental study on 20 individuals recovering from COVID-19, in which participants were engaged in a supervised rehabilitation program incorporating breathing exercises and other techniques under the guidance of a trained physiotherapist. Key outcomes, including exertional dyspnoea, quality of life, and levels of anxiety, were evaluated both before and after the intervention. and the results demonstrated a statistically significant reduction in exertional dyspnoea, state anxiety, and trait anxiety, along with a notable improvement in overall quality of life.(144)

Another study evaluated the effectiveness of two different exercise-based regimens in patients with COVID-19 infection through a randomized controlled experiment. Of the 77 patients, 26 performed strengthening exercises, 29 did breathing exercises, and 22 were in the control group. Assessments were done by the Borg scale, a 6-minute walking test, a 30-second sit-to-stand test, a visual analogue tiredness scale, and multidimensional dyspnea at baseline and on the 14th day. The. The results of the study concluded that the strength and breathing exercise group obtained significant

improvements in fatigue, dyspnoea, and physical state compared to the control group(145)

Similarly, a randomized controlled trial was conducted on 72 recovered participants, out of which 36 patients underwent respiratory rehabilitation for 6 weeks and the rest with no respiratory intervention. Interventions included (1) Respiratory muscle strengthening exercises, (2) assistive cough exercise, (3) Diaphragmatic breathing, (4) general stretching, and home exercises. The purpose is to investigate six weeks of respiratory rehabilitation on older patients' mobility, quality of life, and respiratory function. Thus, the results showed that six weeks of respiratory rehabilitation is effective in improving respiratory functions, QoL, and anxiety of elderly patients (146)

Pulmonary rehabilitation could be effective in increasing the oxygen saturation, reducing dyspnoea, and improving the QOL of patients with severe COVID-19 after discharge from the ICU. Evidence supporting the effectiveness of pulmonary rehabilitation over different outcomes can be understood by numerous studies, some of which are:

- Rayegani S, Bozorgmehr R, Oshnari L, Kaghazi A.(2022)in their quasi-experimental study, over 35 individuals(age 17-35 years) discharged from the intensive care unit after severe infection with COVID-19, pre- and post-exercise-based pulmonary rehabilitation programme of 2 weeks showed improvement with the rehabilitation program; the average oxygen saturation improved (90.41 to 95.11), along with improvement in pulse rate and dyspnoea after two weeks of intervention. (147)
- Ahmed. I. et al. (2022) conducted an interventional study at the Bin Imam Rehabilitation Centre, with 20 patients recruited having a below-standard 6-minute walk test and QoL score were recruited and were given five weeks (3 sessions/ week) of aerobic training (20-60 min/sessions) and breathing exercise training (10 min/session). After five weeks of the intervention, paired sample t-tests were used for assessment. The results show that cardiorespiratory fitness, dyspnoea, and quality of life improved significantly over time . An increase in exercise tolerance was observed in subgroup 1 without ventilator

support, compared to subgroup 2 (who used ventilator support). Thus, the results of the study concluded that rehabilitation training may benefit the recovery after COVID-19(148).

- Cengiz H, Ayhan M, and Guner R. (2022) conducted a randomized controlled clinical trial, and a total of 44 eligible participants were enrolled. Primary outcomes were oxygen saturation and the rate of dyspnoea level, while secondary outcomes included psychological parameters by anxiety level and the effect on quality of life. Patients in the deep breathing group show a shorter hospitalization time, higher SpO2 levels, and a higher quality of life as compared to the usual care group. The results of this study concluded that deep breathing exercises with Triflo increase the oxygen saturation level and quality of life in patients with COVID-19, and also led to a improvement in dyspnoea and anxiety levels (149).
- Chikhanie. Y. et al., (2021). Twenty-one patients recovering from COVID-19 were assessed before and after pulmonary rehabilitation, and their results were compared with a control group of non- infected patients who also underwent rehabilitation after Intensive Care unit admission for respiratory failure. Both groups performed rehabilitation consisting of breathing exercises, strengthening and balance exercises, and walking. Outcome parameters were pulmonary function test, balance measurements, and six-minute walking tests performed at admission and discharge. A group of infected patients showed more improvement after pulmonary rehabilitation compared to other respiratory patients. Thus, the study concluded that pulmonary rehabilitation induced large functional improvement in COVID-19 patients post-ICU (150).

Rehabilitation plays a significant role in managing post-COVID-19 conditions (PCC), addressing persistent symptoms such as fatigue, muscle/joint pain, sleep disturbances, shortness of breath, and functional disability, including balance and gait, cognitive, and psychological functions. These symptoms can significantly diminish the quality of life and impose economic burdens on healthcare systems. Holistic rehabilitation approaches—combining physiotherapy, occupational therapy, and psychological counselling—have been demonstrated to enhance physical functioning

and improve overall quality of life in individuals with post-COVID condition (PCC). For instance, a study published in JAMA Network Open demonstrated that structured rehabilitation interventions can effectively enhance physical capacity and quality of life in individuals with PCC(151).A study conducted on 193 subjects aimed to evaluate the improvement of functional mobility and gait speed showed that a structured rehabilitation program significantly improves balance, speed of gait, and independence in mild-to-moderate post COVID-19 patients when measured by TUG and 10MWT(103).

Despite these advancements, several research gaps persist in the rehabilitation of PCC. Notably, there is a scarcity of evidence synthesizing and evaluating the long-term efficacy of various rehabilitation approaches. The existing research often lacks standardized activity and participation assessments, making it challenging to compare outcomes across studies. Additionally, the optimal timing, intensity, and components of rehabilitation programs for PCC remain unclear. Addressing these gaps is essential for developing evidence-based rehabilitation strategies tailored to the diverse needs of PCC patients(151). The Rehabilitation Program should be directed to fill two important gaps: (1) the need for good-quality research on PAC rehabilitation studies and (2) the need for clinical trials on the development of specialized rehabilitation exercises and outcomes for COVID-19 survivors.

The physiotherapeutic rehabilitation program includes Therapeutic Exercises and Electrotherapy Intervention.

2.2.3.1 Therapeutic Exercises for Post-COVID-19 Syndrome

Exercise leads a crucial role in managing post-COVID-19 syndrome by improving physical and mental health, reducing fatigue, and improving quality of life. Gradual supervised exercises or physical activity help rebuild strength, cardiovascular endurance, and lung function, which may be compromised after COVID-19. Regular aerobic or range-of-motion exercise can also alleviate symptoms such as brain fog, anxiety, and depression improving circulation and the release of endorphins. However, overexertion and worsening of symptoms like post-exertional malaise (PEM) should be taken into consideration. A structured rehabilitation plan, including breathing exercises,

stretching, and low-intensity aerobic activities, can significantly aid in long-term recovery. Exercise Is Beneficial for Immunological Health. Production of chemicals like anti-inflammatory cytokines is are key factor in the beneficial effects of exercise on immunity. It activates immunoreceptors by regulating T-cells to improve the immune response to SARS-CoV-2 antigens.

a) The Potential Role of Exercise on Pain in Post-COVID-19 Syndrome

Regular moderate exercise regulates the immune system by reducing chronic inflammation and promoting the release of anti-inflammatory cytokines (such as IL-10) while suppressing the production of pro-inflammatory cytokines (like IL-6, TNF-α, and IL-1β). This can help prevent or mitigate the severity of a cytokine storm. Additionally, exercise enhances immune resilience by improving metabolic health, reducing oxidative stress, and supporting balanced immune cell function. Regular exercise enhances aerobic capacity, leading to more efficient energy production and less reliance on anaerobic pathways, which can help regulate LDH levels over time and reduce early fatigue and pain. It reduces creatine kinase release over time and improves recovery efficiency. Strength training, including isometric exercises of specific muscle groups, confers unique, multi-systemic benefits to the musculoskeletal system, improving both morphological factors by increasing the number of sarcomeres and synthesis of contractile actin and myosin filaments, altering muscle fibres' composition, and neural factors by improving neuromuscular coordination and regulating the whole body metabolism(27). Ahmed. I. (2022) have also explained the effectiveness of exercise in the management of symptoms like fatigue and myalgia, and improving quality of life after COVID-19 infection(148). Another study demonstrated the effect of eight-week isometric exercise to decrease the levels of inflammatory cytokines (IL-6, TNF-α, and CRP) and significantly reduced the levels of TNF-α and CRP in elderly women with early knee osteoarthritis. Exercise-induced increases in the activity of endogenous opioids in the central and peripheral nervous system simultaneously cause feelings of euphoria and relieve pain (152). However, a tailored specific exercise protocol for COVID-19 recovered patients is not been proposed yet.

b) The role of exercise on balance and gait abnormalities in post-COVID-19 syndrome

Studies are conducted on the effects of an interdisciplinary rehabilitation program in patients with post-COVID-19 syndrome. After 6 weeks of rehabilitation in 97 patients with long COVID-19, the following improvements were observed (i) body composition—increase in skeletal muscle mass and reduction of fat; (ii) dyspnea—according to the Borg scale and the mMRC dyspnea scale; (iii) fatigue—with a decrease in the MFIS scale; and(iv) physical capacity—by significant increase in walking distance, GAIT speed, and chairstand as assessed with the 6MWT, the 30CST, and the SPPB.)(153).Exercise improves GAIT, with trunk and lower limb muscle strength. It also significantly improves $VO_{2peak,}$ improves glycolytic action, liberating energy required to improve GAIT efficiency. Thus, the rehabilitation program should include endurance training like treadmill, cycle ergometer, stair climbing, and resistance training of the upper limb, lower limb, and chest(14).

Neurological and vestibular impairments from COVID-19 can affect balance. Balance training, proprioceptive exercises, and functional movement drills enhance stability and reduce fall risk. The effects of pilates exercises on core muscle strengthening and endurance, and trunk balance in people infected with COVID-19 have resulted in an improvement in the quality of movement patterns, along with the quality of life (157). Exercise also has psychological benefits; it enhances mental well-being, reduces stress, anxiety, and encourages confidence in movement

c) The Role of Exercise on Physical Activity in Post-COVID-19 Syndrome

Physical activity improves cognitive health and aids in the management of neurological conditions by promoting neuroplasticity, improving metabolic efficiency, and strengthening antioxidant defenses. Additionally, regular exercise reduces inflammation by influencing microglial activity in the CNS. Breathing exercises affect mitochondrial biogenesis, improving energy metabolism and reducing post-viral fatigue. Improving stress and muscle weakness exercises tend to decrease energy expenditure during the performance of ADL, thereby improving the physical activity level(155). Cuenca-Zaldivar, J.N. et al., (2022) evaluated the effects of short

Multicomponent exercises (< 4 weeks) among individuals who were diagnosed with post-COVID-19 functional impairments.3 weeks of daily sessions for 40 minutes were given to patients, pre- and post-assessment was done for functionality, muscle strength, balance, gait, and basic ADL's The results showed improvements in physical fitness and frailty using the MEP (123).

Along with exercises, other interventions like MFR techniques, soft tissue manipulation like massage, mobilization, and joint manipulation, dry needling, and hydrocollateral packs may play a role in the reduction of pain; however, there is limited evidence in support. There is a need for more research to fill this gap and examine the effectiveness of these methods for pain management(17).

2.2.3.2 Electrotherapy Management for PCC

Electrotherapy, encompassing modalities such as transcutaneous electrical nerve stimulation (TENS), ultrasound therapy, and low-level laser therapy, is widely utilized in managing various musculoskeletal and neurological conditions. However, its precise function in the treatment of post-COVID-19 conditions (PCC) is yet poorly understood. Current rehabilitation strategies for PCC primarily focus on interventions like physical therapy, cognitive behavioural therapy, and graded exercise programs, which have demonstrated efficacy in improving symptoms such as fatigue, breathlessness, and cognitive impairments.

Transcutaneous electrical nerve stimulation (TENS), a basic, non-invasive analgesic method, in clinical settings to treat pain of any kind. This is the utilization of pulsed rectangular monophasic/biphasic currents using surface electrodes, mainly for pain control. The pulse duration is 50-200 μs, the frequency is 1-120 Hz (up to 200 Hz), and the maximum peak current is 50 mA-100 mA. With the discovery and isolation of opioids as well as the 1965 publication of Melzack and Wall's gate control hypothesis of pain, our understanding of the neuropharmacology and neurophysiology of pain has significantly increased since the mid-1960s. A basic understanding of the nociceptive pathways and the neurophysiology of pain is required to comprehend how TENS, or any other pain-relieving modality, works. The effect of Transcutaneous Electrical Nerve Stimulation (TENS) on respiratory function among COVID-19 patients has been

proposed in a study (16). They proposed that TENS may be a potential and effective therapeutic method with few side effects compared to any other medication to relieve various symptoms and complications of COVID-19 patients (156).

Machado, F. (2021) also proposed the application of TENS for the management of musculoskeletal pain in COVID-19-recovered patients. They highlighted the effectiveness of exercise in reducing shortness of breath, increasing muscle power, balance and coordination, reducing stress, and pain management. It reduces acute and chronic pain, yet their use has to be explored through more research work done on this(17). Similarly, another study emphasized the application of TENS in the treatment of low back pain, knee pain, fibromyalgia, and non-specific musculoskeletal pain (157) .

Post-COVID-19 recovery is primarily associated with musculoskeletal pain, neuropathic pain, myalgia, and generalized fatigue. Interferential Therapy (IFT), a non-invasive electrotherapy modality, has been widely used in pain management and rehabilitation. It includes the interaction of two medium-frequency currents, resulting in the production of a low-frequency current called the 'beat frequency' response in deep tissues. Its role in managing post-COVID-19 pain is gaining attention due to its effectiveness in improving circulation, reducing inflammation, and promoting tissue healing. Another study discussed the role of IFT in reducing pain intensity and improving physical functions (158). Research done on post-COVID-19 musculoskeletal complications and rehabilitation described the prevalence of musculoskeletal pain and suggested electrotherapy treatment as part of rehabilitation strategies(159).

Low-Level Laser Therapy (LLLT), or photobiomodulation (PBM), has emerged as a new promising non-invasive treatment intervention for managing pain, inflammation, and tissue repair in PCC patients. Clinical research has demonstrated that LLLT can promote lung tissue regeneration and mitigate the consequences of COVID-19. In a study involving 106 patients, LLLT was applied during rehabilitation, showing good tolerability and improvement in quality of life. Moskvin et al., (2021) explored the effects of laser therapy (LLLT) as a therapeutic measure against endothelial dysfunction in individuals with COVID-19. The study involved 106 patients from 2

COVID-19 treatment centers in Russia. Findings indicated that LLLT was not only easily acceptable but also effective in reducing the risk of endothelial cell function failure. Additionally, it contributed to better sputum clearance and overall improvement in patient health status.. Thus, LLLT provides evidence for promoting lung tissue regeneration and mitigating the consequences of the disease and, as a result, can be used effectively in the prevention and treatment of COVID-19 patients(160).

However, what physiotherapeutic interventions should be used in outpatient and inpatient settings for Post and long COVID-19 patients still needs to be defined in future studies. Outcome of Numerous physiotherapy interventions, like Physiotherapy, aerobic exercise, physical activity, strength training, passive and active mobilization, manual therapy, massage therapy, lymphatic drainage, electrotherapy, respiratory therapy, proprioceptive neuromuscular facilitation (PNF), Vojta, Bobath, pressure ulcer management, and prevention, is under research(161). The absence of robust clinical trials evaluating electrotherapy's effectiveness in PCC management highlights a significant research gap. Given the diverse and persistent nature of PCC symptoms, there is a compelling need for well-designed studies to explore the potential benefits and safety of electrotherapy modalities in this context. Such research could inform evidence-based guidelines and expand the therapeutic options available for individuals suffering from PCC.

2.3 Dynamic Neuromuscular Stabilization (DNS) Exercise Approach

Dynamic Neuromuscular Stabilization (DNS) is a new emerging concept in rehabilitation. The concept was proposed by Professor Pavel Kolar, inspired by Vojta's work on Reflex locomotion. It is based on the principle of developmental kinesiology, i.e., the study of principles of human movement with relation to mechanics and anatomy. It focuses on optimal breathing exercise patterns by diaphragm stabilization and integrated mechanical activation of the stabilization system of the spine before initiating movements in the extremities. Before any purposeful movement, the activation of the diaphragm and appropriate breathing pattern with core stability is of primary concern. It stimulates the developmental process of the motor nervous system

through activating neurodevelopmental locomotor chains based on motor positions of healthy newborns.

This method evaluate stability, quality, or movements to restore the integrated spinal stabilizing system by utilizing special exercises based on the child's motor developmental position. These exercises activate necessary and appropriate patterns in close and dynamic open kinematic chains, which occur in throwing, standing, squatting, or kicking. The DNS technique is based on human-motor developmental patterns during the initial years of life, which control the maintenance of erect posture against gravity by activating anti-gravity muscles. It involves the integrated action of intrinsic muscles of the spine forming an Integrated Spinal Stabilization System (ISSS). This includes cervical musculature, flexors and extensors, diaphragm, multifidus, transversus abdominis, and pelvic floor(18) (163).Dynamic Neuromuscular Stability (DNS) training has emerged as a promising method, aiming to restore developmental movement patterns and optimize sensorimotor integration(164).

2.3.1 DNS Principle

Developmental Kinesiology (DK), one of the fundamental concepts of the theories, holds that human motor function in early childhood develops a predictable pattern that is genetically predetermined. The central nervous system (CNS) executes the motor programming as it develops, allowing the child/infant to control posture, maintain an upright posture against gravity, and perform purposeful movements through muscular activity. According to developmental kinesiology, there are inborn central movement patterns that naturally occur in a particular developmental order during central nervous system maturation. These patterns are also known as muscle synergy patterns. An increase in IAP stabilizes the spine. The transversus abdominis, pelvic floor, and diaphragm all contribute to anterior lumbopelvic postural stability, which controls the IAP. Working together with intra-abdominal pressure (IAP), these deep spinal stabilizers support the spine and maintain dynamic stability(2) (162).

DNS is a rehabilitation and training approach based on developmental kinesiology principles, as shown in Figure 2.7. These principles include-

- **Developmental kinesiology**: As described by Kobesova and Kolar, developmental kinesiology is based on 3 levels of sensory-motor control.
  - The brain stem and spinal level execute general and gross movements at different speeds and amplitudes.
  - Subcortical level: There is synergistic activation of the diaphragm, spinal extensors, abdominals, and pelvic floor muscles before movement of the head, neck, or extremities.
  - A cortical level involves motor control during the development of the locomotor pattern. In early childhood, the predictable pattern in the development of human motor function activates the muscles. This is required for posture control, maintaining an erect posture against gravity, and purposeful movements.
- **Joint Centration:** The subcortical level of the central nervous system controls both core muscle stability along the functional movement of limbs. The joint comes in a functionally neutral/centered position during movement and posture, controlled by the CNS and optimal balance activation of muscles. This ideally aligned position is a Dynamic Neuromuscular Strategy.
- **Core stabilization Integrated spinal stabilization system (ISSS)**: As described by Kolar, it is balanced co-activation of deep flexors and extensors of the cervical and upper thoracic spine, abdominals and extensors of lower thoracic and lumbar spine, pelvic floor musculature, and diaphragm. The spinal stabilizers work in an integrated manner and are activated before any simple purposeful movements. It is automatic and provides a stable base for movements. This is known as the "Feed Forward Mechanism."
- **Stabilizing function of the Diaphragm:** A correct breathing pattern provides proper stabilization to the spine. During the initial phases of development, the role of the diaphragm is for respiration only, but during the later stage, it develops a role in anti-gravity posture stability. It is provided by activation of ISSS, i.e, diaphragm, abdominal, pelvic, and back muscles. The combination function of a diaphragm for providing stability and respiratory function is possible only when there is perfect motor control(18)(163) ***(Copyright No. L-128437/2023)***

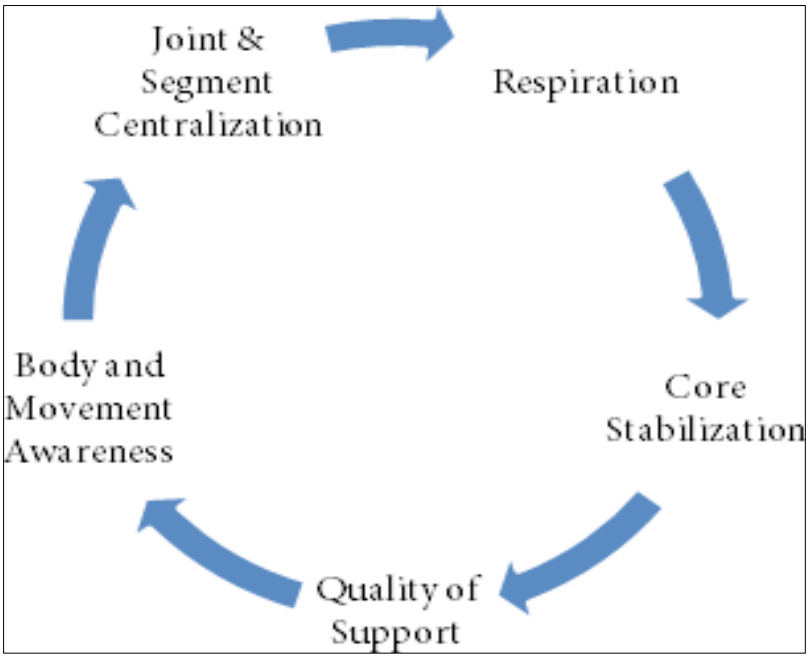


Figure 2.7: DNS Principle,(162)

2.3.2 Mechanism of Action

DNS utilizes these principles and improves core stability, muscle recruitment, and breathing efficiency. This technique of rehabilitation improves balance, movement, and muscle strength by utilizing developmental principles in which an infant learns to go from rolling to crawling to walking. It optimizes movement by reducing the load on joints and the spine. A raised intra-abdominal pressure helps to stabilize the spine. This is achieved by integrated action and co-contraction of the diaphragm, pelvic floor, and abdominal muscles. DNS aims to improve breathing patterns and core stabilization through intra-abdominal pressure and provides a stable base with centered joints during static and dynamic movement. It assists with movement awareness by automatically regulating the diaphragm and other abdominal stabilizing muscles through subconscious activation in specific zones. Based on Jena's Principle of dynamic neuromuscular stability, DNS exercises provide an important component of Integrated Spinal Stabilization and abdominal stabilization before dynamic movement. It restores

optimal movement patterns and spinal stability by combining natural developmental posture and neuromuscular control (18) (165).

- Role of Diaphragm

Kolar. P Kobesova. A, Valouchova. P and Bitnar. P. (2014), in the chapter Recognizing and treating breathing disorders, has discussed the role of the diaphragm (163). The diaphragm functions in respiration during the initial phase, but later on, around 6 months of age, it also serves the function of a postural stabilizer. It aids in the production of intra-abdominal pressure, which is necessary for core stabilization. If the diaphragm contracts down fully, it permits more space to fill the air in the lungs. The increased intra-abdominal pressure helps to stabilize the spine. This is achieved by integrated action and co-contraction of the diaphragm, pelvic floor, and abdominal muscles. DNS breathing exercises particularly target the transverse abdominal muscle. One of the objectives of DNS breathing exercises is to increase abdominal pressure, which is achieved by stimulating the transverse abdominal muscle, which aligns the lumbar spine and strengthens the respiratory muscles in conjunction with other stabilizers. The diaphragm has dual action: respiratory function and postural function for providing spinal stability.

As discussed, the role of the diaphragm in providing spinal stability can be discussed as follows(18):

- Intra-abdominal Pressure Regulation
- Synergy with core muscles (pelvic floor, transverse abdominis, multifidus)
- Load distribution across the spine prevents overloading on specific segments
- Breathing mechanics integration
- Proprioceptive feedback.

2.3.3 The DNS Model

The DNS Model theory integrates principles of neurology, biomechanics, and motor control to improve posture, stability, and movement efficiency. The two major

models of DNS: (a) Developmental Kinesiology Model, (b) Spinal Stabilization Sensitivity Model

2.3.3.1 Developmental Kinesiology Model

Developmental kinesiology provides a fundamental concept of functional interdependence by illustrating how the skeleton, joints, and muscles work together during the performance of movement. It emphasizes the importance of training both static and dynamic muscle functions in an open and closed kinetic chain. Mentioned in a narrative review, the framework of developmental kinesiology is derived from sensorimotor control, consisting of three progressive levels that direct the motor development and coordination(18). The brain stem and spinal cord regulate general motions and rudimentary reflexes in the neonatal stage. After the newborn stage, the first year of life is when the subcortical level of CNS motor control mostly begins and develops. This enables fundamental trunk stabilization, which is necessary for all phasic movements and the extremities' locomotor activity. Lastly, the cortical level, which is the highest level of motor control, increasingly becomes activated. Human ontogenetic models—specifically developmental motor patterns—can serve as valuable tools for identifying and treating dysfunctions within the locomotor system (165). Figure 2.8 reflecting the conceptual framework of developmental kinesiology.

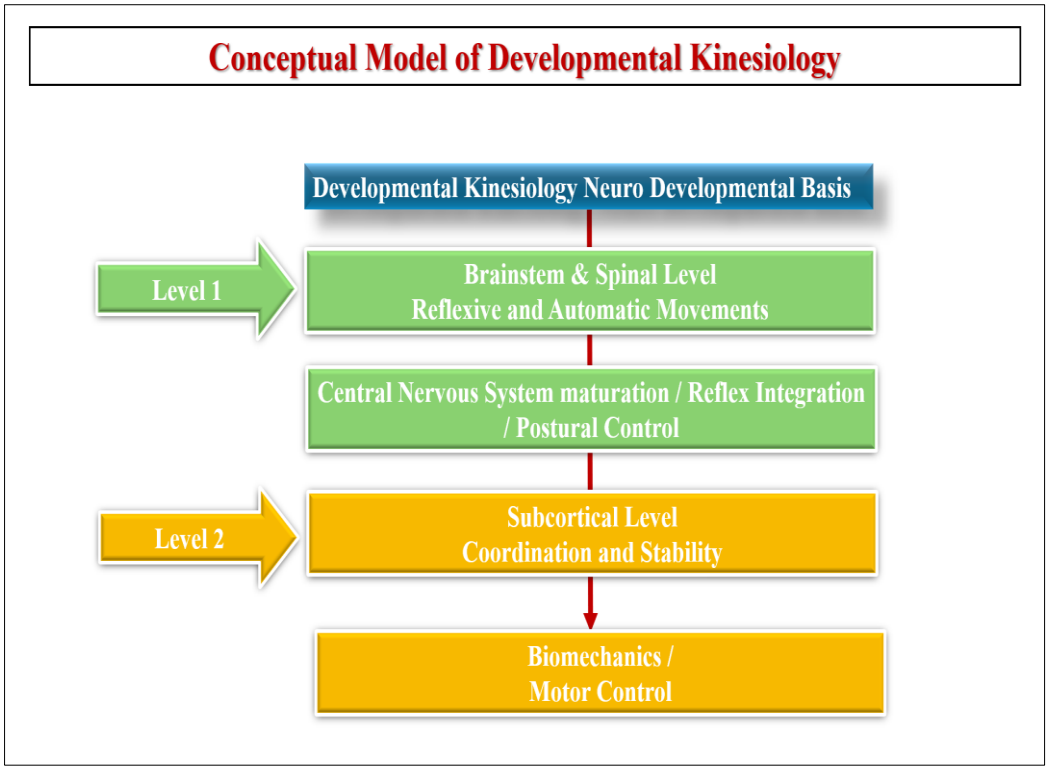


Figure 2.8:Developmental Kinesiology Model

2.3.3.2 Spinal Stabilization Sensitivity Model

The diaphragm, pelvic floor, all abdominal sections, spinal extensors in the lower thoracic and lumbar regions, and deep cervical flexors and spinal extensors in the cervical and upper thoracic regions make up the integrated spinal stabilizing system (ISSS). The diaphragm, pelvic floor, and transversus abdominis regulate IAP and provide anterior lumbopelvic postural stability. Spinal stabilizers (cervical flexors and extensors, diaphragm, transversus abdominis, multifidus, and pelvic floor) get activated together before any simple purposeful movement. This provides spinal stabilization sensitivity and load distribution for the movement contributing to the "Feed forward mechanism". Neuromuscular coordination is maintained by a deep stabilizing system. The diaphragm acts as a bracing mechanism, regulating Intra-abdominal pressure. Thus, disturbance in any one segment affects the entire stabilizing system, compromising the quality of purposeful movement (166)(163).

Figure 2.9 represents the conceptual framework of the ISSS Model. It outlines the hierarchical process of achieving optimal postural control. It begins with sensory input (proprioception, vestibular, and visual cues), which is processed by the central nervous system to integrate sensory-motor information and reflex control. This leads to neuromuscular coordination, involving deep stabilizers like the diaphragm, transverse abdominis (TVA), multifidus, and pelvic floor muscles. Proper intra-abdominal pressure (IAP) regulation through diaphragmatic control and bracing mechanisms ensures spinal stability and load distribution. These foundations enable effective dynamic movement execution, ultimately resulting in optimal postural control. This model is highly relevant in physiotherapy and rehabilitation, especially for individuals recovering from injury, surgery, or post-COVID deconditioning, where restoring spinal stability and postural control is essential for full recovery.



Figure 2.9: Integrated Spinal Stabilization System Model

2.4 Review of the Effect of DNS on Musculoskeletal Pain

DNS exercises help develop efficient, stable, pain-free movement patterns by targeting neuromuscular control and biomechanics. A six-week training program for

flatwater kayakers caused a marked decrease in shoulder-girdle pain and an improvement in peak paddling force (167). Another case study presented a 12-week application of Vojta/Dynamic Neuromuscular Stabilization exercises for chronic migraines, with results indicating a reduction in pain(168). Since post-COVID patients commonly experience respiratory dysfunction, deconditioning, and musculoskeletal pain, this can help reestablish efficient breathing, stabilization, and movement patterns, supporting recovery similar to that in the above research findings.

A study investigated the impact of an eight-week Dynamic Neuromuscular Stabilization (DNS) exercise program on functional disability, pain, and quality of life in individuals with chronic nonspecific low back pain. The sample included 29 participants, allocated to a control group (n = 16) and an exercise group (n = 13). Pain was measured using the Visual Analog Scale, disability using the Oswestry Disability Index, and quality of life using the SF-36 questionnaire at baseline, immediately after the intervention, and again two months later. Participants in the exercise group performed DNS exercises three times per week for eight weeks, while those in the control group maintained their usual daily activities. Data analysis was conducted using mixed-design ANOVA ($P < 0.05$).The findings demonstrated significant improvements in the exercise group, including reductions in pain ($p < 0.001$), decreases in functional disability ($p = 0.02$), and enhanced quality of life ($p = 0.01$). These results indicate that an eight-week DNS program effectively reduces pain and disability while improving quality of life in individuals with chronic nonspecific low back pain (169) .

The principle working of DNS on the improvement of neck pain is explained in a way that by increasing the neurophysiological components of motions, the DNS concept builds upon the scientific principles of kinesiological and biomechanical development. It is essential for deep neck flexor activation, which is difficult to achieve by strengthening exercises like isometrics and other programs of stabilization exercises. On the other hand, the exact synchronization of these muscles with the CNS together intra-abdominal pressure control result in the stability of the nucleus. As a result, DNS exercises are essential for treating people who have persistent neck pain (170)

A previously published study introduced a DNS-based approach aimed at enhancing lumbar flexion movement patterns and improving posture in individuals with

chronic non-specific low back pain. However, the effectiveness of the approach still has to be investigated(171) .One of the mechanisms behind musculoskeletal pain is the abnormal postural activation of the diaphragm. This affects the intra-abdominal pressure and disrupts the integration of the ISSS mechanism, which creates greater stress on the vertebral region of the spinal column along with other joints, resulting in pain. Muscular pain and functional impairments arise from three main factors: psychosocial, pathophysiological, and pathokinesiological. The DNS method specifically targets issues occurring due to pathokinesiological origins, which are linked to neuromuscular dysfunctions without structural abnormalities. This results in biomechanical variations, which in turn are one of the main causes of anatomical deficits. Control dysfunction and impaired coordination are features of neuromuscular disorders. Biomechanical abnormalities include both faulty technique and inappropriate core posture, frequently referred to as misuse. Deviations, instability, and improper alignment are examples of anatomical anomalies. Anatomical deficits include altered alignment, balance impairments, and asymmetry. Multiple biomechanical and anatomical factors result in neuromuscular deficits. These complications can be managed by the technique of neuromuscular restoration, which is the basic principle of DNS exercises (172). However, the technique has not been tested for musculoskeletal problems caused by viral infections; thus, there is a need for the conduct of more superior research studies to test the efficacy of DNS on viral arthralgia, particularly musculoskeletal pain caused by COVID-19 infection, to provide an evidence-based treatment intervention for managing post-COVID-19 syndrome.

2.5 Review of the effect of DNS on balance and gait

Evidence suggests that DNS is linked to enhanced postural stability, particularly in conditions involving internal or external perturbations during dynamic limb activity. It is based on a feedforward mechanism that allows the diaphragm, pelvic floor muscles, abdominal muscles, and spinal extensors to work synergistically to produce optimal IAP. It involves both the nervous system and the muscular system. DNS exercise effects have been assessed over different populations to study improvement in balance performance and gait parameters. It combines flexibility, core stability, balance, and

strength training, which are required for neuromuscular coordination. A study proposed the effectiveness of DNS exercise training on balance and gait function in 30 males aged 60-70 years in Iran. Participants were randomly divided into two groups with 15 subjects in each group. For six weeks, the Control Group (CG) carried on with their routine schedule, while the Experimental Group (EG) performed 3, 45-minute sessions of dynamic neuromuscular stability training per week. Data was collected both before and after the training program using the Berg balance scale (dynamic balance), modified stork stand (static balance), and temporal and spatial gait metrics. The paired t-test and the ANOVA statistical approach were used to evaluate the collected data. The results showed improvement in the experimental group. However, the research recommended testing the DNS over a wider population(23).

Eight weeks of dynamic neuromuscular stabilization (DNS) training affects an older, healthy woman's lower limb strength, fall prevention, and static and dynamic balance. Pre- and post-tests were used in this quasi-experimental study. The exercise/DNS group and the control group were randomly selected from thirty healthy older women (60–79 years old). The study results proved that trainers and therapists could adapt DNS exercises to the specific needs of the elderly, as it appears to reduce fall risk and improve lower limb strength, thereby demonstrating significant effects on static and dynamic balance (173).

An RCT conducted over 23 patients with COVID-19 aimed to investigate the effect of DNS (40 min session 3 times a week for 6 weeks) on postural stability, motor performance, pulmonary function, and quality of life stated that the technique can be effectively integrated into physical exercises and rehabilitation programmes of COVID-19 survivors with post-COVID-19 syndrome (164). However, applying a designed DNS exercise model requires testing over a more diverse population to evaluate its effects on these parameters. The technique is used for neurological conditions; its impact on musculoskeletal problems still needs to be explored in future research.

2.6 Review on the effect of DNS on Physical Activity Performance

Joint centration in DNS refers to the optimal alignment and positioning of a joint to allow for maximal stability and efficient force transfer during movement. Adequate control by the CNS and optimal balance activation of the muscle groups create the functionally centered position of joints during every purposeful posture and movement. The central positioning of the joint represents a dynamic neuromuscular approach that offers a mechanical benefit, facilitating optimal joint movement across its entire range of motion. This facilitates the effective distribution of load across the joint, ensuring the optimal performance of the kinetic chain. Such an arrangement modifies the maximum load experienced and minimizes stress on the joint capsule and tendons, thereby safeguarding the integrity of the joint structure during loading. Additionally, if a single segment of the ISSS stabilizing system is disrupted, it affects the stabilizing system as a whole, thereby reducing the quality of functional movements.

The DNS exercises integrate the optimal functioning of the ISSS mechanism by activating the diaphragm, pelvic, and all sections of the abdominals, as well as spinal extensors in the lower thoracic and lumbar regions. The outcome of joint centration is minimal mechanical stress on relevant structures, causing overactivation of the muscles. This improves the intensity level(18). Eight-week DNS exercises improved walking speed, endurance, and quality of life parameters, and can be utilized as a corrective strategy to enhance physical function and quality of life, as reported by Sima. Z, Behnaz, G., and Saeed, S. (2020) in women with Multiple Sclerosis. It shows that these exercises stimulate the afresh developmental process of the motor nervous system, especially for people with movement problems caused by nervous system disease, through activating neurodevelopmental locomotor chains based on motor positions of a healthy newborn. In this study, walking distance and pace can be improved by DNS exercise, which is followed by phasic and tonic muscular harmony and stability. Finally, improvement in muscular stability function enables patients to keep longer and more complicated postures while walking and, in this way, increases their walking time and pace. Walking patterns are a good motivating factor for patients to enhance the level of their physical function. The increase in daily activities and

improvement in walking ability lead to motor independence in the subjects and are important factors in improving the quality of these patients' lives. The same principle and application of this exercise protocol can be applied to the rehabilitation of patients after COVID-19 infection.

According to Kolar, DNS is a unique activation of the muscle chain. A fundamental tenet of the DNS approach is that, to achieve a neutral position in joints within motor chains, each joint position is dependent upon the stability function and muscular harmony. The degree of this harmonization affects anatomical and biomechanical characteristics in addition to joint function. Walking distance, pace, balance, and postural stability are among the functional aspects that are improved by focusing on the natural development of the motor system. This improves motor potentials, thereby enhancing the individuals' overall quality of life, along with psychological and physical aspects(163).

A study was done on inactive students having bad posture that examined the effects of DNS breathing exercises on multiple postural and functional outcomes, including trunk extensor endurance, thoracic kyphosis, and upper (UCM) and lower (LCM) chest wall mobility.6 weeks of DNS treatment showed significant improvements in the pre- and post-test comparison in the DNS breathing exercise group. Thoracic kyphosis, trunk muscle endurance, and UCM and LCM significantly improved by DNS breathing exercises that emphasize the integrated spinal stabilizing system and breathing techniques. Thus, it is recommended that DNS breathing exercises be implemented to enhance posture and chest mobility and provide physiological stabilization for students' general well-being and physical activity performance in school(173)**.**

A study was done to ascertain how DNS training with inertial water loads affected middle-aged female functional movement and postural sway. The DNS training enhanced the functional movement, torso stability, and dynamic stability of females when standing on one leg. It demonstrated that DNS training programs employing resistance created by the inertia of water were successful in improving movement and posture retention, which benefits middle-aged women's functional movement, equilibrium strategy, and dynamic stability, ultimately improving the intensity level of physical activity. Additionally, regardless of age or gender, trainees who need safe and efficient posture correction can benefit from DNS training (174). Another study on the

treatment of patients with posterior cortical atrophy (PCA) by DNS showed a 60% improvement in ADL, particularly in QOL and musculoskeletal functions. However, since the study was conducted on a single patient, to get a generalized result, more studies have to be conducted over an appropriate sample size (175).

- Critical analysis for the application of DNS exercises among varied populations and post-COVID-19 recovered patients:

A critical review of the DNS literature reveals that most evidence comes from studies involving athletic and neurological groups—settings that are quite different from post-COVID syndrome—yet these findings still provide important insights into underlying mechanisms. In athletes, DNS mainly aims to enhance diaphragmatic function, trunk stability, and movement efficiency, while research in stroke and multiple sclerosis populations concentrates on regaining impaired motor control and improving balance, coordination, and respiratory–postural synchronization. Although post-COVID patients frequently display similar issues such as dysfunctional breathing, reduced motor coordination, fatigue, and balance problems, the underlying pathology is far more varied and often complicated by autonomic dysregulation and post-exertional symptom worsening. These groups share symptoms and functional challenges like:

- Impaired motor control, balance, coordination, and gait impairments: common after stroke and in MS, and frequently reported in post-COVID patients (e.g., “brain fog”, gait instability, reduced balance confidence). DNS targets motor control and coordinated movement.
- Respiratory dysfunction and altered breathing patterns: athletes use DNS to optimize breathing mechanics for performance; stroke/MS and many post-COVID patients present altered respiratory and breathing-pattern dysfunction. DNS techniques (diaphragm activation, rib mechanics) are therefore conceptually applicable for physiotherapy rehabilitation of these individuals.
- Fatigue and reduced endurance — central and peripheral mechanisms to fatigue appear across MS, post-stroke, and post-COVID. DNS’s approach to restoring efficient motor activation by joint centration and optimal postural respiration

may reduce the energy expenditure, which is a plausible mechanism to address fatigue.

Dynamic Neuromuscular Stabilization (DNS) interventions have demonstrated improvements in motor control, respiratory mechanics, and functional capacity in athletic and neurological cohorts (e.g., athletes, multiple sclerosis, stroke). It addresses:

- Sensorimotor re-education and central motor control: It improves developmental movement patterns and reflexive stabilization mechanisms whenever central control is impaired (stroke, MS, possibly post-COVID neuro-autonomic/central effects).
- Core/trunk stability and breathing synergy: DNS links diaphragmatic breathing with intra-abdominal pressure and limb function applicable for integration of breathing mechanics and postural stability.
- Functional, task-oriented performances: The application of technique in improving functional tasks and QOL has been proven in studies done over athletes and neurological patients, which provide evidence for the rehabilitation of post-COVID patients.

However, current evidence does not yet support direct extrapolation. A more rigorous, condition-specific research is required to determine whether D can be safely and effectively adapted for this emerging patient population.

2.7 Review on the role of DNS in Post-COVID-19 Infection.

Post-COVID-19 thrombosis and immune-mediated hypersensitivity responses can manifest as septic arthritis, myositis, pancreatitis, and other conditions, along with cardiopulmonary complications such as declines in respiratory function, fibrosis, pleural effusion, myocarditis, and pericardial effusion. Additional skin, neurological, renal, hematological, endocrine, and systemic manifestations are also among the long-term COVID-19 symptoms. According to reports, patients' mental and emotional health has also been severely affected by ongoing symptoms. Dynamic Neuromuscular

Stabilization (DNS) exercises have been explored as a therapeutic approach for various conditions, including musculoskeletal pain and neuromuscular coordination issues. Direct research on DNS exercises specifically for post-COVID-19 syndrome is limited, except for one study that applied DNS to COVID-19 survivors with postural stability and functional limitations. The method, also known as the Vojta approach, is a rehabilitation technique that uses indirect stimulation of the diaphragm through specific excitation points. This approach has been found to improve diaphragmatic movement during inspiration. Consequently, the Vojta method may offer therapeutic benefits for a range of conditions, including in COVID-19 patients, by improving diaphragm function and coordination. The DNS approach integrates neural stimulation with techniques such as mobilization, manipulation, breathing exercises, postural training, and patient education to deliver a holistic rehabilitation program. Since the diaphragm has dual action in both breathing and maintaining postural stability, interventions focused on improving diaphragmatic function, including DNS, may contribute to enhancing respiratory performance and improving postural control in individuals recovering from COVID-19(164).

Exercise-based rehabilitation programs like DNS exercises, including respiratory training, have shown improvements in exercise capacity, shortness of breath, and quality of life in recovered patients. They can help manage fatigue along with enhancing balance and coordination in individuals with neuromuscular impairments. The focus is on diaphragmatic breathing during the initial phase to restore normal intra-abdominal pressure regulation and prevent dysfunctional breathing patterns. It also aids in postural control and core stability functions. This approach not only targets individual muscle strengthening but also improves neuromuscular coordination and spinal integrity (23). The strength, endurance, and flexibility gained through DNS exercises enhance functional independence among post-COVID-19 patients. Studies have been conducted on similar approaches, such as neuromuscular training. An 8-week neuromuscular training program involving 90 healthy young individuals showed that the program could improve quality of life after the COVID-19 lockdown (177). Another study is proposed to examine the effects of Pilates on peripheral muscle strength, dyspnea, and fatigue in patients with post-COVID-19 syndrome (178). However, further research is needed to explore the effects of DNS on

post-COVID-19 complications for evidence-based practice. The concise, relevant literature search on the DNS approach is presented in Section 2.3.

Table 2.3: Dynamic Neuromuscular Stabilization literature search

Sources of Literature and References	Publication year	Main findings or conclusions relevant to the proposed research work	Remarks/ Analysis
1.) International Journal of Health Science and Research, vol .10. 9	2020	-A narrative review. Provide evidence that DNS tech can be applied for the rehabilitation of musculoskeletal & neurological problems (18)	The DNS protocol for musculoskeletal conditions still needs to be evaluated for its efficacy. Thus, the technique is used for treating musculoskeletal problems caused by viral infections. Also, the study provides evidence that DNS reduces pain.
2) Journal of Bodywork and Movement Therapy	2025	A study aimed to investigate the effects of dynamic neuromuscular stabilization (DNS) exercises on postural stability (PS), pulmonary function (PF), motor performance (MP), and quality of life (QoL) in recovered COVID-19 patients after weaning from mechanical ventilation. They proposed that DNS exercises can be effectively integrated into physical exercise and rehabilitative programs to improve PS, PF, MP, and QoL in COVID-19 survivors with post-COVID symptoms (168)	Thus, the literature supports the evidence that DNS can improve fundamental movements significantly, which might help to improve balance and gait abnormalities in PCC.
		Five Functional Movement tests were employed as pre- and post-assessments of exercise efficacy. Results indicated that the DNS group made more progress than the PF group. The Y-Balance and Functional Movement Screening Tests showed the	

Sources of Literature and References	Publication year	Main findings or conclusions relevant to the proposed research work	Remarks/ Analysis
		largest and smallest variations in the progression rate, respectively, according to Eta-square coefficients(179)	
3). International Journal of Sports Physical Therapy.	2013	Functional, dynamic, and integrated postural stability are prerequisites for optimal movement and performance, whether during activities of daily living or sports activities, or for the recovery of neurology or orthopedic patients. (166)	It explains the principle of DNS (1)" every developmental position is an exercise position", (2) establishes good stability for the dynamic movement of the limbs.
4)BMC Rehabilitation Research Centre (Department of Physiotherapy	2020	The study proposed the effects of DNS on balance impairments and trunk function in subjects diagnosed with multiple sclerosis and proposed a trial on 64 patients with Multiple sclerosis to compare the effects of core strengthening with DNS(19)	DNS improves trunk function, balance, fear of fall, and Forward Head posture (Postural alignments), thus providing evidence for the application of the technique in the improvement of MSD, balance, and GAIT abnormalities in the targeted population in the current study.
5). Cell, Gene, and Therapy	2020	Sima Z and Behnaz G surveyed to study the effect of DNS exercise on multiple sclerosis on quality of life, pace, endurance, and physical function improvement. (162)	8 weeks of DNS exercises result in improvement of quality of life, strength, endurance, and physical activity function. This study helps in designing the DNS exercise protocol in 3 levels -Simple, Intermediate, and Advanced
6). International Journal of Physiotherapy	2020	Dynamic Neuromuscular Stabilization therapy demonstrated a greater enhancement in race walkers' performance levels when compared to those who trained. (181)	DNS is based on developmental kinesiology and the combination of neurophysiology and biomechanical principles. It is equally effective in improving the level of performance in a race walker through parachute resistance training.
7). SAGE Journal	2021	An RCT was carried out on 40 obese postpartum women experiencing	Provide evidence of pain reduction by DNS in musculoskeletal conditions.

Sources of Literature and References	Publication year	Main findings or conclusions relevant to the proposed research work	Remarks/ Analysis
		low back pain. Participants were randomly assigned to undergo either Dynamic Neuromuscular Stabilization (DNS) training or general exercise, administered six times per week for six weeks. The outcomes proved that the DNS group experienced more improvements than general exercises (218)	
8). Elseviers Journal HomePage (Contemporary Clinical Trials communication)	2022	Compared the techniques of DNS exercise and Yoga in ch. low back pain on MRI of fat infiltration and thickness of the ThLu fasciae over lumbar multifidus (182)	Provide evidence for DNS application in Chronic low back pain patients.
9)Journal of Mechanics in Medicine and Biology	2021	The study compared the impact of dynamic neural stability exercises on young baseball players for scoliosis and pain management. The DNS exercise was equally effective in improving scoliosis as the gym ball exercise (183)	Cobb's angles and pain were improved by the DNS exercise, which also increased cervical-lumbar spinal stability. Thus, it can be used in subjects with lower back pain in the proposed study.
10)Journal of Chiropractic Medicine	2023	Effect of Vojta Therapy and Dynamic Neuromuscular Stabilization on Respiratory Complications in Neuromuscular Pathology (184)	DNS improves diaphragm function in patients with neuromuscular pathologies.
11). Journal of Canadian Chiropractic Association	2015	A case study on the use of chiropractic manipulation and dynamic neuromuscular stabilization (DNS) to treat a patient with posterior cortical atrophy (175)	DNS is effective in improving Balance and musculoskeletal functions. Provide evidence for the application of DNS for Neurodegenerative Syndrome

Sources of Literature and References	Publication year	Main findings or conclusions relevant to the proposed research work	Remarks/ Analysis
12)University of California	2020	Dynamic neuromuscular stabilization has long-term effectiveness in treating chronic musculoskeletal pain (20)	-DNS decreases chronic pain-spine and knee -Decrease in pain is independent of age and gender
13). International Journal of Neurorehabilitation	2020	A randomized control experiment evaluated the effects of dynamic core-postural stabilization on posture stability, abdominal muscle volume, and diaphragmatic movement in patients with cerebrovascular accident (185)	According to this innovative clinical study, DNS training improved postural control and GAIT through balanced diaphragm co-activation more effectively than NDT training. Thus, DNS is used as an intervention in the experimental group
14). American Journal of Sports Medicine	2006	This study demonstrated the Impact of Balance Training and Plyometric with Dynamic Stabilization on Lower limb Biomechanics. Plyometric and dynamic stabilization exercises combined with neuromuscular training alter kinetic and kinematics and lower the risk of ACL injuries in female athletes(186)	Both exercises should be applied in the prevention of injury protocols. Both are equally effective in improving balance. Hence, DNS is used for improving balance impairments in PCC.
15). Archives of Physical Medicine and Rehabilitation	2018	DNS is effective for improving compensatory postural adjustment (APA) control, balance performance, and fear of fall in hemiplegics.	Provide evidence of increased muscle thickness and muscle activity (transverse abdominis/internal obliques) on EMG by the DNS group of exercises. Thus, it can be used for improving MSD, gait, and balance impairments after COVID-19 infection.
16). School of Rehabilitation Science, Malaysia		This study evaluates the efficacy of a DNS-based joint-centered exercise rehabilitation program in subjects with non-specific low back pain(171)	DNS can be used with TENS and Strengthening exercises to give significant results in Ch non-specific Low Back pain; thus, it can be applied for the treatment of patients with Low Back pain after the COVID-19 virus

Sources of Literature and References	Publication year	Main findings or conclusions relevant to the proposed research work	Remarks/ Analysis
17)Iranian rehabilitation Journal	2021	Highlight the effectiveness of DNS training on balance and gait functions in the elderly(23)	Due to the movement of body parts and their impact on improving muscle strength, flexibility, joint range of motion, and physical activities, the DNS technique can be effective in balance and gait function.
19). Journal of Bodywork and Movement Therapies	2020	Developed a new examination method for functional postural-stabilization tests based on the DNS approach(166)	This paper presents a logical model of assessment based upon well-established developmental kinesiological standards.

(Note: *DNS: Dynamic Neuromuscular Stabilization, NPRS: Numeric Pain Rating Scale, PCC: Post-COVID-19 Syndrome, PF: Physical Fitness, MSD: Musculoskeletal Disorder, ACL: Anterior cruciate ligament, EMG: Electromyography, LBP: Low Back pain*)**.**

A critical appraisal of the literature on Dynamic Neuromuscular Stabilization was conducted to evaluate the available studies' quality, relevance, and methodological rigor. The databases used for the search were PubMed, Scopus, and Google Scholar.

- Based on the literature, symptoms of post-COVID-19 common musculoskeletal issues are low back pain, muscle weakness, fatigue, balance, and gait abnormalities. Therefore, in the proposed study, the prevalence of musculoskeletal, balance, and gait impairments will be assessed through a survey of COVID-19 recovered subjects diagnosed by RT-PCR report. This will provide data on the persistence of these problems. Additionally, a review article has been published on the same.
- Dynamic Neuromuscular Stabilization Exercises have been shown to effectively improve both static and dynamic balance, muscle strength, postural alignment, pain, gait abnormalities, but the technique has never been used in the rehabilitation of COVID-19 recovered patients. Research proposed the future application of techniques for the management of orthopedic problems like back pain, knee pain, and shoulder pain.

- Application of Transcutaneous Electrical Nerve Stimulation for pain management has been used in previous research, but it was used during the acute phase of disease. Based on the effectiveness of results used in COVID-19 patients, the TENS has been used as an intervention in the Control and Experimental groups.
- Based on the literature search, the Tinetti scale for balance and gait assessment and Borg Rating of Perceived Exertion have been used as dependent variables, as these scales have been used as outcomes for results in previous research.
- The DNS exercise protocol for post-COVID-19 syndrome has not yet been specifically designed for patients experiencing musculoskeletal problems after COVID-19 infection. It improves static and dynamic balance by a "feed-forward mechanism".

Ashish. Y, Kiran. S. (2020) proposed that the concept is a therapeutic approach aimed at activating the deep stabilizing muscles of the spine along with correct breathing patterns before performing functional movements. This method emphasizes the subconscious engagement of specific reflex zones, which facilitate the activation of the diaphragm and other core stabilizers, thereby enhancing movement control and postural awareness. 6 weeks of DNS exercises result in improvement of quality of life, pace, endurance, and physical function(18)

The superior effect of the GS combined with the DNS on pain control and the reduction of scoliosis from youth baseball is evident. The DNS impacts the improvement of Functional Movements, muscle flexibility, and strength. (185). The prevalence of Fatigue (d/t inc BMI) was found to be the most common musculoskeletal symptom. Higher prevalence was found in low back pain, followed by neck pain and arthralgia. Findings regarding prevalence may assist in providing measures and exercises to the affected population (12)

The effectiveness and application of an exercise therapy program that implements the DNS approach to joint centration among adults with chronic non-specific low back pain is being conducted. It can be used with TENS and strengthening exercises to achieve significant results in chronic non-specific low back pain; Thus, it can be applied to treat patients with low back pain following the COVID-19 virus

infection. Due to different movement and their effects on improvement in muscle strength and flexibility, joint range of motion, and physical fitness, the technique is applied to study its effects on improving balance and mobility dysfunction after post-COVID-19 infection (173).

The appraisal highlighted a limited number of high-quality randomized controlled trials, with many studies presenting moderate methodological limitations like sample size, lack of a Control group, or inadequate blinding, but the evidence suggests potential benefits in improving postural balance, pain, and motor control. However, COVID-specific DNS approach research is limited. Critical analysis is shown in Table 2.4 by the JBI critical appraisal list

Theoretical basis and early clinical observations suggest that it may offer a promising adjunctive approach in the rehabilitation of individuals with post-COVID-19 infection.

Table 2.4: JBI critical appraisal checklist for Studies reported data

Reviewer: _____ Date: _____

Author: _____ Year: _____ Record No.: _____

JBI Critical Appraisal Checklist for Studies Reported

Study No.	Citation (Short)	Study Design	JBI Appraisal (Key Criteria)	Overall Quality
1	Sharma 2020	Narrative Review	No systematic search; no explicit inclusion criteria; no critical appraisal	Weak
2	Karimzadeh 2025	Experimental comparative study	Intervention and outcome measures clearly described; baseline comparability reported; limited blinding and allocation concealment details.	Moderate to high
3	Frank 2013	Conceptual / Theoretical	Not empirical; no clinical data; strong	Weak–Moderate

Study No.	Citation (Short)	Study Design	JBI Appraisal (Key Criteria)	Overall Quality
			theoretical rationale only	
4	Abadi Marand 2022	Trial Protocol	Planned RCT; no results; methods proposed only	Weak
5	Zamani 2020	Interventional (pre–post or unclear)	Positive results; unclear randomization/control; limited reporting	Moderate
6	Int. J. Physiotherapy 2020	Comparative Sports Trial	Comparative design; unclear randomization/blinding; limited generalizability	Moderate
7	Ghavipanie & Rahimi 2021	RCT	Randomized; n=40; unclear blinding/ITT; valid pain & function outcomes	Moderate
8	Venkatesan 2022	Comparative Clinical Trial	Objective MRI outcomes; unclear randomization/blinding; sample size not reported	Moderate
9	Park 2021	Comparative (Scoliosis)	Objective Cobb angle & pain; unclear randomization; unknown sample size	Moderate
10	Chiropractic Med. 2023	Literature Review	Not systematic; useful synthesis; limited method transparency	Weak–Moderate
11	Francio 2015	Case Report	Single case; no controls; limited generalizability	Weak
12	Bokarius (U. California)	Observational/Report	Long-term outcomes described; unclear methods; no comparison group	Weak–Moderate
13	Yoon 2020	RCT (Stroke)	Randomized; strong clinical relevance; diaphragm & gait outcomes; incomplete reporting on blinding	Moderate–Strong
14	Myer 2006	Neuromuscular Training Trial	High-quality journal; strong design; not	Moderate–Strong

Study No.	Citation (Short)	Study Design	JBI Appraisal (Key Criteria)	Overall Quality
			DNS-specific, but supports a mechanism	
15	Arch Phys Med Rehab 2018	Clinical Trial	EMG + functional outcomes; good journal; unclear randomization/blinding methods	Moderate –Strong
16	Yi Lin Lim (Springer)	Interventional LBP Study	Positive findings; multimodal program confounds DNS-specific effects	Moderate
17	Mansori 2021	Elderly Balance Study	Clinically relevant; unclear design details & controls	Moderate
18	Rahimi 2021	Exercise Protocol Trial/Review	Provides protocol; unclear evidence level; limited methodological detail	Weak–Moderate
19	Kobesova 2014	Method Development	Strong assessment development; not treatment-effect evidence	Moderate

Overall Evidence Quality:

The collective articles of DNS literature demonstrate moderate overall quality, with several small RCTs providing early clinical support for improvements in balance, gait, trunk stability, and pain. However, heterogeneity in study design, inconsistent reporting of randomization/blinding, small sample sizes, and limited data in post-COVID populations reduce the certainty of evidence. The literature is promising but lack a definitive part, supporting the need for a well-powered, methodologically rigorous clinical trial in PCC, which is the objective of this research.DNS has a moderate evidence base supporting improvement in balance, postural control, trunk/diaphragm function, and pain in a variety of populations. For PCC specifically, direct evidence is limited and mainly derived from stroke, MS, chronic LBP, and other populations. Thus, the application of DNS in post-COVID syndrome will present definitive evidence and justify the need for a well-designed controlled RCT in post-COVID-19 infection. The literature also demonstrates that DNS interventions are effective across neurological,

musculoskeletal, and respiratory conditions, including stroke rehabilitation, chronic low back pain, multiple sclerosis, scoliosis, and post-COVID rehabilitation. The consistency of positive outcomes across diverse populations suggests that DNS has broad rehabilitative potential and justifies its investigation in PCC patients.JBI critical appraisal revealed that higher-quality studies commonly included: Random allocation of participants, Comparable baseline groups, Standardized intervention protocols, Valid and reliable outcome measures, and appropriate statistical analysis. However, many studies also reported limitations such as: small sample sizes, Lack of blinding, short-term follow-up, and inadequate allocation concealment. These methodological gaps indicate the need for a more rigorously designed RCT with adequate sample size, concealed allocation, blinded outcome assessment, and longer follow-up duration. Conducting such an RCT would provide stronger evidence regarding the efficacy of DNS in improving balance, gait, musculoskeletal dysfunction, respiratory function, and quality of life in individuals with Post-COVID Condition.

Therefore, based on the current evidence and JBI appraisal findings, present study RCT can be as considered as an appropriate study design to establish causal relationships and generate high-quality evidence for the effectiveness of DNS rehabilitation in PCC patients.

Analysis of Literature Supporting the Hypothesis

The reviewed literature collectively supports the alternate hypothesis that Dynamic Neuromuscular Stabilization (DNS) exercises produce statistically significant improvements in pain, balance, gait, and perceived exertion in subjects with post-COVID-19 infection. Although the quality of evidence varies from weak to strong, the majority of studies demonstrate positive neuromuscular, musculoskeletal, and functional outcomes associated with DNS intervention.

Higher-quality studies such as Karimzadeh (2025), Yoon (2020), and Ghavipanie & Rahimi (2021) used experimental or randomized controlled designs and demonstrated improvements in postural stability, pulmonary function, gait performance, pain reduction, and quality of life following DNS exercises. These studies provide moderate-to-strong evidence supporting the effectiveness of DNS in functional rehabilitation and

directly strengthen the proposed alternate hypothesis. The study by Karimzadeh (2025) is particularly important because it evaluated recovered COVID-19 patients and found significant improvements in balance, motor performance, and functional movement after DNS intervention. These findings closely relate to the present study objectives involving pain, balance, gait, and perceived exertion in post-COVID individuals.

Several moderate-quality studies, including Zamani (2020), Park (2021), and Mansori (2021), demonstrated that DNS improves trunk stability, gait function, muscle coordination, flexibility, and spinal alignment. These improvements indirectly support reduced fatigue and perceived exertion because better neuromuscular efficiency lowers energy expenditure during movement and functional activities. Pain reduction is consistently supported in studies such as Ghavipanie & Rahimi (2021), Venkatesan (2022), and the Archives of Physical Medicine and Rehabilitation (2018) trial, where DNS interventions significantly improved musculoskeletal pain, postural control, and core muscle activation. Since post-COVID patients frequently experience chronic musculoskeletal pain and physical deconditioning, these findings strongly support the pain-related component of the alternate hypothesis. Theoretical and conceptual studies by Frank (2013) and Kobesova (2014) further strengthen the study's scientific rationale. These studies explain that DNS is based on developmental kinesiology principles, emphasizing diaphragmatic activation, spinal stabilization, ideal posture, and coordinated movement patterns. Such mechanisms are clinically relevant for post-COVID patients who commonly exhibit impaired breathing mechanics, reduced endurance, balance deficits, and gait abnormalities.

Although several studies were rated weak-to-moderate due to methodological limitations like lack of control group etc, the overall literature consistently support DNS intervention. None of the study reported negative outcomes of DNS exercises instead showed clinically meaningful improvements in outcomes like functional performance, balance, gait, respiratory function, and pain reduction.

Therefore, the literature collectively rejects the null hypothesis and provides substantial support for the alternative hypothesis that Dynamic Neuromuscular Stabilization exercises can significantly improve pain, balance, gait, and perceived exertion in subjects with post-COVID-19 infections. Furthermore, limitations in previous studies

justify the need for the present randomized controlled trial to generate stronger and more specific evidence in the post-COVID population supporting the need for testing of the hypothesis.

CHAPTER - III

3 METHODOLOGY

Research design and sampling, data collection procedure, and statistical tools for data analysis are covered in detail in this chapter. It involves a complete description of conducting the survey procedure and the procedure of a randomized control trial for an intervention study. The present study was conducted in 2 phases.

PHASE 1

3.1 Public Survey Methodology

3.1.1 Research Design

For the prevalence study: A cross-sectional survey of the affected population was conducted to assess the prevalence of musculoskeletal problems, balance issues, and gait impairments in individuals with post-COVID-19 infection (based on COREQ guidelines). The survey took place at the DAV Institute of Physiotherapy and Rehabilitation, Jalandhar, from May 2023 to February 2024, involving individuals who had recovered from COVID-19. The study aimed to identify post-COVID-19 musculoskeletal, balance, and gait impairments.

- Population Survey: conducted in face-to-face mode
- Physician Survey: conducted by the Interview method, face-to-face

3.1.2 Study Location

The public survey was done in Jalandhar City at DAV Institute of Physiotherapy and Rehabilitation, Orthopedic OPD.

3.1.3 Study Population and Sampling

The study population included individuals who recovered from COVID-19, tested positive on RT-PCR, and were willing to participate in the survey. A purposive or

judgmental sampling method, based on RT-PCR results. Purposive sampling (also known as judgmental sampling) is a non-probability sampling technique in which the researcher intentionally selects participants who are most relevant to the purpose/objectives of the study. Participants were selected by inclusion and exclusion criteria. Participants ranged in age from 18 to 45 years and had different durations since recovery to capture a broad spectrum of musculoskeletal, balance, gait abnormalities, and functional impairments.

3.1.4 Sample Size

The sample size for the survey was 381. To calculate the sample size for a prevalence study of musculoskeletal, balance, and gait abnormalities among post-COVID-19 recovered individuals in Jalandhar City for the year 2023, we can use the formula for estimating a proportion in a population:

Equation 3.1*: Sample Size Calculation*

$$\boldsymbol{n = \frac{Z^2 X p X (1 - p)}{E^2}}$$

Where:

- n = sample size
- Z = Z-score corresponding to the desired confidence level (e.g., 1.96 for 95% confidence)
- p = 50% estimated prevalence of the condition,
- E = 5% margin of error (precision)

Assumptions:

- Confidence Level: 95% (Z = 1.96)
- Estimated Prevalence (p): Since specific prevalence data for these abnormalities post-COVID-19 is limited, a conservative estimate of 50% (0.5) is often used to maximize sample size and ensure adequacy. Since specific prevalence data for post-COVID-19 is limited, a conservative estimate of 50% (0.5) is often used to maximize sample size and ensure adequacy. Based on continental regions, pooled

PCS prevalence was estimated at 49.79% (95% CI: 30.05%-69.54%) in Asia (31) (188)

- Margin of Error (E): 5% (0.05)

Calculations:

$$n = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.05)^2} = 380.16$$

Rounding up to the nearest whole number, the required sample size is 381 individuals.

3.1.5 Selection Criteria

Subjects were recruited based on the following inclusion and exclusion Criteria:

- Inclusion Criteria:

1. Subjects clinically diagnosed with COVID-19 by RTPCR report positive and have post-COVID-19 syndrome based on the history, physical examination, and radiology, if necessary.
2. Subjects willing to give written consent
3. Subjects with age group between 18-45 years
4. Gender, both male and female
5. Subjects with no pre-existing musculoskeletal, balance, and gait abnormality before COVID-19 infection.
6. Subjects with no pre-existing deformity before COVID-19 infection.
7. Subjects complaining of joint pain (knee, spine), Muscle weakness, and Joint stiffness (knee and spine) after COVID-19 infection.
8. Subjects complaining of balance abnormalities or gait deviation after COVID-19 infection.
9. Subjects complaining of early Fatigue post-COVID-19 infection.
10. Subjects with reduced functional efficiency after COVID-19 infection.
11. Patients on specific medication -calcium, vitamin D, and painkillers.

- Exclusion Criteria

1. Bedridden patients
2. Pregnancy.
3. Uncooperative patient.
4. Subjects having metal implants.
5. Subjects having any psychosomatic disorder.
6. Recent fractures
7. Malignancy
8. Any neurological condition, including vestibular/cerebellar disorders affecting gait and balance coordination.
9. Post-COVID stroke patients.
10. cardiovascular conditions, like subjects with pacemakers.
11. Patients on any previous medications, specifically on drugs like antipsychotics, antidepressants, immunosuppressants, multivitamins, or any nutritional supplements except painkillers, calcium, and Vit D.
12. Skin disease around the knee and spine.

3.1.6 Tools and Equipment (for survey)

1. Verified self-designed survey Questionnaire – For conducting a Public Survey and a Physician Survey.
2. Notepad
3. Pen/pencil
4. Informed Consent Form (public survey)
5. Patient Information Sheet (public survey)
6. List of target population
7. Bag/folders
8. Mobile phone

3.1.7 Variables

- Independent variables:
    1. Questionnaire for the survey (population and Physician survey)

- Dependent variables:
  2. Scores of Questionnaires (population and Physician survey)

3.1.8 Procedure

The survey was conducted in person with face-to-face interviews following COREQ guidelines at the DAV Institute of Physiotherapy and Rehabilitation in Jalandhar, where trained physiotherapists guided participants to ensure accurate responses and reduce response bias.

COREQ Flow Chart Details (

Figure 3.1 **)**

- Participant Selection and Eligibility Criteria: 1,917 individuals were initially identified from RT-PCR reports and reviewed for eligibility. The inclusion and exclusion criteria were applied to ensure the selection of suitable participants for the survey.
- Exclusion Based on Age Factor: Out of the initial 1,917 records, 743 individuals were excluded due to age-related criteria.
- Screening and Initial Contact: After applying for the initial exclusion, 1,174 potential participants were contacted via phone calls to confirm their eligibility and willingness to participate.
- Further Exclusion and Non-Response: During the telephonic screening, additional exclusions and non-responses were recorded:
- Excluded as per study criteria: 76 individuals were excluded after detailed telephonic screening due to other pre-defined exclusion criteria (such as pre-existing musculoskeletal conditions).
- Non-responders:
  - Not answering / Not reachable: 278 individuals were unavailable despite multiple attempts.
  - Not interested: 289 individuals declined to participate.
- Agreement to Participate and Final Sample: 531 individuals agreed to participate in the survey after exclusions and non-responses. However, final participation was categorized as follows:

Survey and Interview Completed: 382 participants completed the survey and interview process.

Dropout Cases: 6 participants initially agreed but later withdrew before completing the survey.

Did Not Turn Up: 143 individuals who had agreed to participate failed to attend or complete the survey.

Data Collection: The survey was conducted in person, with face-to-face interviews at DAV Institute of Physiotherapy and Rehabilitation, Jalandhar, where trained physiotherapists guided participants to ensure accurate responses and minimize response bias. A structured questionnaire was used for data collection, developed based on previous literature and expert consultation. The questionnaire was designed to assess:

- Demographic details (age, gender, occupation, medical history)
- Post-COVID-19 musculoskeletal symptoms (joint pain, muscle weakness, stiffness)
- Balance-related issues (dizziness, unsteadiness, risk of falls)
- Gait abnormalities (altered walking pattern, reduced mobility)
- Functional limitations affecting daily activities and fatigue

The data collection process was facilitated by the researcher to ensure clarity, accuracy, and consistency in responses.

Ethical Considerations: Ethical approval was taken from the Institutional Ethical Committee of Applied Medical Sciences, Lovely Professional University EC/NEW/INST/2022/3110, and the DAV Institutional Ethical Committee, IEC Reg. no. 2021-2024, before collecting data. The aim of the study was explained to subjects in his/her language by a patient information sheet, and written informed consent was obtained from subjects before participation. The confidentiality and anonymity of participants were maintained throughout the study.

Data Analysis: The collected data were analyzed using SPSS Software to determine the prevalence of musculoskeletal problems, balance, and gait abnormalities in post-COVID-19 recovered individuals. The frequency and percentage distribution of symptoms were calculated. Chi-square tests or t-tests were used to assess associations between demographic variables and post-COVID-19 complications.

The survey adhered to the COREQ framework, as detailed in Table 3.1. The Consolidated Criteria for Reporting Qualitative Research (COREQ) is a 32-item checklist structured to improve the quality of reporting in interviews and focus group studies(189)

Table 3.1: COREQ Checklist

No. Item	Guide questions/description
Domain 1: Reactivity and Researcher group *Personal Information*	
1. Interviewer	Vijayshree Singh
2. Credentials	Research scholar
3. Occupation	Research Scholar, LPU
4. Gender	Female
5. Research Experience and training	Course Work,
Relationship withparticipants	
6. Relationship established	NO
7. Participants' familiarity with the interviewer	Participants are aware of the researcher's reasonsfor doing the research through the patient information sheet, to study the Prevalence of musculoskeletal problems, balance, and gait impairments after COVID-19 infection.
8. Interviewer characteristics	The objective of the research work is to study the prevalence of musculoskeletal, Balance and gait impairments in COVID-19 recovered subjects.

No. Item	Guide questions/description
Domain 2: Study Design *Theoretical framework*	
9. Methodological orientation and Theory	Ethnography- face-to-face interview
Participant selection	
10. Sampling	Purposive/ judgmental sampling
11. Method of approach	Participants were approached telephonically & a personal interview was conducted in face-to-face mode
12. Sample size	381
13. Non-participation	439
Setting	
14. Setting of data collection	Data was collected at DAVIPTR Ortho OPD, Jalandhar
15. Presence of non-participants	MPT ortho students working as team, helper.
16. Description of sample	COVID-19 subjects were selected based on RTPCR report taken from Government authorized COVID-19 testing center
Data collection	
17. Interview guidance	Survey questionnaire was given to participants and after taking consent, questions were asked to the subject and response were recorded.
18. Frequent interviews	NA
19. Audio/visual recording	NA
20. Research field notes	Not Applicable
21. Time Duration	5 months
22. Data recording	Yes

No. Item	Guide questions/description
23. Document returned	No, a questionnaire was submitted to the interviewer after the response.
Domain 3: Analysis and Findings ***Data analysis***	
24. Number of data analysts	2
25. An explanation of the statistical test	Yes, according to the objectives and selection of the parametric /non-parametric test
26. Concepts based	Derived from data
27. Software	SPSS version, PYTHON Programming with NUMPY,
28. Participant verification	Done by RT-PCR report
Reporting	
29. Questionnaire presented	Each question is identified and analyzed
30. Consistent data and conclusions	There is consistency between the data presentation and the interpretations.
31. Clarity of objectives	Presented in results using Graphs plotted by SPSS
32. minor concepts clarity	Yes. By the CONSORT flowchart

The COREQ checklist demonstrates that the study was conducted using a well-structured qualitative research framework with appropriate methodological rigor. The research was conducted by a trained female research scholar through face-to-face ethnographic interviews using purposive sampling among COVID-19 recovered subjects. Data collection was systematically done in the orthopedic outpatient department with verified participants based on RT-PCR reports. Ethical procedures, including informed consent and participant awareness regarding the study objectives, were maintained throughout the research process. Statistical analysis was conducted by

using SPSS software, ensuring suitable parametric and non-parametric tests according to the study objectives. Overall, the reporting reflects consistency between the collected data, analysis, and conclusions, with findings clearly presented through graphs and flowcharts in the results chapter. In conclusion, the COREQ checklist highlights that the study was conducted with methodological transparency, appropriate participant selection, systematic data collection, and reliable analytical procedures. Overall, the study provides a comprehensive and well-documented evaluation of musculoskeletal, balance, and gait impairments among post-COVID-19 subjects.

COREQ guidelines helped streamline the survey process by providing a structured framework for reporting key methodological components, including participant selection, researcher characteristics, data collection procedures, and study context. Applying COREQ principles enhanced transparency and consistency in the documentation of the survey methodology, facilitated clear reporting of participant recruitment and responses, and reduced the risk of omissions in describing the research process. This structured approach strengthened the methodological rigor, reproducibility, and credibility of the survey findings. It helped the post-COVID condition (PCC) prevalence study by providing a structured framework to ensure that the survey process was reported consistently and transparently. It supported clear documentation of participant selection, eligibility criteria, recruitment, study setting, questionnaire administration, and data collection procedures, which are important when estimating the prevalence of PCC-related musculoskeletal, balance, and gait impairments. The survey helped to study the prevalence and pattern of post-COVID condition (PCC)-related functional impairments in the target population. By systematically collecting information on musculoskeletal symptoms, balance disturbances, and gait changes after COVID-19 infection, the survey quantified how frequently these problems occurred and identified the major functional domains affected. The findings provided an important baseline epidemiological picture of PCC-related impairments and highlighted the need for physiotherapy assessment and rehabilitation.

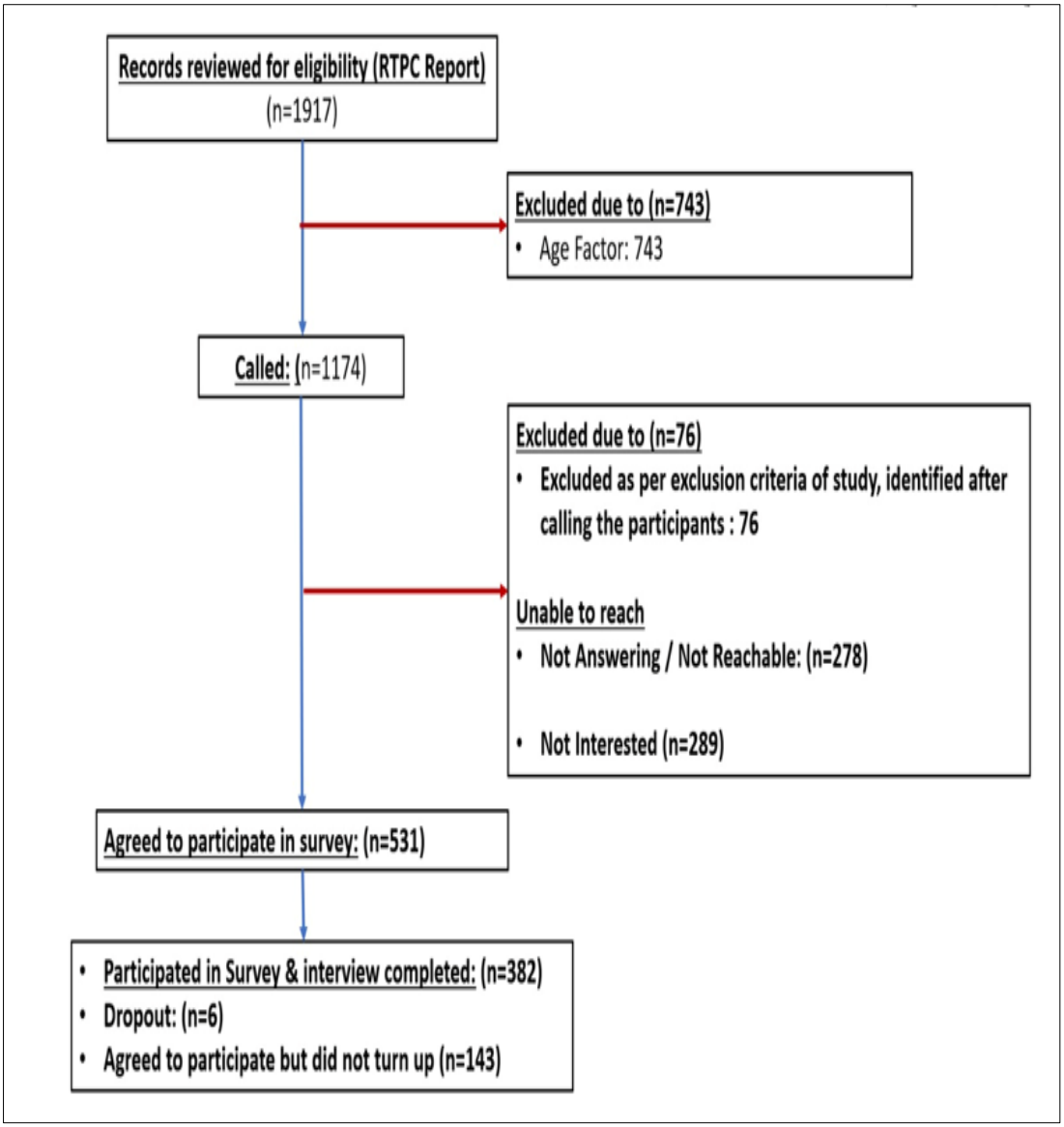


Figure 3.1: COREQ Flowchart for Public Survey

3.2 Physician Survey Methodology

3.2.1 Study Design:

This study was designed as a cross-sectional survey conducted between May 2023 - October 2023, aimed at gathering expert opinions from 50 physicians regarding the prevalence of musculoskeletal problems, balance, and gait impairments in individuals with post-COVID-19 infection.

3.2.2 Study Setting:

The study was conducted in four cities: Indore, Bhopal, Datia, and Jalandhar- targeting healthcare professionals with direct experience in managing post-COVID-19 complications.

- Punjab Institute of Medical Sciences (PIMS), Jalandhar (Punjab)
- Sacred Heart Hospital, Jalandhar (Punjab)
- People's College of Medical Sciences & Research Centre, Bhopal (Madhya Pradesh)
- Apollo Hospital, Indore (Madhya Pradesh)
- Shree Aurobindo Institute of Medical Sciences (SAIMS), Indore (Madhya Pradesh)
- Geeta Bhawan Trust Hospital, Indore (Madhya Pradesh)
- Shree Cloth Market Hospital, Indore (Madhya Pradesh)
- Datia GMC (Madhya Pradesh)
- Private Hospitals and clinics

3.2.3 Study Population and Sampling:

A purposive sampling technique was employed. In this method, the researcher exercises deliberate judgment to identify individuals who are most likely to provide accurate and relevant information for the study. Physicians with relevant clinical experience actively involved in treating post-COVID-19 infected patients were selected across multiple

healthcare Institutions. The participants included: Orthopaedic Consultants, General Physicians, Chest Physicians, Residents and Professors, Associate and Assistant Professors in Medical Colleges, and General Practitioners.

3.2.4 Data Collection:

Data were collected using a validated structured questionnaire aimed at assessing physicians' perspectives on the prevalence and characteristics of musculoskeletal problems, balance, and gait abnormalities in individuals with post-COVID-19 syndrome. The questionnaire was made after a thorough literature review and expert consultation. It included both closed- and open-ended questions, covering:

- Demographic details of physicians (e.g., Name, age, gender, Institution, designation)
- Observed prevalence of musculoskeletal, balance, and gait abnormalities in post-COVID-19 patients.
- Common symptoms and impairments are reported by patients clinically and radiographically.
- Clinical approaches and rehabilitation strategies adopted by physicians

The questionnaire was distributed in person, based on the availability and preference of the participants.

Figure 3.2 show the COREQ flowchart of the Physician survey.

Data Analysis:

The gathered data were examined through descriptive statistics to assess the frequency and distribution of reported abnormalities related to musculoskeletal issues, balance, and gait. Qualitative responses were categorized thematically to identify common trends and expert recommendations. Statistical analysis of data was done using SPSS (or another relevant software) to assess the significance of observed trends.

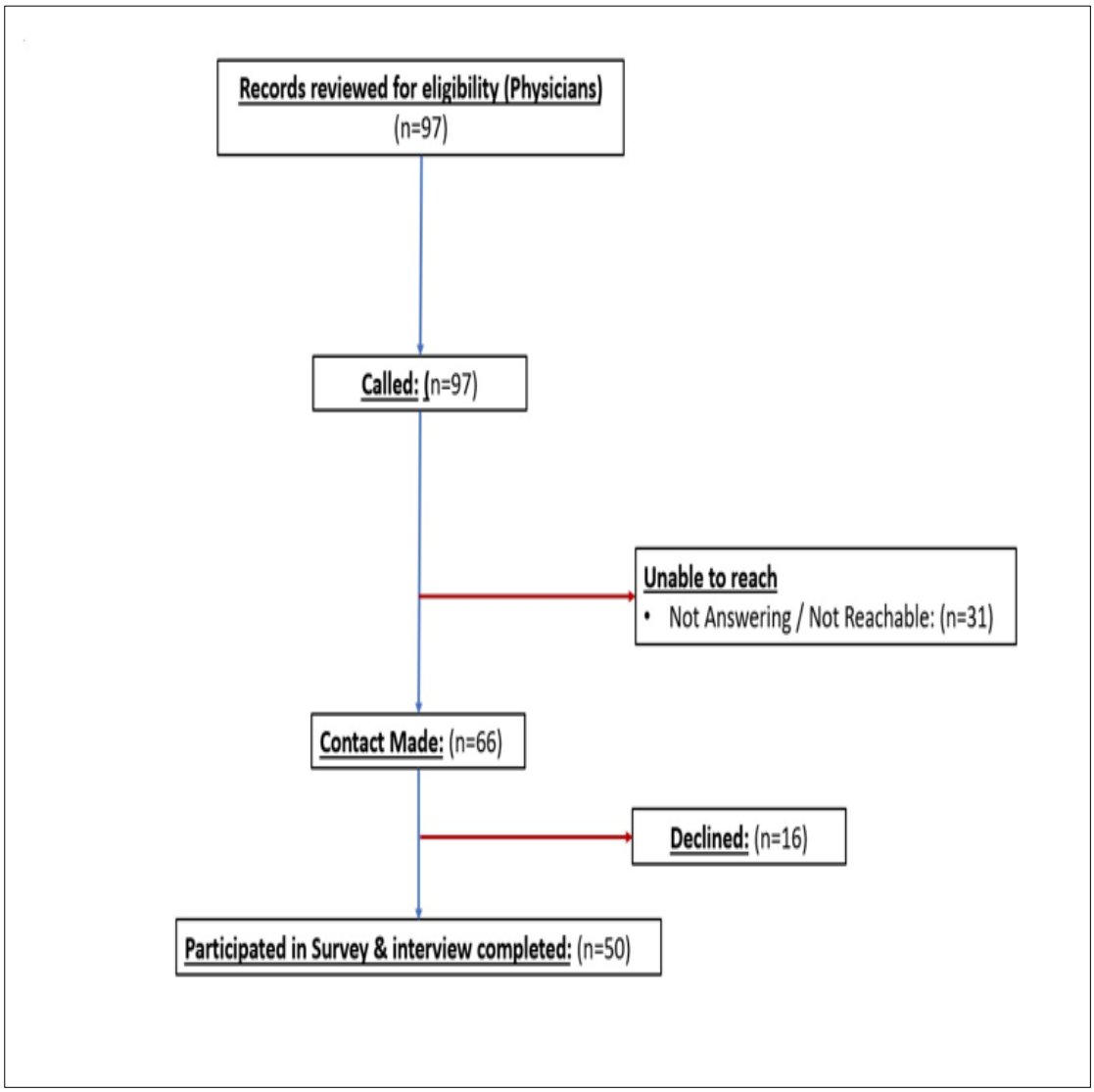


Figure 3.2: COREQ Flowchart Physician Survey

Phase 2: Intervention Study

3.3 Intervention Methodology

3.3.1 Research Design

The intervention part of the present study is a Randomized Controlled Trial, a single-blinding randomized controlled design based on CONSORT guidelines. Ethical approval was taken from the Institutional Ethics Committee, Lovely Professional University, reg. no.- EC/NEW/INST/2022/3110. And from the DAV Institutional Ethical Committee, dated 15-Oct-2022. (Annexure-10).

3.3.2 Study Population and Location

Individuals recovered from COVID-19, having positive RT-PCR reports, and were willing to participate in the clinical trial. A study was done in Jalandhar City at DAV Institute of Physiotherapy and Rehabilitation, Orthopaedic OPD.

3.3.3 Sampling and Randomization

A simple random sampling method was used. It is a method of probability sampling in which every member has an equal opportunity of being selected as a part of the sample. Randomization was done using a computer-generated randomization sequence by Python software (Programming with NUMPY)

3.3.4 Sample Size calculation

The sample was calculated by G-Power software(Figure 3.3)

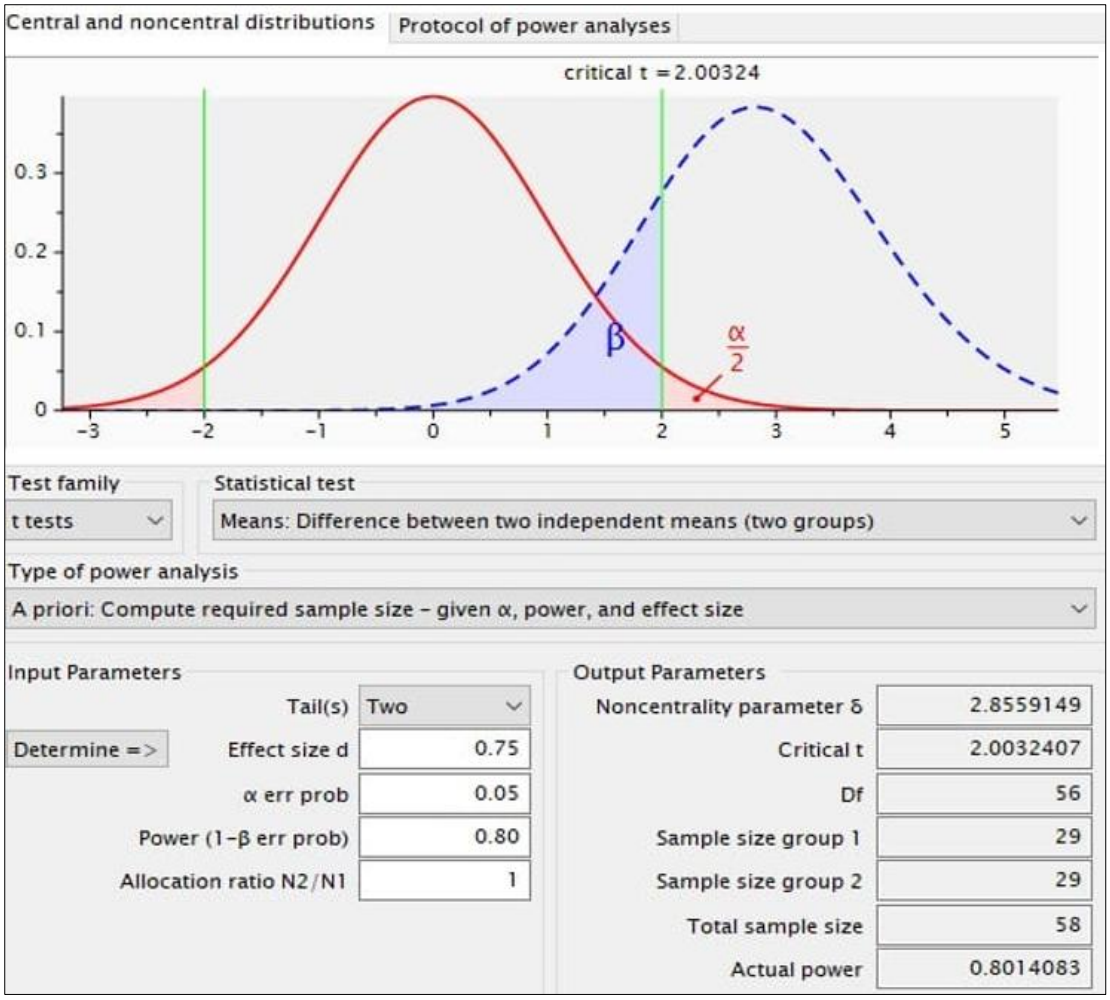


Figure 3.3: Sample size calculation by G power

t tests - Means: Difference between two independent means (two groups)

The estimated sample size is 58, assuming a 95 percent confidence interval, effect size 0.75, and 80 percent power, with 29 participants in each group, for a total of 58 subjects.

(An effect size (Cohen's d) of 0.75 represents a moderate to large effect, indicating a statistically significant difference between the two groups, the control and intervention group. Power 80% provides a practical balance between Type II error risk and feasibility.

The sample size certificate is given in Annexure 19.

Table 3.2: Sample size calculation parameters

Input Parameters	Value
Tail(s)	Two
Effect size d	0.75
α err prob	0.05
Power (1-β err prob)	0.80
Allocation ratio N2/N1	1
Output Parameters	**Value**
: Noncentrality parameter δ	2.8559149
Critical t	2.0032407
Df	56
Sample size group 1	29
Sample size group 2	29
Total sample size	58
Actual power	0.8014083

3.3.5 Selection Criteria

Subjects were recruited based on the following inclusion and exclusion Criteria as mentioned in Survey phase 1.

3.3.6 Tools and Equipment (for RCT)

1. DNS exercise protocol- Copyright Registration Number: L-128437/2023 dated:07/07/2023.

2. Orthopedic Assessment form- Assessment tool.

3. Tinetti balance and gait assessment tool- For balance and gait assessment

4. NPRS Scale- for Pain assessment

5. Borg rating of Perceived Exertion Scale- For evaluating Physical Activity Intensity level

6. TENS machine (Physio TENS 4000, Model no. IEMP3034, S/No TF1379)

7. Exercise Mat(1*1 mtr, jumprfit Gym interlocking floor mat)

3.3.7 Variables

- Independent variables:
    3. TENS (frequency: 1-20 Hz, Pulse width: 150-300 microseconds, duration: -20 min, once a week for 6 weeks (190) (191).
    4. Isometric exercises: (20 minutes (10 repetitions,2 sets) 6-sec contractions,4-sec break (152)
    5. Dynamic Neuromuscular Stabilization Exercises (Copyright Registration Number: L-128437/2023 dated:07/07/2023)

- Dependent variables:

    1. Score of the Numeric Pain Rating Scale

    2. Tinetti balance and gait assessment score

    3. Borg Rating of Perceived Exertion score

3.3.8 Procedure

The first phase consisted of a Pilot Study. It was done over 20 subjects divided into 2 groups,10 subjects in each group, with a history of COVID-19, complaining of musculoskeletal, balance, and gait impairments. Group A, the Control group, received Isometric strengthening exercises with TENS, and Group B, the Experimental group, was given DNS exercises along with conventional treatment. A 6-week period of DNS exercises resulted in the improvement of pain, balance, and gait abnormalities, and physical activity intensity level.

The second phase extended the intervention study. Subjects reporting pain in the spine (cervical/lumbar) and knee joints were screened using the Screening Form. Based on screening, selected participants were invited for baseline assessment. Sample selection was based on inclusion and exclusion criteria. A total of 58 subjects were initially recruited using simple random sampling and were equally divided into two groups, Control Group A (n=29) and Experimental Group B (n=29). A parallel-group RCT was conducted, and randomization was generated using a computer-generated, web-based sequence in Python software (www.randomization.com, Programming with NUMPY), as shown in the CONSORT flow chart (Figure 3.6).

Binding and Allocation Concealment: Single blinding was maintained by ensuring that the participants remained unaware of their group assignment throughout the study. Participants were informed that they would receive one of the study treatments but were not informed whether they belonged to the intervention group or the control group(Therapist blinding was challenging due to the implementation of the intervention). Allocation concealment was achieved using sequentially numbered, opaque, sealed envelopes (SNOSE) prepared by an investigator who was not involved in participant recruitment, treatment administration, or outcome assessment. Each envelope contained the group assignment and was opened by the treating physiotherapist immediately before the intervention session. This procedure ensured that group allocation remained concealed until the point of treatment administration.

The patient information sheet was completed in three languages (English, Hindi, and Punjabi), which the patient easily understood. Written informed consent was taken from each patient before assessment. Baseline assessment included demographic information and a detailed evaluation procedure to confirm the diagnosis, along with history taking of pre- and post-COVID-19 musculoskeletal, balance, and gait abnormalities and physical examination of the knee joint and spine (cervical and Lumbar). Confirmation of COVID-19 was done by an RTPCR report performed at the DAV Ayurvedic Institute Testing Centre. The remaining assessment and treatment were done at the DAV Institute of Physiotherapy and Rehabilitation. Pain assessment included history of onset of pain (pre-COVID, post-COVID), site, nature, and aggravating and relieving factors. A detailed history of any pre-existing

orthopedic/Neurological problems like fractures, infective or degenerative pathologies, other vestibular problems, including stroke, GBS, or muscle dystrophy, was taken. Any previous history of surgery and medications was also reported.

Primary and Secondary outcome measures on day 1(pre-treatment) included pain assessment, balance, gait, and functional disability assessment using the NPRS scale, the Tinetti gait and balance assessment tool, and the Borg Rating of Perceived Exertion scale. X-RAY reports of affected painful joints were taken to study the effects of degeneration. For the detection of early degenerative changes, Risk factor identification was carried out, which included a Blood Marker study: Serum Ca+ and Vit. D level, Smoking, Drinking, or any kind of unhealthy lifestyle.

3.3.9 OUTCOME MEASURES

3.3.9.1 Musculoskeletal Pain (Spine/Knee joint pain)

Musculoskeletal pain over the spine(lumbar/cervical) and knee joint was measured using the Numeric Pain Rating Scale (NPRS), a self-reporting scale consisting of a 10-point horizontal line with numerical values ranging from 0 “no pain” to 10 “worst pain” placed at equal intervals along its length (Annexure-12)(192). Subjects were instructed to indicate their pain level by marking an impression over the horizontal line, with scores recorded as a whole number(193). The validity and Reliability of the NPRS scale are good (The numeric scale ICC obtained value r = 0.99)(194). A good-to-excellent correlation is found between the two scales, VAS and NRS (r = 0.941)

3.3.9.2 Balance and Gait

The Tinetti Balance and Gait Measurement scale (Tinetti Mobility Test, TMT), also known as the Performance-Oriented Mobility Assessment, was used for balance and gait measurement. The TMT evaluated in this research has two separate components: a balance subscale (9 items, total of 16 points) and a gait subscale (8 items, total of 12 points). In total, the test includes 17 items, each scored on a scale of 0, 1, or 2, resulting in a maximum score of 28 points (Annexure 13 & 14). Administering the TMT takes around 10 minutes per participant. The interrater reliability for the balance subscale is high, with values ranging between 0.94 and 0.98, and an ICC of 0.97. Similarly, the

gait subscale shows interrater reliability values from 0.90 to 0.97, with an ICC of 0.94. Test-retest reliability, indicating intra-rater consistency, was ICC = 0.97 for the balance subscale and ICC = 0.96 for the gait subscale. Cronbach's alpha coefficients for the internal consistency of the Tinetti balance and gait scale were 0.74 and 0.72, respectively, with a confidence interval from 0.69 to 0.77 and from 67 to 0.7(127). Studies have used the Tinetti balance and gait test on post-COVID-19 patients to evaluate the effects of a short multicomponent exercise program on balance and gait(123). Another study was done aimed to evaluate postural balance in non-hospitalized post-COVID-19 individuals using various balance assessment tools and to identify the most effective predictor of functional status. The findings demonstrated that the Tinetti Balance Test was the most reliable tool for predicting post-COVID-19 functional status, indicating its effectiveness in identifying postural balance impairments. These results suggest that the Tinetti Balance Test can serve as a valuable clinical assessment tool for evaluating postural control deficits and guiding rehabilitation strategies in post-COVID-19 individuals (39). The assessment of scale in the present study is shown in Figures 3.4 and Figure 3.5.

3.3.9.3 Physical Activity Intensity Level:

The Borg Rating of Perceived Exertion scale measures the rate of perceived exertion. Swedish researcher Gunnar Borg constructed the scale. It ranges from 6-20 and can denote a heart rate ranging from 60-200 beats per minute (Annexure-15). The numerical value 6 represents "no exertion," and 20 indicates "maximum effort." The correlation between RPE and heart rate ranges from 0.80 to 0.90; a high correlation with other variables has also been found. Research has demonstrated the validity of using the Borg RPE scale to assess muscle fatigue during resistance exercises. Studies indicate that RPE correlates with physiological indicators of muscle fatigue, making it a useful tool for monitoring fatigue in both clinical and sports settings. The scale has been validated against physiological markers, particularly heart rate and oxygen consumption (VO_2)(195). Test-retest reliability is high, with correlations above 0.80 in a controlled exercise setting(134). The effectiveness of the respiratory telerehabilitation programme on COVID-19 patients, when assessed by the Borg scale in a study, showed

improvement in physical activity, thereby recommending the use of the scale on a large sample size in future studies(131).



Figure 3.4: Tinetti Assessment tool: Balance



Figure 3.5: Tinetti Assessment Tool: GAIT

3.3.10 Intervention Implementation

- Intervention for group A-Control Group

Group A, the Control group, was treated using Conventional therapy, which included TENS along with Isometric strengthening exercises as mentioned in (152)

Table 3.3. (152). Application of TENS over the affected painful area- Spine (cervical, Lumbar)/ knee joint.

Dosage: Low TENS, frequency: 1-20 Hz, Pulse width- 150-300 microseconds, duration -20 min, once a week for consecutive 6 weeks (190), (191)

Isometric Strengthening Exercise- cervical/Lumbar isometrics, Knee-Isometric quadriceps and Hamstrings. A rolled towel was placed below the affected painful area(knee/Lu), and subjects were asked to press it for 10 seconds and then relax.20 minutes (10 repetitions,2 sets) 6-sec contractions,4-sec break

Dosage: 20 minutes (10 repetitions,2 sets) 6-sec contractions,4-sec break (152)

Table 3.3: Interventions for Control Group A

S. No	Intervention	Duration
1.	TENS application (low TENS)	20 minutes, frequency: 1-20 Hz, Pulse width- 150-300 microsec, 6 weeks
2.	Isometric strengthening exercise (cervical/lumbar/knee)	20 minutes (10repetitions,2 sets) 6-sec contractions,4-sec break for 6 weeks

- Intervention for group B –Experimental group

Group B, the Experimental group, received Dynamic Neuromuscular Stabilization exercises along with conventional therapy (n = 29) as mentioned in Table 3.4.

1. Application of TENS: same as the control group

2. Isometric strengthening exercise: same as a control group
3. Dynamic neuromuscular stabilization exercise protocol- duration: 60-70 min.

Dosage: 10 min warm-up exercises, 40 min DNS exercises protocol, and 10 min cool-down phase, 2 weeks for each level of exercise. Total weeks-6

Table 3.4: Interventions for Experimental Group B

S. No.	Intervention	Duration
1.	Application of TENS (low tens)	Same as the control group
2.	Isometric strengthening exercise (cervical/lumbar/knee)	Same as the control group
3.	DNS exercises, 3-level exercise	40 min DNS exercise with 10 min warm-up and 10 min cool-down, 6 weeks (2 weeks each level exercise)

Follow-Up Assessments:

Follow-up assessments were conducted at the 3rd week(post-intervention) and 6th week (post-intervention). Outcome measures were re-assessed using the same tools as used at baseline, i.e, NPRS score, Tinetti balance and gait assessment score, and a score of Borg Rating of Perceived Exertion, respectively. Adherence to the intervention was done throughout the completion of the study, and any adverse events or withdrawals were documented as drop-outs.

Ethical Considerations:

The study followed ethical guidelines as declared by the Declaration of Helsinki. Ethical approval was obtained from

1. The Institutional Ethical Committee of Applied Medical Sciences, Lovely Professional University EC/NEW/INST/2022/3110, and

1. DAV Institutional Ethical Committee IEC Reg no,2021-2024.

Written informed consent was obtained from all participants before study participation, and the confidentiality of participant data was maintained throughout the study. Detail of the intervention procedure is shown by the CONSORT flowchart in Figure 3.6.

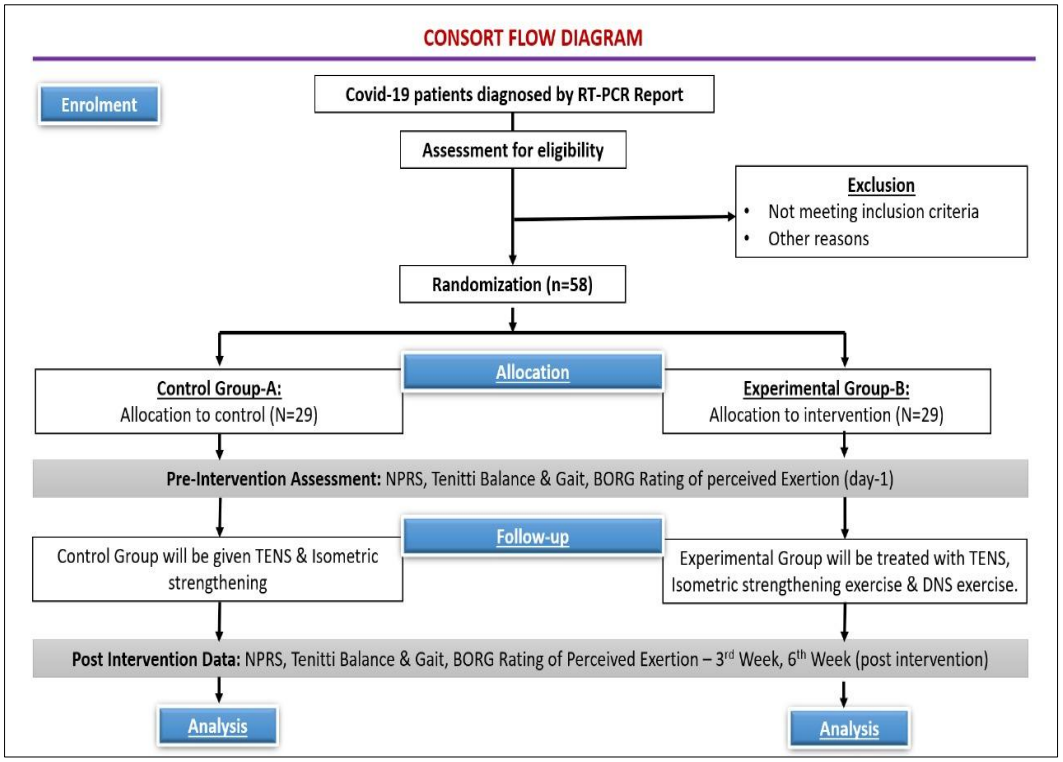


Figure 3.6: CONSORT Flow Diagram

3.3.10.1 DNS Exercise Protocol for Post-COVID-19 Syndrome

An evidence-based DNS exercise protocol has been designed for COVID-19-recovered individuals and registered with the Copyright Office, Government of India, with Registration No. L-128437 /2023, dated 7/7/2023.The present protocol is designed for the management of specifically post–COVID–19 syndrome (PCC/Long COVID), focusing on the musculoskeletal problems, balance and gait abnormalities, and complications of early fatigue. Following history taking and detailed physical assessment of onset, nature, type, and site of pain, subjects allocated to group B, the experimental group, were given 6 weeks of DNS exercise training protocol, which

began with Simple level exercises, which were given for 2 weeks. After 2 weeks, progress was made for strengthening exercises by Theraband, and at the next level, the Intermediate level. Later, after a further 2 weeks, advanced-level training was incorporated, which included exercises with a Swiss ball for improving balance and proprioception.

Warm-up:

- Position of the patient: the patient was seated on a static cycle for 5 minutes.
- Position of the therapist: The therapist stood beside the patient.

Simple Level exercise:

Deep Diaphragmatic Breathing Training: At every step, diaphragmatic breathing is emphasized in each prescribed exercise. The exercises were performed in 4 positions: supine, prone, sitting, and standing, as follows:

- ❖ Supine: patient will lie in the supine position and start with a deep diaphragmatic breathing exercise (Shavasana pose).
    - o Hip and knee flexed to 90 degrees with hip slightly abducted and externally rotated.
    - o Hip and knee flexed, the patient will raise his hands to touch the knees first and then the toes.
    - o The patient will turn from supine to side-lying, then prone.
- ❖ Prone: prone lying with forearm support.
    - o Prone lying with forearm support, one hip and knee flexion. Then repeat the same exercise with the opposite extremity.
    - o Taking weight over palms, with the forearm and pelvis lifted off the ground, the patient will reach to quadruped position.
- ❖ Quadruped Position: In this position, both hands and knees are on the ground. The patient will move one extremity forward by flexing the hip and knee like a baby crawling.
- ❖ Standing Position: By bearing weight on palms with the elbow extended, the patient will lift the pelvis up, extending knees to gradually assume a standing position.
- ❖ Squatting Position: arms placed in front, hip and knee flexed with feet apart on the ground, the patient will bend to adopt a squatting position.

Figure 3.7 shows a DNS simple level exercise performed on patients with post-COVID-19 syndrome in the present study.

Intermediate Level Exercise:

- Diaphragmatic breathing exercise.
- Supine: Supine lying with knees bent down. Place the middle of the band around the feet, holding the ends of the band with both hands, now gradually extending knees against resistance (red dress).
- Supine lying with one knee extended and the opposite knee bent loops the middle of the band around the sole of the flexed knee. Hold the ends of the band with each hand near the shoulder. Now extend the hip and knee against resistance. Hold for 5 sec, then repeat the same exercise with another extremity.
- Prone position: patient will lift one arm and leg, hold the position for 5 sec then repeat the same exercise with the opposite extremity.
    - Theraband knee flexion: fix one end of the loop near the floor and the other end around the ankle. The patient will flex and extend the knee against the band.
    - Theraband knee extension: wrap the middle of the band around the foot and hold the other ends over the shoulder. The patient will flex and extend the knee against resistance.
- Side-line-loop theraband over the waist, stretch the band by holding the ends of the band with both hands.
- Long Sitting Position: sit in a long sitting position with feet apart; wrap the middle of the band around the foot, keeping the knee flexed. Wrap the around each hand, holding firmly. Now, gradually extend the knee, keeping your hands close to your chest.
- Quadruped Position: wrap the middle of the band around the foot, holding the end with both hands. Now extend the hip and knee against resistance and maintain balance over the other lower extremities.
- Standing Position: Hold the ends of the theraband with both hands. Now, gradually stretch the band by opening arms against resistance.

- ❖ Squat Position: Stand in the middle of the band, placing both feet over the band. Hold the band at hip level, and the patient will do squats.

Fig.3.8 shows the intermediate-level DNS exercise protocol

Advanced level

- ❖ Diaphragmatic breathing exercise.
- ❖ Supine: 90-90 degree hip and knee flexion, hold the swiss ball between both knees.
  - ➢ SLR, place foot over a Swiss ball. Press the ball with foot against resistance (bridges).
  - ➢ Prone: Swiss ball-prone cobra pose.
  - ➢ Quadruped position: Place the ball below the hips in a quadruped position. The patient will lift their arm and leg.
  - ➢ Standing: forward bending, pushing and stabilizing the ball against the wall. Progression can be done by single limb standing and balancing against a ball (table tops).
- ❖ Squatting: wall squats. Stand with feet wide apart. Place the ball between the lower back and the wall, and the patient will squat down gradually till the knee flexes to 90 degrees, with the ball supporting the back.

Cool down: 05 minutes active stretching (30-sec hold,3 repetitions)

Figure 3.9 show Advance level exercise protocol.

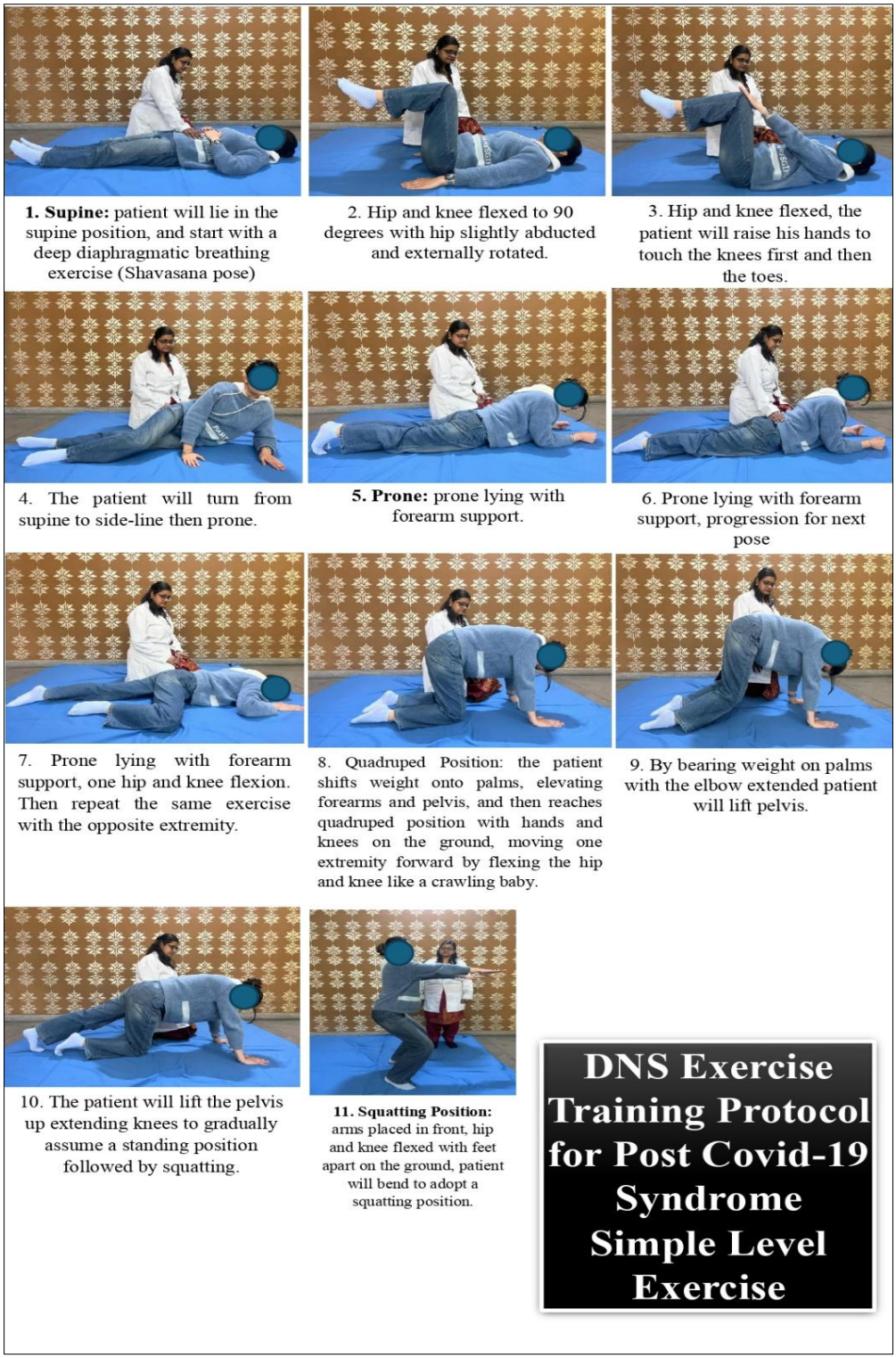


Figure 3.7: DNS Simple Level Exercise

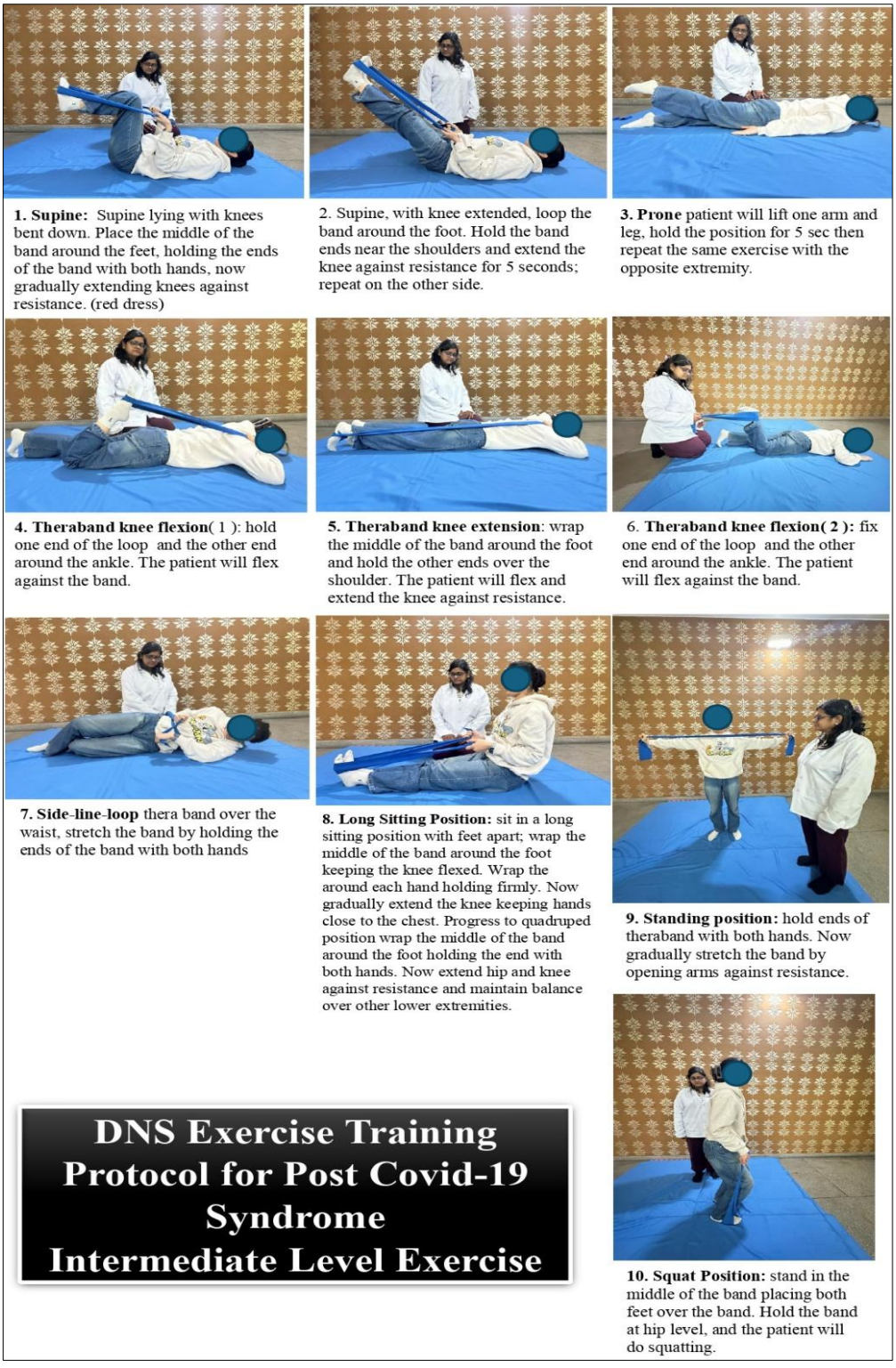


Figure 3.8: Intermediate Level Exercise

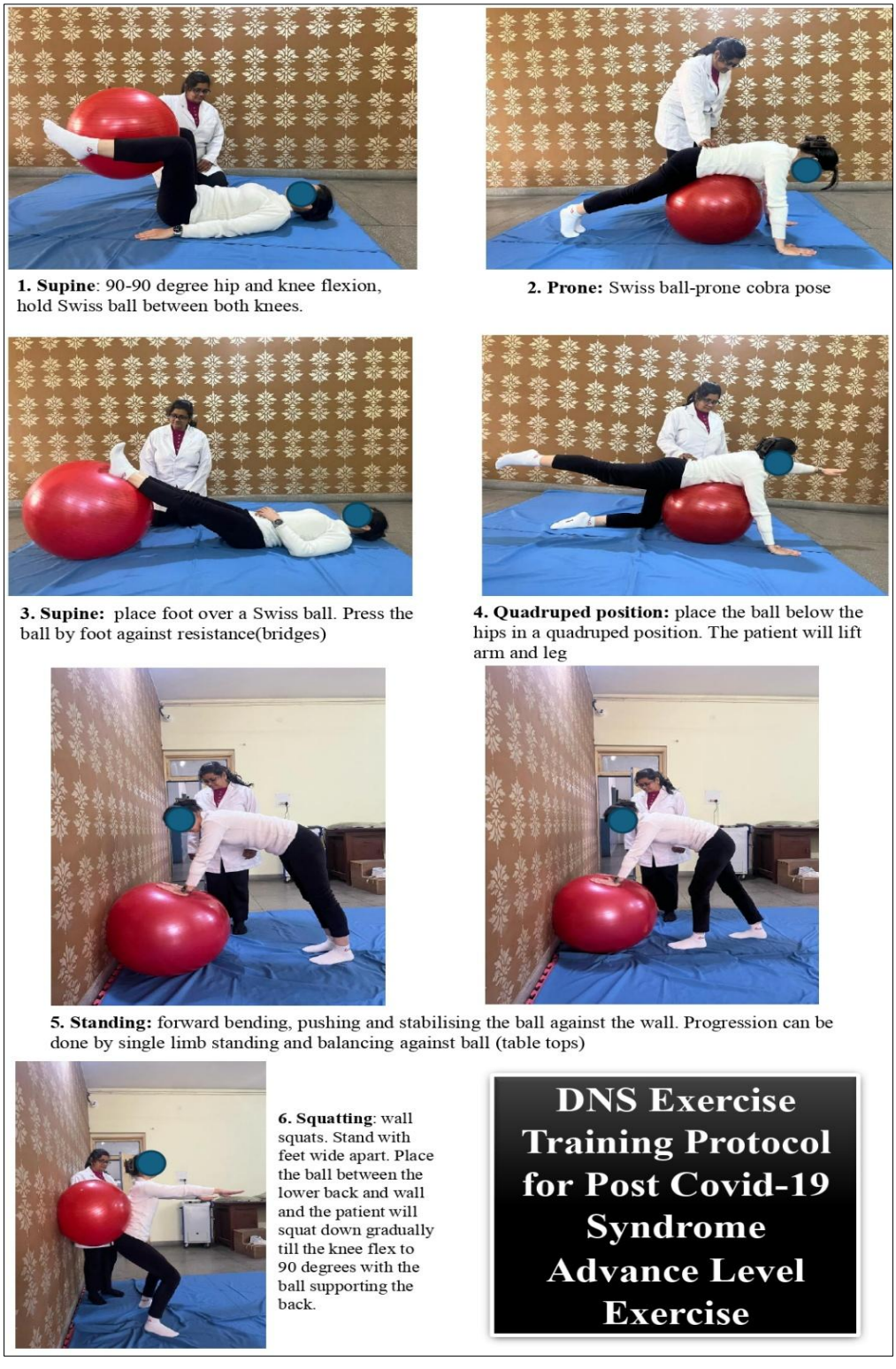


Figure 3.9: Advanced Level Exercise

3.3.11 Conventional Physiotherapy Management

The conventional management includes electrotherapeutic intervention and Isometric exercises. The procedure for the application of conventional treatment is as follows:

Patient Preparation: Informed consent was taken, and the treatment plan was discussed. An assessment of medical history, including COVID-19, pain intensity, balance, gait and physical activity intensity level, was taken. The patient was seated in a comfortable position for treatment.

3.3.11.1 Electrotherapeutic Intervention

Transcutaneous electrical nerve stimulation (TENS) is defined by the American Physical Therapy Association as the application of electrical stimulation to the skin for pain control. TENS is non-invasive, inexpensive, safe, and easy to use (215). By definition, it covers a complete range of transcutaneously applied currents used for nerve excitation.

TENS was applied to relieve pain over the affected painful areas, as shown in Figure 3.10 and Figure 3.11. the Spine (cervical, Lumbar) and the knee joint. Low TENS, Pulse frequency: 1-20 Hz, Pulse width: 150-300 microseconds, duration:20 min, once a week for a consecutive 6 weeks was applied to study the effects of TENS on PCC outcomes (16)(190)(191).

- Application over the lumbar area: The patient was made to lie in a prone position, and electrodes were placed bilaterally over the lumbar paraspinal muscles at the pain site, as in
- Application over the Cervical area: The patient was placed in a sitting or supine position with neck support electrodes placed along the cervical paraspinal muscles Figure 3.11.
- Application over the Knee joint: The patient was made to lie in a supine position with knees slightly flexed, and electrodes were placed one above and one below the patella for generalized knee pain or along the medial and lateral joint lines(191), as shown in Figure 3.10

The intensity of the current was increased until the subject felt a light tingling sensation without any observable muscle contraction.

3.3.11.2 Isometric Strengthening Exercises

Isometric exercises are exercises with potent efficacy for increasing muscle strength, and they can be applied to patients with motion limitation (213). Isometric exercises were given to stabilize joints, especially in the lumbar spine, cervical spine, and knees, to reduce pain and discomfort. It aimed to develop neuromuscular control and stability by activating deep stabilizing muscles.

- Isometric Strengthening exercises for the Lumbar spine: The patient was made to lie in a supine position with knees bent. A rolled towel was placed below the lumbar area. The patient was asked to press the rolled towel for 10 seconds and then relax. The duration was 20 minutes (10 repetitions,2 sets), 6-sec contractions,4-sec break (152), as shown in Figure 3.10.
- Isometric Strengthening exercises for the cervical spine: The patient was sitting, placed a hand against the forehead or side of the head, and was asked to press the head into the hand without movement.10 repetitions were done in different directions with 6-second contractions, 4-second breaks, and 2 sets as shown in Figure 3.11.
- Isometric Strengthening exercises for the knee joint: For the Quadriceps, the patient was made to lie supine with the knee extended. A towel roll was placed under the knee joint. The subject was asked to press the rolled towel by tightening the thigh muscle and pushing the knee down. Hold for 5 sec. with 20 repetitions. For the Hamstring muscle group, the patient was made to sit with knees bent at 90 degrees and was asked to push heel into the floor without moving as shown in Figure 3.10.



Fig. 3.12: Application of TENS(Knee joint)



Fig. 3.13: Knee Isometric exercise (for Quadriceps muscle group)



Fig. 3.14: : Lumbar Isometric Exercises



Fig. 3.15: : Application of TENS(Lumbar)

Figure 3.10:Application TENS and Isometric Exercise for Knee/Lumbar region



Fig. 3.16: Application of TENS(neck)



Fig. 3.17: Neck Isometric exercises

Figure 3.11:Application of TENS and Isometric Exercise for the Cervical region

3.4 DATA ANALYSIS

FOR PREVALENCE STUDY: Public and Physician Survey

The Statistical Program for Social Sciences (SPSS, v. 21) was used to analyze the collected data. The analysis and interpretation were conducted according to the study's established objectives. This analysis aims to condense the data into a format that is both interpretable and meaningful, facilitating comparisons and the identification of significance. The data analysis involved calculating scores based on frequency, percentage, mean, standard deviation, chi-square, and paired T-test. The demographic data obtained describe age (in years), marital status, gender, occupation, time of infection, mode of recovery, steroids taken, and dosage of vaccination in a prevalence study conducted through public surveys. The level of significance was at $p \leq 0.05$.

FOR INTERVENTION STUDY: RCT

Data were initially assessed for normality using the Kolmogorov-Smirnov test, and all outcome variables exhibited distributions suitable for parametric analysis. Mauchly's test of sphericity was applied to each repeated-measure variable; when the sphericity assumption was violated, Greenhouse–Geisser corrections were used. Descriptive statistics for all outcomes (NPRS pain scores, Tinetti balance and gait scores, and Borg rating of perceived exertion) were calculated as mean ± standard deviation across the first, third, and sixth weeks. To evaluate changes over time and differences between groups (DNS intervention vs. control), separate two-way repeated-measures ANOVAs (Group × Time) were performed for each outcome measure. Significant main effects and Group × Time interactions were followed by Bonferroni-adjusted post-hoc comparisons. Effect sizes were reported using partial eta squared (ηp^2), and the significance level was set at $p < .05$.

CHAPTER - IV

4 RESULT

CHAPTER OVERVIEW

This chapter describes the results of this current study, which explains the prevalence of post-COVID-19 musculoskeletal problems, balance and gait abnormalities in COVID-19 recovered individuals by survey response analysis, secondly, analysis of medical expert opinions over PCC conditions, and the analysis of the outcome measures like musculoskeletal pain, balance and gait abnormalities, and physical activity intensity level among the two intervention study groups.

The primary outcomes of the study included the prevalence of the condition within the target population, and secondary outcomes included the efficacy of the intervention part on pain intensity, balance, gait performance, and perceived exertion. Pain was assessed using the Numeric Pain Rating Scale (NPRS), while balance and gait were evaluated using the Tinetti Balance and Gait Assessment Scale. Perceived exertion was measured using the Borg Rating of Perceived Exertion (RPE). All primary outcomes were recorded at baseline (Day 1), mid-intervention (Week 3), and post-intervention (Week 6).

Analysis for Prevalence of Musculoskeletal problems, balance, and gait abnormalities post COVID-19 infection

4.1 Public Survey

Descriptive Statistics:

- This section outlines the demographic features of the sample being examined. The collected data details characteristics related to Age (measured in years), Marital Status, Gender, and Occupations, Time of having COVID-19 infection, Mode of Recovery, Steroids Taken, Dosage of Vaccination**, and** Demographic Analysis.

Figure Showing the Frequency Distribution of the Variable:

4.1.1 Analysis for Age Distribution:

Figure 4.1 shows the Percentage and Frequency distribution of age groups. The statistical result of the variable shows that the percentage of the population up to 20 years age group is 12% with a frequency of 46, the 21-30 years age group is 44% with a frequency of 167, the 31-40 years is 31% and frequency 118, and the population with the age group of 40-45 years is 13% with frequency 50.

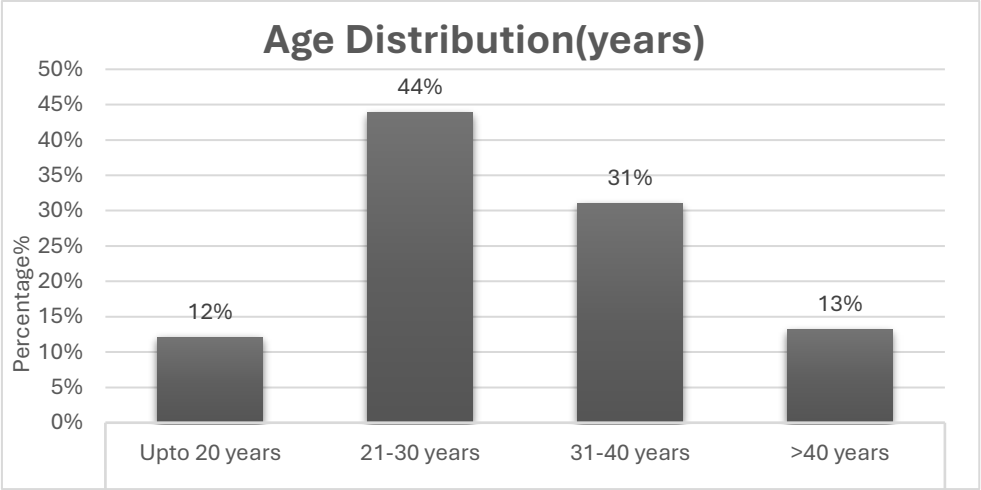


Figure 4.1: Analysis of age distribution

4.1.2 Analysis of Gender Variability

Figure 4.2 shows gender distribution. A total of 381 subjects were enrolled in the survey, of whom 179(47 %) were males, and 202(53 %) were females.

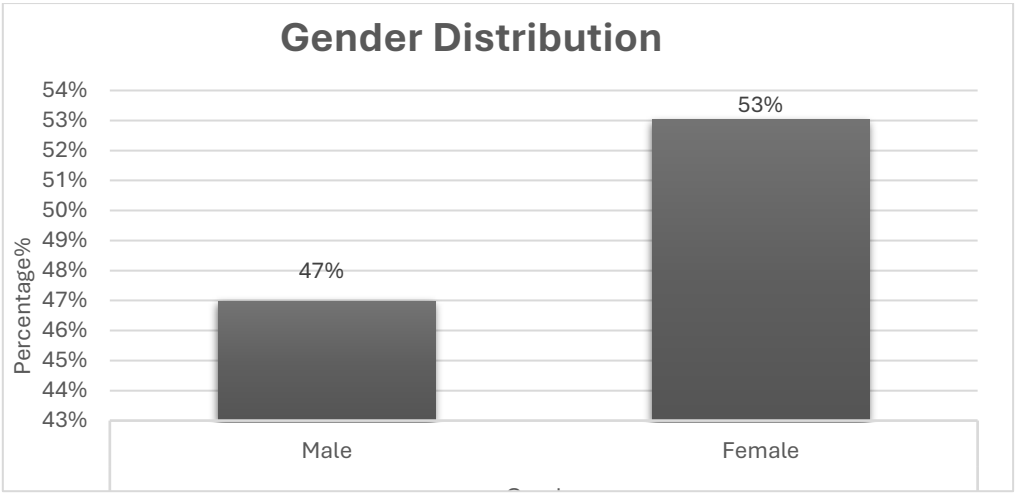


Figure 4.2: Analysis of gender variability

4.1.3 Analysis for dosage of vaccination after COVID-19 infection:

Figure 4.3 shows an analysis of vaccination dosage after COVID-19 infection, 40(10%) have taken only 1st dose of COVID-19 vaccine,259(68%) have taken both doses of the vaccine whereas 82(22%) have taken the booster dose.

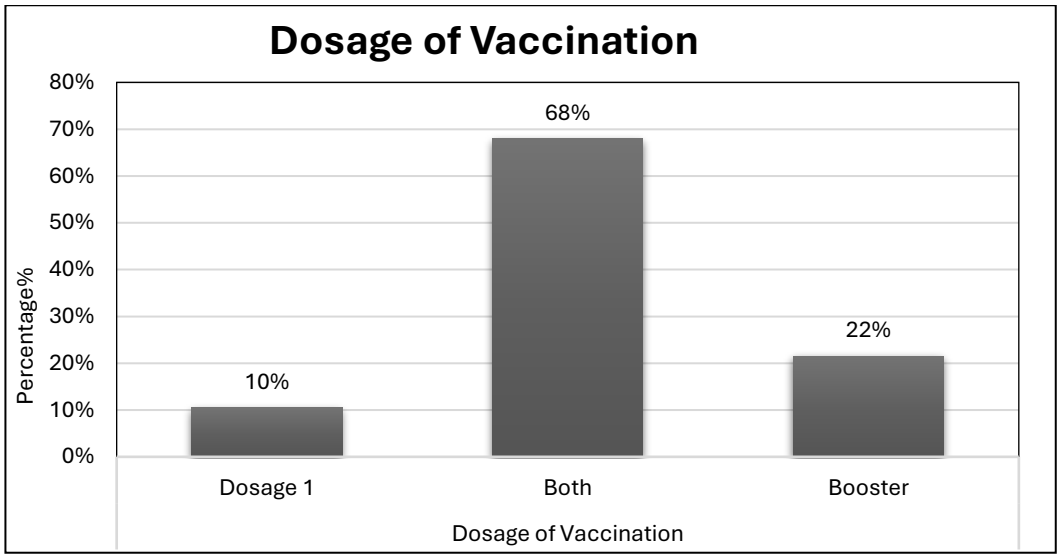


Figure 4.3: Analysis for the dosage of vaccine taken after COVID-19 infection

ANALYSIS OF GENERAL QUESTIONS FOR THE PREVALENCE OF MUSCULOSKELETAL PROBLEMS AFTER COVID-19 INFECTION

The analysis of general questionnaire responses (Q01–Q21), as shown in Table 4.2, indicates a high prevalence of musculoskeletal and functional impairments after COVID-19 infection. A large proportion of participants (88%) reported the onset of musculoskeletal pain after COVID-19 infection, whereas only 11% experienced pain before infection, indicating a strong association between COVID-19 and new-onset musculoskeletal symptoms.

Among the affected regions, **neck pain (69%),** upper back pain (62%), and **lower back pain** (51%) were the most commonly reported complaints, indicating a predominance of axial musculoskeletal involvement. Peripheral joint involvement was also noted, particularly in the knee (59%), ankle/foot (30%), and hips/thigh (27%). Upper limb symptoms, including pain in the arm (16%), forearm (13%), and wrist/hand (15%), were less prevalent.

Post-COVID functional limitations were also noted. More than half of the participants (52%) reported an increased time required to perform physical activities due to pain or other MSD's, while 61% experienced early fatigue while performing ADLs. Respiratory symptoms such as shortness of breath during activity (53%) were more pronounced than at rest (11%), reflecting reduced exercise tolerance. Additionally, muscle cramps (41%) and joint swelling (36%) were frequently reported, indicating persistent neuromuscular and inflammatory manifestations. Only 10% of participants had pre-existing comorbidities or substance use history (20%), suggesting that the observed musculoskeletal symptoms are more likely attributable to post-COVID sequelae rather than prior health conditions.

Overall, these findings highlight a high prevalence of post-COVID musculoskeletal dysfunction, particularly affecting the spine and lower limbs, along with significant fatigue and functional impairment. This underscores the need for targeted rehabilitation interventions to address these persistent symptoms.

ANALYSIS FOR PREVALENCE OF BALANCE ABNORMALITIES AFTER COVID-19 INFECTION

The analysis of balance-related responses (Q29–Q35) shown in Table 4.2 indicates a considerable prevalence of postural/balance-related instability. The incidence of dizziness increased progressively with activity complexity: 15% reported dizziness while sitting, 27% while standing, 37% while walking, and the highest prevalence was observed during running (60%). This trend suggests that balance impairments become more pronounced during dynamic postures and physically demanding tasks.

In addition to dizziness, a substantial proportion of participants reported balance disturbances during transitional movements. Nearly half of the participants experienced difficulty changing position from sitting to standing (48%), and 43% reported imbalance during standing-to-sitting transitions. Similarly, 44% of individuals experienced balance disturbances when initiating walking from a standing position. These findings indicate impairments in postural control, coordination, and dynamic stability.

Our study results demonstrate that balance abnormalities are prevalent in post-COVID individuals, particularly during movement and positional transitions. The increased frequency of dizziness and instability during higher-level activities highlights deficits in vestibular function, neuromuscular coordination, and postural control mechanisms. These impairments may contribute to reduced functional independence and increased risk of falls, emphasizing the need for targeted balance rehabilitation in this population.

ANALYSIS FOR PREVALENCE OF GAIT ABNORMALITIES AFTER COVID-19 INFECTION

The analysis of gait-related questionnaire responses (Q22–Q28) shown in Table 4.2 indicates a notable prevalence of locomotor disturbances among individuals following COVID-19 infection. A majority of participants (59%) reported a change in walking rhythm, suggesting altered coordination and timing of gait cycles. Additionally, 57% of participants experienced a decrease in walking speed, reflecting reduced functional mobility and possible deconditioning. Alterations in gait stability were also evident. Approximately 41% of individuals reported walking with a wide-based gait, which is

commonly associated with compensatory mechanisms to enhance balance and stability. Similarly, 35% of participants reported irregular foot placement, showing that an altered gait pattern may indicate impaired motor control and reduced gait precision. Functional difficulties during gait transitions and step patterns were moderately prevalent. Around 38% of participants experienced difficulty initiating walking from a standing position, as well as difficulty taking short steps, suggesting impairments in dynamic balance and motor planning. Furthermore, 46% reported difficulty in taking long steps, which may reflect reduced stride length, muscle weakness, or fear of instability.

The prevalence findings of our study demonstrate that post-COVID individuals frequently exhibit gait abnormalities, including altered rhythm, reduced speed, impaired balance, and compromised step mechanics. These deficits highlight the impact of COVID-19 on neuromuscular coordination and functional mobility.

Figure 4.4 illustrates the mean percentage distribution of musculoskeletal disorder (MSD) severity among post-COVID participants based on survey scores. The findings indicate that the majority of participants fell within the moderate severity category (12–22), accounting for 58.8% of the total sample. This suggests that musculoskeletal symptoms of moderate intensity were the most commonly experienced complaints following COVID-19 infection. Furthermore, 33.6% of participants were categorized under the mild severity group (0–11), indicating that approximately one-third of the participants experienced relatively less severe musculoskeletal symptoms. In contrast, only 7.6% of participants were classified within the severe category (23–35), demonstrating that severe MSD symptoms were less prevalent in the studied population. These results suggest that post-COVID musculoskeletal disorders were predominantly moderate in severity, highlighting the substantial burden of persistent musculoskeletal symptoms among recovered individuals.

4.1.4 Frequency & Percentage Distribution Level of Public Survey.

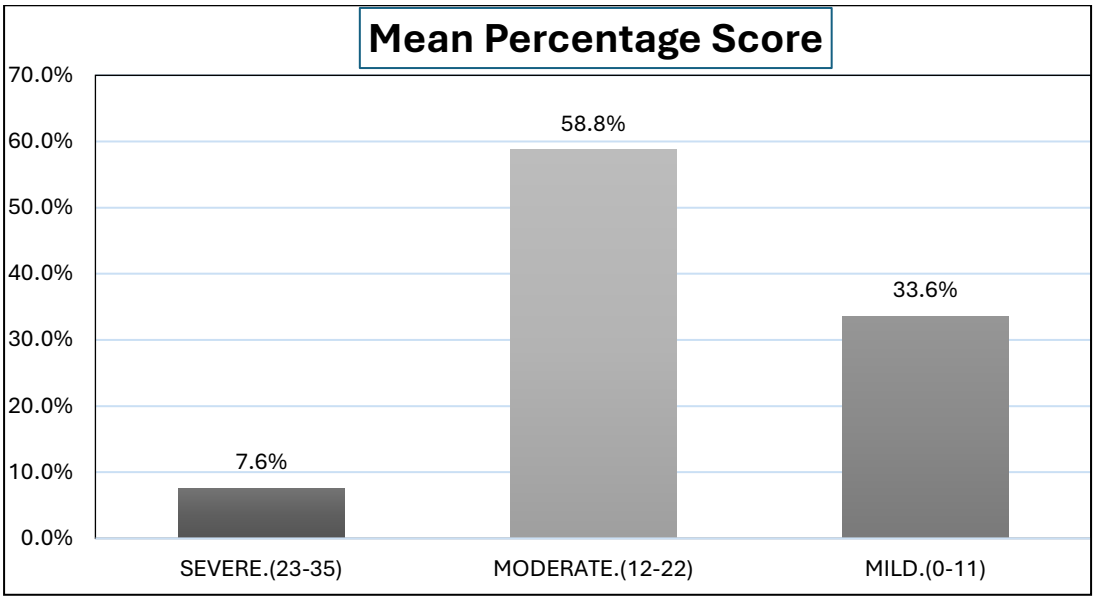


Figure 4.4:Diagram Showing Mean Percentage Scores

4.1.5 Chi-Square analysis of scores and demographic data

This section deals with the findings related to the association between scores and selected demographic variables in Table 4.1. The chi-square test was used to determine the association between the score levels and selected demographic variables. The Chi-square analysis demonstrated significant associations between several demographic variables and the muscle and bone problems faced score among post-COVID-19 subjects. Age showed a statistically significant association ($\chi^2 = 61.455$, $p < 0.001$), indicating that individuals aged 21–40 years experienced more moderate to severe musculoskeletal problems than other age groups. Marital status was also significantly associated with musculoskeletal problem severity ($\chi^2 = 44.736$, $p < 0.001$), with married participants reporting comparatively greater moderate and severe symptoms. Occupational status also showed a significant association ($\chi^2 = 54.500$, $p < 0.001$), with professionals and business owners reporting higher levels of musculoskeletal complaints. Similarly, mode of recovery was significantly associated with symptom severity ($\chi^2 = 37.900$, $p < 0.001$), where hospitalized participants demonstrated a greater

proportion of severe musculoskeletal problems compared to those under home quarantine. Steroid intake also showed a statistically significant association (χ^2 = 19.935, $p < 0.001$), indicating increased severity of symptoms among participants who had taken steroids during COVID-19 treatment.

However, gender (χ^2 = 3.428, p = 0.180), duration since COVID-19 infection (χ^2 = 5.221, p = 0.073), and vaccination dosage status (χ^2 = 5.005, p = 0.287) did not show statistically significant associations with muscle and bone problem scores, suggesting that these variables did not substantially influence musculoskeletal symptom severity in the study population.

Table 4.1: Chi-Square Analysis

DEMOGRAPHIC DATA		**LEVELS (N=381)**			**ASSOCIATION WITH MUSCLE AND BONE PROBLEMS FACED SCORE**				
Variables	**Opts**	**SEVERE**	**MODERATE**	**MILD**	**Chi Test**	**P Value**	**df**	**Table Value**	**Result**
Age	Upto 20 years	2	12	32	61.455	<0.001	6	12.592	Significant
	21-30 years	5	94	68					
	31-40 years	18	81	19					
	>40 years	4	37	9					
Marital Status	Married	22	139	41	44.736	<0.001	6	12.592	Significant
	Single	7	78	87					
	Divorced	0	6	0					
	Widowed	0	1	0					
Gender	Male	17	109	53	3.428	0.180	2	5.991	

DEMOGRAPHIC DATA		LEVELS (N=381)			ASSOCIATION WITH MUSCLE AND BONE PROBLEMS FACED SCORE				
	Female	12	115	75					Not Significant
Occupations:	Student	5	56	78	54.500	<0.001	6	12.592	Significant
	Professional	9	57	21					
	Own Business	11	65	22					
	Housewife	4	46	7					
Time of having COVID-19 infection	6 to 12 months	3	10	2	5.221	0.073	2	5.991	Not Significant
	More than 1 Year	26	214	126					
Variables	**Opts**	**SEVERE**	**MODERATE**	**MILD**	**Chi Test**	**P Value**	**df**	**Table Value**	**Result**
Mode of Recovery	Home quarantine	14	160	120	37.900	<0.001	2	5.991	Significant
	Hospitalized	15	64	8					
Steroids Taken	Yes	23	129	50	19.935	<0.001	2	5.991	Significant
	No	6	95	78					
Dosage of Vaccination	Dosage 1	4	24	12	5.005	0.287	4	9.488	Not Significant
	Both	18	145	96					
	Booster	7	55	20					

4.1.6 Analysis of Public Survey Scores

Table 4.2: Analysis of Public Survey Scores

Area>	Category	QUESTIONS	YES Freq (%)	NO Freq (%)
PART - B –MUSCULOSKELETAL, GAIT AND BALANCE PROBLEMS FACED	**General Questions**	**Q01**-Having addiction of Smoking/Alcohol before COVID-19 infection	75(20%)	306(80%)
		Q02-Medical Condition: presence of any underline disease before COVID-19 infection	40(10%)	341(90%)
		Q03-Medical Condition: Without Any medical condition before COVID-19	284(5%)	97(25%)
		Q04-Onset of Musculoskeletal pain: Before getting COVID-19 Infection	43(11%)	338(89%)
		Q05-Onset of Musculoskeletal pain: After getting COVID-19 infection	337(88%)	44(12%)
		Q06-Location of musculoskeletal pain: Neck Pain	264(69%)	117(31%)
		Q07-Location of musculoskeletal pain: Upper Back	235(62%)	145(38%)
		Q08-Location of musculoskeletal pain: Lower Back	195(51%)	186(49%)
		Q09- Location of musculoskeletal pain: Arm	60(16%)	320(84%)

Area>	Category	QUESTIONS	YES Freq (%)	NO Freq (%)
		Q10- Location of musculoskeletal pain: Fore Arm	50(13%)	331(87%)
		Q11-Location of musculoskeletal pain: Wrist/Hand	57(15%)	324(85%)
		Q12-Location of musculoskeletal pain: Hips/Thigh	104(27%)	227(73%)
		Q13-Location of musculoskeletal pain: Knee	224(59%)	157(41%)
		Q14-Location of musculoskeletal pain: Ankle/Foot	115(30%)	266(70%)
		Q15-Swelling in joints post COVID-19 infection	136(36%)	245(64%)
		Q16-Amount of time taken for any physical activity has increased after Codiv-19 infection	198(52%)	183(48%)
		Q17-Do you get tired easily, while doing daily routine work?	231(61%)	150(39%)
		Q18-Do you have pain in Chest/between ribs?	84(22%)	297(78%)
		Q19-Shortness of breath after COVID-19 infection, while Taking Rest	42(11%)	339(89%)
		Q20-Shortness of breath after COVID-19 infection, while Doing Activity	203(53%)	117(46%)
		Q21-Increased muscle cramps after COVID-19 Infection	158(41%)	223(59%)

Area>	Category	QUESTIONS	YES Freq (%)	NO Freq (%)
	GAIT related Questions	**Q22**-Change in walking rhythm after COVID-19 infection	223(59%)	158(41%)
		Q23-Irregular foot placement after COVID-19 infection	135(35%)	246(65%)
		Q24-Walk with wide based after COVID-19 infection	155(41%)	226(59%)
		Q25-Decrease in Walking Speed after COVID-19 infection	219(57%)	162(43%)
		Q26-Do you face any difficulty while shifting position from standing to walking?	143(38%)	238(62%)
		Q27-Do you feel any difficulty in taking short steps while walking?	143(38%)	238(62%)
		Q28-Do you feel any difficulty in taking long steps while walking?	175(46%)	206(54%)
	Balance related Questions	**Q29**-Experience dizziness during: Sitting	57(15%)	324(85%)
		Q30-Experience dizziness during: Standing	101(27%)	280(73%)
		Q31-Experience dizziness during: Walking	142(37%)	239(63%)
		Q32-Experience dizziness during: Running	228(60%)	153(40%)
		Q33-Do you feel any disturbance in balance while changing position from sitting to standing?	181(48%)	200(52%)

Area>	Category	QUESTIONS	YES Freq (%)	NO Freq (%)
		Q34-Do you feel any disturbance in balance while changing position from standing to sitting?	164(43%)	217(57%)
		Q35-Do you feel any disturbance in balance while changing position from standing to walking?	167(44%)	214(56%)

4.1.7 Correlation Analysis of the Survey questionnaire

Table 4.3 represents the Karl-Pearson Correlation Coefficient to analyse the significance of correlation between general questions, balance-related questions, and gait-related questions. The result showed a significant relationship between the questions

Table 4.3:Pearson Correlation Analysis

Pair 1	vs	Pair 1	r value	P value	Result
General Questions	vs	GAIT-related Questions	.513**	<0.001	Significant
General Questions	vs	Balance related Questions	.554**	<0.001	Significant
GAIT related Questions	vs	Balance related Questions	.631**	<0.001	Significant

1. General Questions vs gait Related Questions: Correlation Coefficient (r value): 0.513**, P value: <0.001, shows a significant result.

Interpretation: There is a positive correlation between general questions and gait-related questions. This indicates that responses to general questions are correlated with gait. The correlation is statistically significant, suggesting a reliable association.

2. General Questions vs Balance Related Questions: Correlation Coefficient (r value): 0.554**. P value: <0.001, showing a significant result.

Interpretation: There is a positive correlation between general questions and balance-related questions, but slightly stronger than the correlation with gait-related questions. The correlation is statistically significant, suggesting a reliable association.

3. Gait Related Questions vs Balance Related Questions: **Correlation Coefficient (r value)**: 0.631**, **P value**: <0.001, showing a significant result.

Interpretation: This pair shows the strongest correlation among the three tested. A moderate to strong positive correlation exists between gait-related and balance-related questions. The correlation is statistically significant, suggesting a reliable association.

4.2 PHYSICIAN SURVEY

To support the results of the public survey, the opinions of medical specialist concern with COVID patients were obtained by conducting a Physician Survey on 50 doctors specialized in numerous branches like orthopedics, neurology, respiratory, etc. The result of the survey is discussed below.

4.2.1 Demographic Analysis:

Table 4.4, shows the percentage and Frequency distribution of Organization, Specialization and Designation. The statistical result of the variable shows that the frequency percentage of different organization 6(12%), 28(56%),2(4%),6(12%), 3(6%),5(10%), frequency Percentage of different specialization 1(2%), 5(10%),21(42%), 15(30%), 4(8%), 4(8%), Frequency percentage of different Designation variable 2(4%), !7(34%), 19(38%), 8(16%), 3(6%) respectively.

Table 4.4:Demographic Analysis of the Subjects

Variables	Opts	Percentage (%)	Frequency(f)
Name of Organization	a) Index Medical College	12%	6
	b) SAIMS	56%	28
	c) PIMS	4%	2
	d) People's Medical College	12%	6
	e) Apollo Hospital	6%	3
	f) Sacred Heart Hospital	10%	5
Specialization	a) MCH	2%	1
	b) Neurologist	10%	5
	c) Orthopaedics	42%	21
	d) Chest Physician	30%	15
	e) Neurophysician	8%	4
	f) Rheumatologist	8%	4
Designation	a) Professor	4%	2
	b) Assistant professor	34%	17
	c) Associate professor	38%	19
	d) Senior Residents	16%	8
	e) Consultants	6%	3
	f) Junior Residents	2%	1

4.2.2 Percentage distribution of Musculoskeletal disorder

Table 4.5 shows the Percentage and Frequency distribution of Mild, Moderate, and Severe Musculoskeletal disorders. The frequency of mild musculoskeletal disorders in the survey is 0(0%), for Moderate musculoskeletal disorders is 22(44%), and for Severe musculoskeletal disorders is 28(56%). The result shows the prevalence of severe musculoskeletal disorders after COVID-19 according to physicians' opinions.

Table 4.5:Musculoskeletal Disorder Score

CRITERIA MEASURE OF MUSCULOSKELETAL DISORDER SCORE Maximum =85 Minimum=17		
LEVEL OF SCORES N= 50	**PERCENTAGE**	**FREQUENCY**
SEVERE MUSCULOSKELETAL DISORDER. (62-85)	56.0%	28
MODERATE MUSCULOSKELETAL DISORDER. (40-61)	44.0%	22
MILD MUSCULOSKELETAL DISORDER. (17-39)	0.0%	0

4.2.3 Descriptive statistics of Musculoskeletal disorders.

Table 4.6 represents Descriptive statistics analysis of musculoskeletal disorder score showing a Mean ± Standard deviation of 62 ± 6.58, a mean% of 73.55 with a range of 32, respectively. The Mean Percentage Score of musculoskeletal disorders is 73.55 %.

Table 4.6: Descriptive statistics of Musculoskeletal disorders.

DESCRIPTIVE STATISTICS	Mean	Median	S.D.	Maximum	Minimum N=	Range 50	Mean %
MUSCULOSKELETAL DISORDER SCORE	62.52	62.5	6.58	82	50	32	73.55
Maximum=85 Minimum=17							

4.2.4 Item-Wise Analysis of Musculoskeletal Disorder Scores.

Table 4.7 shows the percentage distribution of responses to each question across the categories of Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree. The survey findings indicated that a majority of medical specialists perceived a noticeable increase in musculoskeletal complaints among patients following COVID-19 infection. Most respondents either strongly agreed or agreed that there was an increased prevalence of myalgia, viral arthralgia, arthritis pain, joint pain, early fatigue, reduced physical activity with mild exertion, and new-onset hip/knee, neck, and back pain in the post-COVID population. The highest levels of agreement were observed for increased prevalence of myalgia (100%) and early fatigue (98%), suggesting that these symptoms are among the most commonly encountered post-COVID musculoskeletal manifestations. A considerable proportion of specialists also reported increased evidence of joint swelling, decreased calcium and vitamin D levels, and early degenerative radiological changes in adults aged 18–45 years. In contrast, opinions regarding increased gait abnormalities and balance impairment were more divided, with a larger percentage of respondents remaining agree or undecided, and for fracture incidence, disagreeing. This variation in opinion may indicate that such complications are less frequently encountered, underreported, or influenced by factors such as age, pre-existing comorbidities, and severity of infection. Nevertheless, the presence of a notable proportion of specialists acknowledging balance and gait-related issues suggests that neurological and functional impairments may still exist in this population.

The expert opinions obtained through this survey in our study provide additional support and greater clinical validity for the findings of the public survey, reinforcing the association between post-COVID syndrome and increased musculoskeletal, balance, and gait-related impairments.

Table 4.7: Item-Wise Analysis of Musculoskeletal disorder Scores.

sam	Question	Strongly Agree	Agree	Undecided	Disagree	Strongly disagree
MUSCULOSKELETAL DISORDER	Is there an increase in number of patients with Musculoskeletal problems in OPD after COVID-19.	14.0%	72.0%	4.0%	10.0%	0.0%
	Is there an increase in incidence of fracture after COVID-19.	2.0%	12.0%	60.0%	26.0%	0.0%
	Is there an increase in evidence of strain/sprain after COVID-19?	4.0%	38.0%	42.0%	16.0%	0.0%
	Is there an increase in the prevalence of viral arthralgia after COVID-19.	16.0%	68.0%	16.0%	0.0%	0.0%
	Is there an increase in the prevalence of myalgia after COVID-19.	26.0%	74.0%	0.0%	0.0%	0.0%
	Is there an increase in the prevalence of arthritis pain after COVID-19.	16.0%	54.0%	26.0%	4.0%	0.0%
	Is there an increase in the incidence of symptoms of early fatigue after COVID-19.	32.0%	66.0%	0.0%	2.0%	0.0%
	Is there any decrease in the physical activity on mild exertion after COVID-19.	12.0%	72.0%	12.0%	4.0%	0.0%
	Is there an increase in incidence of new onset of backache after COVID-19.	10.0%	46.0%	34.0%	8.0%	2.0%
	Is there an increase in incidence of new onset of neck pain after COVID-19.	8.0%	48.0%	30.0%	12.0%	2.0%
	Is there an increase in Incidence of new onset of hip/knee pain after COVID-19.	24.0%	52.0%	18.0%	6.0%	0.0%

sam	Question	Strongly Agree	Agree	Undecided	Disagree	Strongly disagree
	Is there an increase in history of frequent fall and GAIT abnormalities after COVID-19.	6.0%	34.0%	30.0%	28.0%	2.0%
	Is there an increase in history of Balance impairment after COVID-19.	10.0%	34.0%	30.0%	22.0%	4.0%
	Is there an increase in evidence of frequency of joint pain after COVID-19.	16.0%	74.0%	8.0%	2.0%	0.0%
	Is there an increase in frequency of swelling in and around joints after COVID-19.	6.0%	58.0%	18.0%	18.0%	0.0%
	Is there an increase in prevalence of decrease in Ca+ and Vitamin D levels after COVID-19.	12.0%	44.0%	34.0%	10.0%	0.0%
	Is there an increase in incidence of radiological evidence of degeneration changes present among targeted age group population (18 to 45 years).	14.0%	50.0%	28.0%	4.0%	4.0%

4.3 Intervention Study (RCT)– RESULTS

This section contains a description of intergroup and intragroup analysis of the application of DNS exercises, along with conventional treatment by a randomized controlled trial. The section consists of descriptive statistical analysis for all outcome measures. Statistical assumptions relevant to the repeated-measures ANOVA approach used in the study, including tests of normality and sphericity. After confirming that the assumptions were satisfied or appropriately corrected, the findings from the repeated-measures ANOVA for each outcome variable are reported.

4.3.1 Normality testing

Normality of the outcome variables was examined by the Kolmogorov-Smirnov test, as shown in Table 4.8. The results showed that the distribution of residuals did not substantially deviate from normality. Although some minor deviations were observed, they fell within acceptable limits for repeated-measures ANOVA, which is considered moderate violation. For the NPRS scores, both tests were statistically significant ($p < .05$), indicating deviations from ideal normality. Similarly, the Tinetti balance scores demonstrated acceptable normality at Day 1(Shapiro–Wilk, $p = .133$), while Week 3 showed borderline deviation and Week 6 indicated non-normality. For the Tinetti Gait scores, all time points showed statistically significant results on both tests ($p < .05$), indicating deviations from a perfectly normal distribution. Similarly, the BORG Rating scores demonstrated significant results at all three time points, suggesting non-normality. Despite these statistical findings, the sample size (n =58) is sufficiently large, and repeated-measures ANOVA is well-established as robust to moderate violations of normality. Therefore, the distributions were considered appropriate for conducting RM ANOVA, supporting the continued use of parametric analysis without compromising the validity of the results. Thus, the assumption of normality was considered to be fulfille

Table 4.8: Normality distribution by the Kolmogorov-Smirnov test

		Kolmogorov-Smirnova	**Tests of Normality**		**Shapiro-Wilk**	
	Statistic	df	Sig.	Statistic	df	Sig.
NPRS Score - Day 1	0.277	58	0	0.799	58	0
NPRS Score - Week 3	0.241	58	0	0.876	58	0
NPRS Score - Week 6	0.243	58	0	0.872	58	0
TINETTI Assessment (Balance) Score - Day 1	0.138	58	0.008	0.968	58	0.133
TINETTI Assessment (Balance) Score - Week 3	0.12	58	0.036	0.957	58	0.039
TINETTI Assessment (Balance) Score - Week 6	0.18	58	0	0.906	58	0
TINETTI Assessment (GAIT) Score - Day 1	0.159	58	0.001	0.949	58	0.016
TINETTI Assessment (GAIT) Score - Week 3	0.165	58	0	0.93	58	0.002

		Kolmogorov-Smirnova	Tests of Normality		Shapiro-Wilk	
TINETTI Assessment (GAIT) Score - Week 6	0.247	58	0	0.795	58	0
BORG Rating - Day 1	0.181	58	0	0.894	58	0
BORG Rating - Week 3	0.22	58	0	0.902	58	0
BORG Rating - Week 6	0.184	58	0	0.915	58	0.001
a. Lilliefors Significance Correction						

4.3.2 Sphericity Assessment:

Before conducting the repeated-measures ANOVA, the assumption of sphericity was examined using Mauchly's Test of Sphericity for all outcome measures. Sphericity evaluates whether the variances of the differences between repeated measurements are equal, which is required for accurate F-statistics in RM ANOVA. When Mauchly's test is significant ($p < .05$), the assumption is considered violated; however, this does not invalidate the analysis. Instead, appropriate correction factors—such as the Greenhouse–Geisser or Huynh–Feldt estimates—are applied to adjust the degrees of freedom and ensure valid statistical conclusions. Therefore, sphericity testing was performed to verify this assumption and to determine whether corrected ANOVA values were necessary for the final interpretation of treatment effects.

- Sphericity for the Numeric Pain Rating Scale:

Mauchly's test of sphericity, indicated in Table 4.9 shows that the assumption of sphericity was violated for the NPRS scores, $\chi^2(2) = 28.04$, $p < .001$, $W = .61$. This suggests that the variances of the difference scores between repeated measurements were not equal, indicating non-sphericity in the within-subject covariance structure. Because sphericity is required for an uncorrected repeated-measures ANOVA, degrees of freedom were adjusted using the Greenhouse–Geisser ($\varepsilon = .72$) and Huynh–Feldt ($\varepsilon = .73$) corrections. The corrected analyses yielded the same conclusion as the uncorrected model, showing a significant effect of treatment on NPRS scores, Greenhouse–Geisser: $F(1.43, 81.79) = 188.71$, $p < .001$, $\eta^2 = .77$; Huynh–Feldt: F(1.46,

83.32) = 188.71, $p < .001$, $\eta^2 = .77$. These results indicate a robust and large treatment effect despite the violation of the sphericity assumption.

Table 4.9: Mauchly's Test of Sphericity and RM ANOVA for NPRS Scores

Mauchly's Test of Sphericity:

Statistic	**Value**
Mauchly's W	0.61
χ^2 (df = 2)	28.04
p-value	< .001
Greenhouse–Geisser ε	0.72
Huynh–Feldt ε	0.73

Repeated-Measures ANOVA (Within-Subject Factor: Treatment):

Sphericity Correction	**Type III Sum of Squares**	**df**	Mean Square	**F**	**p**	**η^2**
Treatment						
None (Uncorrected)	130.56	2.00	65.28	188.71	<.001	0.77
Greenhouse–Geisser	130.56	1.43	90.99	188.71	< .001	0.77
Huynh–Feldt	130.56	1.46	89.32	188.71	< .001	0.77
Residual						
None (Uncorrected)	39.44	114.00	0.35	—	—	—
Greenhouse–Geisser	39.44	81.79	0.48	—	—	—
Huynh–Feldt	39.44	83.32	0.47	—	—	—

- Sphericity for the Tinetti balance assessment score:

Mauchly's Test of Sphericity was significant ($p < .001$), indicating that the assumption of sphericity was violated for the Tinetti Balance scores across the three time points, as shown in Table 4.10. As a result, the Greenhouse–Geisser and Huynh–Feldt

corrections were applied to adjust the degrees of freedom and provide a more conservative estimate of the F-value. However, even after applying these corrections, the repeated-measures ANOVA remained highly significant ($p < .001$), demonstrating a strong treatment effect over time. This indicates that the violation of sphericity did not compromise the validity of the analysis, and the improvement in Tinetti Balance scores is statistically robust and reliable.

Table 4.10: Mauchly's Test of Sphericity and RM ANOVA for Tinetti Balance Scores

Mauchly's Test of Sphericity for Tinetti balance variable:

Statistic	Value
Mauchly's W	0.48
χ^2 (df = 2)	41.45
p-value	< .001
Greenhouse–Geisser ε	0.66
Huynh–Feldt ε	0.67

Repeated-Measures ANOVA (Within-Subject Factor: Treatment):

Sphericity Correction	Type III Sum of Squares	df	Mean Square	F	p	η^2
Treatment						
None (Uncorrected)	282.56	2.00	141.28	91.11	<.001	0.62
Greenhouse–Geisser	282.56	1.31	215.17	91.11	<.001	0.62
Huynh–Feldt	282.56	1.33	212.16	91.11	<.001	0.62
Residual						
None (Uncorrected)	176.77	114.00	1.55	—	—	—
Greenhouse–Geisser	176.77	74.85	2.36	—	—	—
Huynh–Feldt	176.77	75.91	2.33	—	—	

- Sphericity for the Tinetti gait assessment score:

Mauchly's Test of Sphericity, as shown in Table 4.11, indicated a significant result ($W = 0.83$, $\chi^2(2) = 10.30$, $p = .006$), showing that the assumption of sphericity was violated for the Tinetti gait scores across the three assessment points. Consequently,

Greenhouse–Geisser and Huynh–Feldt corrections were applied to adjust the degrees of freedom and ensure more accurate F-statistics. The repeated-measures ANOVA revealed a statistically significant effect of treatment on gait performance across time ($F = 116.10$, $p < .001$, $\eta^2 = 0.67$), which remained highly significant after applying both sphericity corrections. These results indicate a consistent and substantial improvement in gait function over time, demonstrating that the intervention had a meaningful impact and that this effect is reliable even after accounting for the violation of sphericity.

Table 4.11: Mauchly's Test of Sphericity and RM ANOVA for Tinetti Gait Scores

Mauchly's Test of Sphericity for Tinetti Gait variable:

Statistic	Value
Mauchly's W	0.83
χ^2 (df = 2)	10.30
p-value	.006
Greenhouse–Geisser ε	0.86
Huynh–Feldt ε	0.88

Repeated-Measures ANOVA (Within-Subject Factor: Treatment):

Sphericity Correction	Type III Sum of Squares	df	Mean Square	F	p	η^2
Treatment						
None (Uncorrected)	130.56	2.00	65.28	116.10	<.001	0.67
Greenhouse–Geisser	130.56	1.71	76.24	116.10	<.001	0.67
Huynh–Feldt	130.56	1.76	74.16	116.10	<.001	0.67
Residual						
None (Uncorrected)	64.1	114	0.56	—	—	—
Greenhouse–Geisser	64.1	97.61	0.66	—	—	—
Huynh–Feldt	64.1	100.34	0.64	—	—	—

- Sphericity for the Borg rating of perceived exertion score:

Mauchly's test of sphericity indicated a significant violation of the sphericity assumption for the BORG Rating across repeated measurements ($W = 0.70$, $\chi^2(2) =$

19.76, $p < .001$) as shown in Table 4.12. Because the assumption was not met, the Greenhouse–Geisser and Huynh–Feldt corrections were applied to adjust the degrees of freedom. Despite this violation, the repeated-measures ANOVA demonstrated a strong and statistically significant effect of time on perceived exertion, with consistent results across all correction methods ($F = 180.37$, $p < .001$, $\eta^2 = 0.76$). This indicates that participants showed a substantial improvement in BORG scores over the intervention period, and the corrected analyses confirm that these findings are consistent and reliable.

Table 4.12: Mauchly's Test of Sphericity and RM ANOVA for Borg Rating Scores

Mauchly's Test of Sphericity for Borg's rating of perceived exertion

Statistic	Value
Mauchly's W	0.70
χ^2 (df = 2)	19.76
p-value	< .001
Greenhouse–Geisser ε	0.77
Huynh–Feldt ε	0.79

Repeated-Measures ANOVA (Within-Subject Factor: Treatment):

Sphericity Correction Treatment	Type III Sum of Squares	df	Mean Square	F	p	η^2
None	202.63	2	101.32	180.37	<.001	0.76
Greenhouse–Geisser	202.63	1.54	131.44	180.37	<.001	0.76
Huynh–Feldt	202.63	1.58	128.56	180.37	<.001	0.76
Residual						
None	64.03	114	0.56	—	—	—
Greenhouse–Geisser	64.03	87.87	0.73	—	—	—
Huynh–Feldt	64.03	89.84	0.71	—	—	—

Note: W = Mauchly's W statistic; χ^2 = Chi-square value; ε = epsilon (Greenhouse–Geisser / Huynh–Feldt correction factor); η^2 = partial eta squared effect "—" indicates that F and p values are not applicable for residual rows.

4.3.3 Demographic Analysis

As shown in Table 4.13 in the given data, Group A consists of 58.6% males (17 individuals) and 41.4% females (12 individuals), while Group B has 62.1% males (18 individuals) and 37.9% females (11 individuals). Both groups have a higher percentage of males than females, with Group B showing a slightly higher male representation compared to Group A. The mean age (mean ±SD) between Group A is 31.38±8.313 and Group B mean ±SD is 32.55±9.152, respectively.

Table 4.13: Demographic Analysis of RCT

Group	Number	Age (Mean± S.D)	Male	Female
Group A	n=29	31.38(±8.313)	17(58.6%)	12(41.4%)
Group B	n=29	32.55(±9.152)	18(62.1%)	11(37.9%)

4.3.4 Descriptive and Inferential Statistics

4.3.4.1 Analysis of NPRS Score

- Descriptive statistics:

Table 4.14 presents the mean scores (±SD) and standard errors (SE) of the outcome measure for both the Experimental Group (B) and Control Group (A) across the three assessment points (Day 1, Week 3, and Week 6). At baseline (Day 1), the Experimental Group (6.07 ± 0.59, SE = 0.11) and the Control Group (5.86 ± 0.74, SE = 0.14) demonstrated comparable values. By Week 3, the Experimental Group B showed a marked reduction (4.66 ± 0.72, SE = 0.13), whereas the Control Group demonstrated only a modest decline (5.03 ± 1.02, SE = 0.19). At Week 6, the Experimental Group continued to show improvement, with mean scores decreasing further to 3.41 ± 0.78

(SE = 0.14), while the Control Group's mean decreased to 4.28 ± 1.39 (SE = 0.26). Overall, these descriptive results indicate that participants in the Experimental Group exhibited a greater and more consistent reduction across the intervention period compared to the Control Group, suggesting a beneficial effect of the intervention

Table 4.14: Descriptive statistics analysis of NPRS Score

Experimental Group B						**Control Group A**					
Day 1		Week 3		Week 6		Day 1		Week 3		Week 6	
MEAN±SD	SE	MEAN±SD	SE	MEAN± SD	SE	MEAN ± SD	SE	MEAN± SD	SE	MEAN± SD	SE
6.07±0.59	0.11	4.66±0.72	0.13	3.41±0.78	0.14	5.86±0.74	0.14	5.03±1.02	0.19	4.28±1.39	0.26

- Inferential statistics:

Table 4.15 shows the repeated measures ANOVA examined changes in NPRS scores across three time points (Day 1, Week 3, and Week 6) between the Experimental and Control groups. The analysis revealed a significant main effect of time ($F(2,112) = 234.90$, $p < .001$), indicating that NPRS scores decreased significantly across the three measurement points regardless of group. The effect size was large ($\eta p^2 = 0.81$), showing that a substantial proportion of the variance in NPRS scores was explained by time. The main effect of group was not statistically significant ($F(1,56) = 2.67$, $p = .108$), suggesting that, when averaged across all time points, there was no overall difference in NPRS scores between the Experimental and Control groups. However, the interaction between time and group was statistically significant ($F(2,112) = 14.95$, $p < .001$), with a moderate effect size ($\eta p^2 = 0.21$). This indicates that the pattern of change in NPRS scores over time differed between groups. Specifically, the experimental

group demonstrated a greater and more consistent reduction in NPRS scores across the six weeks compared to the Control Group.

Table 4.15: Analysis of Variance for NPRS Score

	Sum of squares	df	Mean Squares	F	p	η^2	η^2_p
NPRS Score - Day 1, NPRS Score - Week 3, NPRS Score - Week 6	130.56	2	65.28	234.9	<.001	0.46	0.81
Group of Patient	5.17	1	5.17	2.67	0.108	0.02	0.05
RM Factor x Group of Patient	8.31	2	4.16	14.95	<.001	0.03	0.21
Residuals (Between Subjects)	108.53	56	1.94				
Residuals (Within Subjects)	31.13	112	0.28				

Figure 4.5 shows Mean scores (±SE) of the outcome measure for the Experimental Group (B) and Control Group (A) across Day 1, Week 3, and Week 6. The graph shows a progressive reduction in mean values in the Experimental Group, with the steepest decline observed between Day 1 and Week 6. In contrast, the Control Group demonstrated only a modest reduction over the same period. Error bars represent the standard error of the mean

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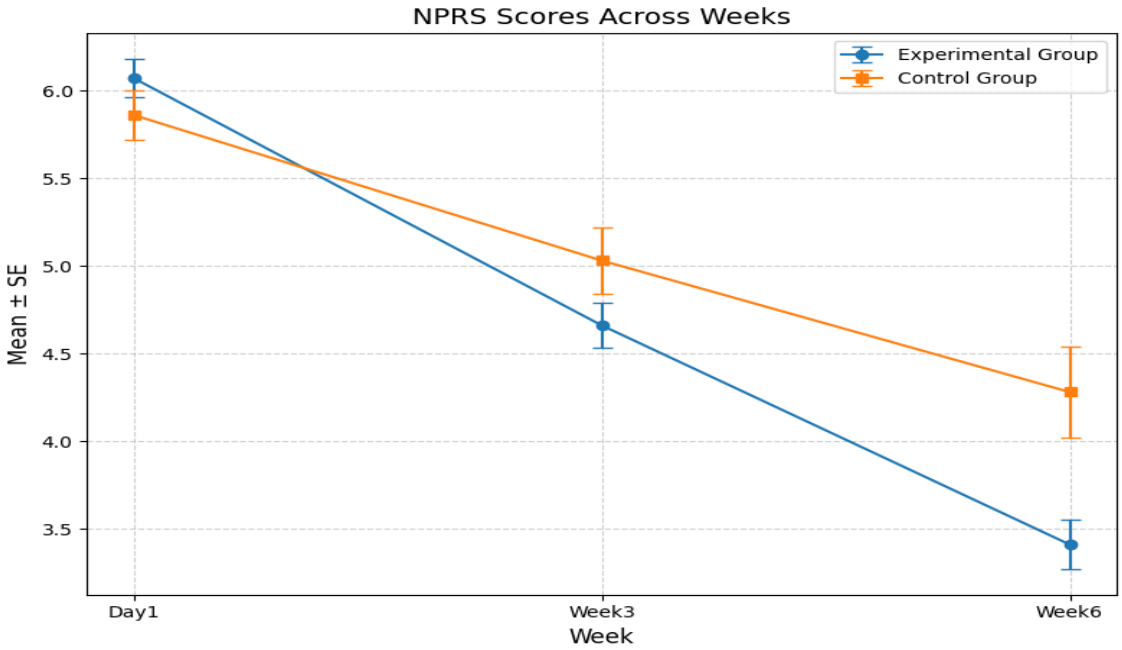


Figure 4.5:Analysis of NPRS Score

At baseline (Day 1), both groups reported comparable NPRS scores, with the Experimental Group averaging approximately 6.1 and the Control Group averaging 5.8. By Week 3, the Experimental Group had shown a marked reduction in pain scores, reaching around 4.8, whereas the Control Group had demonstrated only a modest decline to 5.0. At Week 6, the Experimental Group exhibited a further sharp decrease in scores, reaching 3.4, while the Control Group showed a more gradual reduction to 4.3.

Interpretation: Both groups experienced reduced pain over time, indicating the effectiveness of their respective interventions. The Experimental Group (B) showed a steeper and more consistent decline in NPRS scores compared to the Control Group. This suggests the experimental intervention significantly alleviated pain more than the standard/control approach. Repeated-measures ANOVA revealed a significant main effect of Time on NPRS scores, $F(2,112) = 234.9$, $p < .001$, with a very large effect size ($\eta p^2 = 0.81$). This indicates substantial improvement across Day 1, Week 3, and Week 6. The main effect of Group was not statistically significant, $F(1,56) = 2.67$, $p = 0.108$, with a small-to-moderate effect size ($\eta p^2 = 0.05$). However, the Time × Group interaction was significant, $F(2,112) = 14.95$, $p < .001$, with a large effect size ($\eta p^2 =$

0.21), demonstrating that the magnitude of improvement over time differed between groups, with the DNS group showing greater reduction in pain.

Post-hoc Analysis by Group: Bonferroni-adjusted pairwise comparisons were conducted separately for the Experimental and Control groups to clarify the significant time × group interaction as shown in Table 4.16. In the Experimental Group (B), NPRS scores showed a significant decrease from Day 1 to Week 3 (mean difference ≈ 1.4, $p < .001$), from Day 1 to Week 6 (mean difference ≈ 2.7, $p < .001$), and from Week 3 to Week 6 (mean difference ≈ 1.3, $p < .001$). This demonstrates a steady and substantial decline across all measurement points. In the Control Group (A), scores also decreased over time, but the reductions were smaller. A modest change was observed from Day 1 to Week 3 (mean difference ≈ 0.8, $p < .05$) and from Day 1 to Week 6 (mean difference ≈ 1.6, $p < .001$). The reduction from Week 3 to Week 6 (mean difference ≈ 0.7, $p < .05$) was less pronounced compared to the Experimental Group. Overall, these post-hoc analyses confirm that both groups improved over time, but the Experimental Group experienced a greater and more consistent decrease in NPRS scores, supporting the intervention's effectiveness.

Table 4.16: NPRS Bonferroni Post-hoc-Tests RM Factor

		Mean diff.	Std. Error	t	p	95% CI lower limit	95% CI upper limit
NPRS Score - Day 1	NPRS Score - Week 3	1.12	0.092	12.144	<.001	0.94	1.31
NPRS Score - Day 1	NPRS Score - Week 6	2.12	0.139	15.223	<.001	1.84	2.4
NPRS Score - Week 3	NPRS Score - Week 6	1	0.089	11.276	<.001	0.82	1.18

Table 4.17:NPRS Bonferroni Post-hoc-Tests Group of Patients

	Mean diff.	Std. Error	t	p
B - Experimental Group-A - Control Group	-0.34	0.21	-1.63	0.108

Minimal Clinically Important Difference (MCID) for NPRS:

The minimal clinically important difference (MCID) was assessed using two commonly accepted criteria for the NPRS: a 2-point reduction and a 30% improvement from baseline.

The experimental group demonstrated a mean reduction of 2.66 points between Day 1 and Week 6, exceeding both MCID thresholds (≥2 points; ≥30%). Conversely, the control group showed a mean reduction of 1.58 points, which did not meet either MCID criterion. These results indicate that the DNS intervention produced a clinically meaningful reduction in pain intensity in COVID-19 recovered patients with low back pain, cervical or knee pain, compared to the control group intervention, shown in Table 4.18.

Table 4.18: MCID Achievement for NPRS Scores

Group	Baseline Mean ± SD	Week 6 Mean ± SD	Mean Change	30% Improvement Threshold	2-Point MCID Achieved?	30% MCID Achieved?
Experimental (DNS)	6.07 ± 0.59	3.41 ± 0.78	2.66	1.82	Yes	Yes
Control	5.86 ± 0.74	4.28 ± 1.39	1.58	1.76	No	No

4.3.4.2 Analysis of the Tinetti Balance score Assessment

- Descriptive statistics**:**

Table 4.19 shows the analysis of the Tinetti balance score at different timelines. At baseline (Day 1), the Experimental Group had a mean Tinetti Balance Score of 9.97 ± 2.06 (SE = 0.38), while the Control Group scored slightly higher at 11.00 ± 3.22 (SE = 0.60). By Week 3, the Experimental Group improved to 12.31 ± 2.07 (SE = 0.38), whereas the Control Group showed only a modest increase to 11.90 ± 2.97 (SE = 0.55).

At Week 6, the Experimental Group demonstrated a further increase to 14.14 ± 1.68 (SE = 0.31), compared with the Control Group's score of 13.07 ± 2.31 (SE = 0.43). The descriptive statistics of showed progressive improvement in both the experimental and control groups over the study period. In the experimental group, the mean score increased from 9.97±2.06 on Day 1 to 12.31±2.07 at Week 3 and further to 14.14±1.68 at Week 6, indicating a consistent enhancement in balance performance. Similarly, the control group demonstrated improvement from 11±3.22 at Week 1 to 11.9±2.97 at Week 3 and 13.07±2.31 at Week 6. Overall, both groups improved in balance scores over the six weeks; however, the Experimental Group showed a greater and more consistent improvement compared to the Control Group. The progressive increase in mean scores in the Experimental Group indicates that the intervention contributed positively to balance recovery, while the Control Group exhibited a smaller, less significant improvement suggesting a more effective impact of the intervention on balance outcomes.

Table 4.19: Descriptive statistics Analysis of Tinetti Balance Score

Experimental Group						Control Group					
Day 1		Week 3		Week 6		Week 1		Week 3		Week 6	
MEAN±SD	SE	MEAN±SD	SE	MEAN±SD	SE	MEAN±SD	SE	MEAN±SD	SE	MEAN±	SE
9.97±2.06	0.38	12.31±2.07	0.38	14.14±1.68	0.31	11±3.22	0.60	11.9±2.97	0.55	13.07±2.31	0.43

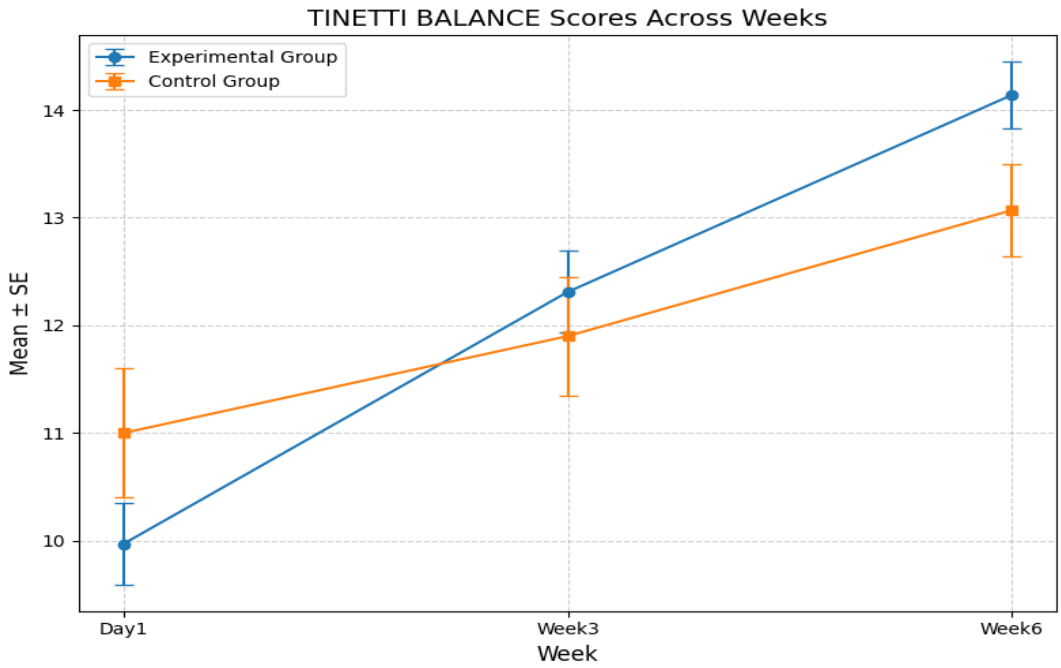


Figure 4.6:Analysis of Tinetti Balance Score

Figure 4.6 shows Mean Tinetti Balance Scores (±SE) for the Experimental and Control Groups across Day 1, Week 3, and Week 6. Both groups demonstrated progressive improvements in balance scores over time; however, the Experimental Group showed a greater and more consistent increase (from 10.0 at baseline to 14.1 at Week 6) compared with the Control Group (from 11.0 to 13.1 over the same period). Error bars represent the standard error of the mean (SE), reflecting the precision of the sample mean as an estimate of the population mean. Smaller error bars indicate higher precision, while larger error bars reflect more variability in the data.

- Inferential Statistics: RM-ANOVA

A two-way repeated measures ANOVA was conducted with time (Day 1, Week 3, and Week 6) as the within-subjects factor and group (Experimental vs. Control) as the between-subjects factor.As shown in Table 4.20, the analysis revealed a significant main effect of time, $F(2,112) = 110.52$, $p < .001$, $\eta^2 = .21$, $\eta p^2 = .66$, indicating that Tinetti Balance Scores improved significantly across the three measurement points regardless of group. This represents a large effect size, suggesting that time accounted for a substantial proportion of variance in balance scores. The main effect of group was not significant, $F(1,56) = 0.06$, $p = .803$, $\eta^2 = .00$, $\eta p^2 = .00$, showing that there was no

overall difference in balance scores between the Experimental and Control groups when averaged across time. The time × group interaction was statistically significant, $F(2,112) = 13.14$, $p < .001$, $\eta^2 = .03$, $\eta p^2 = .19$, with a moderate effect size. This indicates that the pattern of improvement differed between groups, with the Experimental Group showing a steeper and more consistent increase in balance scores across time compared with the Control Group.

Table 4.20: Analysis of Variance for Tinetti Balance Score

	Sum of squares	df	Mean Squares	F	p	η^2	η^2_p
TINETTI Assessment (Balance) Score - Day 1, TINETTI Assessment (Balance) Score - Week 3, TINETTI Assessment (Balance) Score - Week 6	282.56	2	141.28	110.52	<.001	0.21	0.66
Group of Patient	0.97	1	0.97	0.06	0.803	0	0
RM Factor x Group of Patient	33.6	2	16.8	13.14	<.001	0.03	0.19
Residuals (Between Subjects)	862	56	15.39				
Residuals (Within Subjects)	143.17	112	1.28				

Post-hoc Analysis by Group (Tinetti Balance Score)

As shown in Table 4.21 and Table 4.22, Bonferroni-adjusted pairwise comparisons for the time factor confirmed that balance scores improved progressively across all measurement points. Scores increased significantly from Day 1 to Week 3 (mean difference = –1.62, $p < .001$, 95% CI [–2.03, –1.21]), from Day 1 to Week 6 (mean difference = –3.12, $p < .001$, 95% CI [–3.73, –2.52]), and from Week 3 to Week 6 (mean difference = –1.50, $p < .001$, 95% CI [–1.84, –1.16]). These findings

confirm a consistent upward trend in balance performance, with the greatest improvement between Day 1 and Week 6. When examined separately by group, the Experimental Group demonstrated significant improvements across all time intervals (Day 1–Week 3 ≈ +2.34, $p < .001$; Day 1–Week 6 ≈ +4.17, $p < .001$; Week 3–Week 6

≈ +1.83, $p < .001$). The Control Group also improved, but the changes were smaller (Day 1–Week 3 ≈ +0.90, $p < .05$; Day 1–Week 6 ≈ +2.07, $p < .001$; Week 3–Week 6 ≈ +1.17, $p < .05$). This indicates that while both groups benefitted over time, the Experimental Group experienced a larger and more consistent gain. Finally, Bonferroni post-hoc comparison of group differences averaged across all time points revealed no significant difference between the Experimental and Control groups (mean difference = 0.15, $p = .803$). However, the significant interaction effect confirms that the Experimental Group's improvement trajectory was steeper, highlighting the added benefit of the intervention on balance recovery over time. This supports the potential effectiveness of the experimental intervention, DNS, enhancing balance over time.

Table 4.21: Bonferroni Post-hoc-Tests RM Factor for Tinetti Balance score

		Mean diff.	Std. Error	t	p	95% CI lower limit	95% CI upper limit
TINETTI Assessment (Balance) Score - Day 1	TINETTI Assessment (Balance) Score - Week 3	-1.62	0.203	-8.001	<.001	-2.03	-1.21
TINETTI Assessment (Balance) Score - Day 1	TINETTI Assessment (Balance) Score - Week 6	-3.12	0.302	-10.323	<.001	-3.73	-2.52
TINETTI Assessment (Balance) Score - Week 3	TINETTI Assessment (Balance) Score - Week 6	-1.5	0.167	-8.968	<.001	-1.84	-1.16

Table 4.22: Bonferroni Post-hoc-Tests Group of Patients for Tinetti Balance Score

	Mean diff.	Std. Error	t	p
B - Experimental Group-A - Control Group	0.15	0.59	0.25	0.803

Minimal Detectable Change (MDC) for Tinetti Balance Score

The Tinetti Assessment Tool (POMA) does not have an officially established MCID in the literature. Most studies report Minimal Detectable Change (MDC) instead of MCID. It indicates whether the observed changes in balance are greater than potential measurement error. Minimal Detectable Change (MDC) for the Tinetti Balance subscale was set at 3 points, based on previously published reliability studies.The experimental group demonstrated an improvement of 4.17 points from Day 1 to Week 6, exceeding the MDC threshold. In contrast, the control group showed a smaller improvement of 2.07 points, which did not reach the MDC. These findings indicate that only the DNS intervention produced a change in balance performance that exceeded measurement error and can therefore be considered a clinical, meaningful improvement, shown in Table 4.23.

Table 4.23: MDC Achievement in the Tinetti Balance Score

Group	Day 1 Mean ± SD	Week 6 Mean ± SD	Mean Change	MDC (3 points) Achieved?
Experimental	9.97 ± 2.06	14.14 ± 1.68	4.17	Yes
Control	11.00 ± 3.22	13.07 ± 2.31	2.07	No

4.3.4.3 Analysis of the Tinetti gait Score Assessment

- Descriptive Statistics:

As shown in Table 4.24, at baseline (Week 1), the Experimental Group recorded a mean gait score of 8.83 ± 1.00 (SE = 0.19), while the Control Group scored slightly higher at 9.00 ± 2.12 (SE = 0.39). By Week 3, the Experimental Group showed a notable improvement to 10.10 ± 0.86 (SE = 0.16), whereas the Control Group increased only modestly to 9.72 ± 0.61 (SE = 0.30). At Week 6, the Experimental Group demonstrated a further rise in gait performance, reaching 11.38 ± 0.73 (SE = 0.14), compared with the Control Group's score of 10.69 ± 1.39 (SE = 0.26). In the experimental group, the mean score increased from 8.83±1.00 at Week 1 to 10.10±0.86 at Week 3 and 11.38±0.73 at Week 6, reflecting consistent enhancement in gait stability and mobility. The control group also showed improvement from 9.00±2.12 at Week 1 to 10.69±1.39

at Week 6; however, the magnitude of improvement was comparatively lower and showed greater variability. Theoretically, these findings suggest that the intervention may have contributed to improved functional gait performance over time. Overall, both groups exhibited progressive improvements in gait scores across the six weeks; however, the Experimental Group revealed a greater and more consistent upward trajectory. The pattern of results suggests that the intervention applied in the Experimental Group was found to be more effective in improving gait functions compared with the Control Group, which showed improvement but to a lesser degree.

Table 4.24: Descriptive statistics of the Tinetti gait Score Assessment

Experimental						Control					
Week 1		Week 3		Week 6		Week 1		Week 3		Week 6	
Mean ±SD	SE	Mean ±SD	SE	Mean ±SD	SE	Mean ±SD	SE	Mean ±SD	SE	Mean ±SD	SE
8.83 ± 1.00	0.19	10.10 ± 0.86	0.16	11.38 ± 0.73	0.14	9.00 ± 2.12	0.39	9.72 ± 0.61	0.30	10.69 ± 1.39	0.26

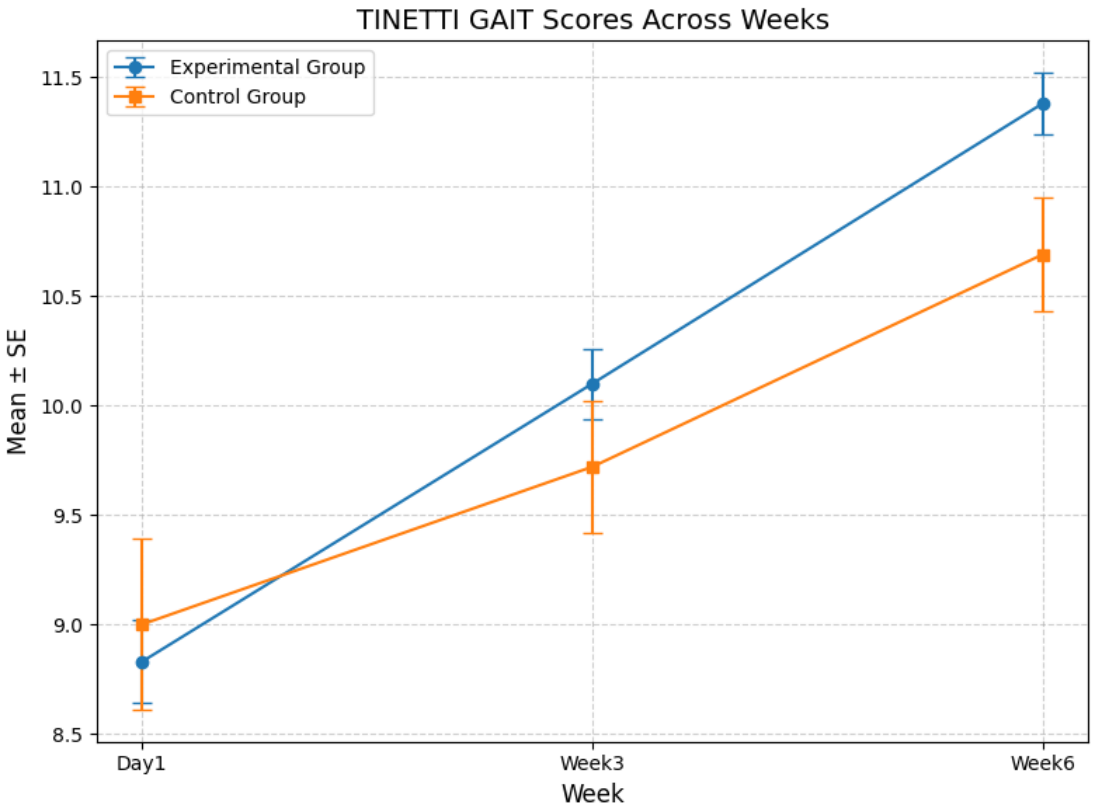


Figure 4.7:Analysis of Tinetti gait Score

Figure 4.7 illustrates the changes in Tinetti gait Scores across three assessment points (Day 1, Week 3, and Week 6) for the Experimental and Control groups. Both groups demonstrated progressive improvement over time, indicating overall gains in gait performance. At baseline (Day 1), both groups had comparable scores (Experimental ≈ 8.8, Control ≈ 9.0), suggesting no substantial initial difference. By Week 3, both groups showed improvement, but the Experimental Group exhibited a greater increase (≈ 10.1) compared to the Control Group (≈ 9.7). By Week 6, this trend became more significant, with the Experimental Group reaching a mean gait score of ≈ 11.4, while the Control Group achieved ≈ 10.7. The steeper trajectory of improvement in the Experimental Group compared to the Control Group suggests that the intervention facilitated more rapid gains in gait function. Although both groups improved significantly over time (main effect of time), the widening gap between the two groups by Week 6 indicates a potential time × group interaction, meaning the Experimental Group benefited more substantially from the intervention.

- Inferential Statistics: RM-ANOVA

Table 4.25 shows repeated measures ANOVA was conducted to evaluate changes in Tinetti gait Scores across three time points (Day 1, Week 3, Week 6) and to compare differences between the experimental and control groups as shown in table 4.26. The analysis revealed a significant main effect of time, $F(2,112) = 124.82$, $p < .001$, $\eta^2 = 0.29$, $\eta^2p = 0.69$. This indicates that gait scores significantly improved over time in the overall sample, regardless of group. The large partial eta squared ($\eta^2p = 0.69$) suggests that approximately 69% of the variance in gait scores can be attributed to the repeated measures factor (time). The main effect of group was not statistically significant, $F(1,56) = 0.85$, $p = 0.362$, $\eta^2p = 0.01$. This suggests that, when averaged across all time points, the experimental and control groups did not significantly differ in overall gait scores. Thus, there was a significant interaction between time and group, $F(2,112) = 5.29$, $p = 0.006$, $\eta^2p = 0.09$. This indicates that the pattern of gait score improvement differed between groups, with the experimental group demonstrating greater improvements over time compared to the control group. The effect size ($\eta^2p = 0.09$) reflects a moderate interaction effect.

Table 4.25: RM-ANOVA for Tinetti GAIT Score

	Sum of squares	df	Mean Squares	F	p	η^2	η^2_p
TINETTI Assessment (GAIT) Score - Day 1, TINETTI Assessment (GAIT) Score - Week 3, TINETTI Assessment (GAIT) Score - Week 6	130.56	2	65.28	124.82	<.001	0.29	0.69
Group of Patient	3.89	1	3.89	0.85	0.362	0.01	0.01
RM Factor x Group of Patient	5.53	2	2.76	5.29	0.006	0.01	0.09
Residuals (Between Subjects)	257.08	56	4.59				
Residuals (Within Subjects)	58.57	112	0.52				

Group-wise Post-hoc Analysis (Tinetti Gait Score)

In the Experimental Group (B), Bonferroni-adjusted comparisons showed a significant increase in gait scores from Day 1 to Week 3 (mean diff. ≈ –1.0, $p < .001$), with further improvement by Week 6 (Day 1 vs. Week 6 mean diff. ≈ –2.12, $p < .001$; Week 3 vs. Week 6 mean diff. ≈ –1.12, $p < .001$). This indicates a consistent and progressive enhancement in gait function throughout the intervention period. Similarly, the Control Group (A) also demonstrated significant improvements across all time points, though the magnitude of change was comparatively smaller than in the experimental group. Gait scores improved steadily from baseline to Week 3 and further to Week 6, confirming that both groups benefitted from the passage of time and standard care, but the experimental group showed a steeper rate of improvement, indicating DNS to be effective in improving gait score (shown in Table 4.26 and Table 4.27).

Table 4.26: Bonferroni Post-hoc-Tests RM Factor for Tinetti gait score

		Mean diff.	Std. Error	t	p	95% CI lower limit	95% CI upper limit
Tinetti Assessment (gait) Score - Day 1	Tinetti Assessment (gait)Score - Week 3	-1	0.128	-7.824	<.001	-1.26	-0.74
Tinetti Assessment (gait) Score - Day 1	Tinetti Assessment (gait) Score - Week 6	-2.12	0.165	-12.842	<.001	-2.45	-1.79
Tinetti Assessment (gait)Score - Week 3	Tinetti Assessment (gait) Score - Week 6	-1.12	0.121	-9.286	<.001	-1.36	-0.88

Table 4.27: Bonferroni Post-hoc-Tests Group of Patients

	Mean diff.	Std. Error	t	p
B - Experimental Group- A - Control Group	0.3	0.32	0.92	0.362

Minimal Detectable Change (MDC) for Tinetti Gait Score:

Minimal Detectable Change (MDC) for the Tinetti Gait subscale was set at 3 points, based on previously published reliability data. The experimental group showed an improvement of 2.55 points from Week 1 to Week 6, which did not reach the MDC threshold. The control group improved by 1.69 points, also falling below the set criterion. These findings suggest that although both groups demonstrated numerical improvement in gait performance, the magnitude of change did not exceed measurement error and therefore cannot be considered clinically meaningful, as shown in Table 4.48.

Table 4.28: MDC Achievement for Tinetti Gait Score

Group	Week 1 Mean ± SD	Week 6 Mean ± SD	Mean Change	MDC (3 points) Achieved?
Experimental	8.83 ± 1.00	11.38 ± 0.73	2.55	No
Control	9.00 ± 2.12	10.69 ± 1.39	1.69	No

4.3.4.4 Analysis of the Borg Rating of Perceived Exertion Scores

- Descriptive statistics:

The Borg Rating of Perceived Exertion (RPE) scores demonstrated a progressive decline over the intervention period in both groups, indicating reduced subjective effort during physical activity as shown in table 4.29. At baseline (Day 1), the Experimental Group (B) reported a mean RPE of 15.72 ± 0.84**,** comparable to the Control Group (A) at 15.28 ± 1.22**,** reflecting a relatively high perception of exertion. By Week 3, both groups exhibited a reduction in perceived exertion, with Group B decreasing more substantially **(**14.07 ± 0.96**)** compared to Group A **(**14.00 ± 1.20**).** By Week 6, this downward trend continued, with the Experimental Group showing a sharper decline to 12.48 ± 1.12, while the Control Group reached 13.24 ± 1.50**.** The lower RPE scores in the experimental group suggest that participants experienced greater improvements in physical tolerance and efficiency, likely attributable to the intervention. In contrast, although the control group also showed improvement over time, the magnitude of reduction was less pronounced, underscoring the superior effectiveness of the targeted training program in reducing perceived exertion.

Table 4.29: Descriptive Analysis of Borg rating Score

Experimental Group B						Control Group A					
Day 1		Week 3		Week 6		Day 1		Week 3		Week 6	
MEAN±SD	SE	MEAN±SD	SE	MEAN±SD	SE	MEAN±SD	SE	MEAN±SD	SE	MEAN±SD	SE
15.72±0.84	0.16	14.07±0.96	0.18	12.48±1.12	0.21	15.28±1.22	0.23	14±1.2	0.22	13.24±1.5	0.28

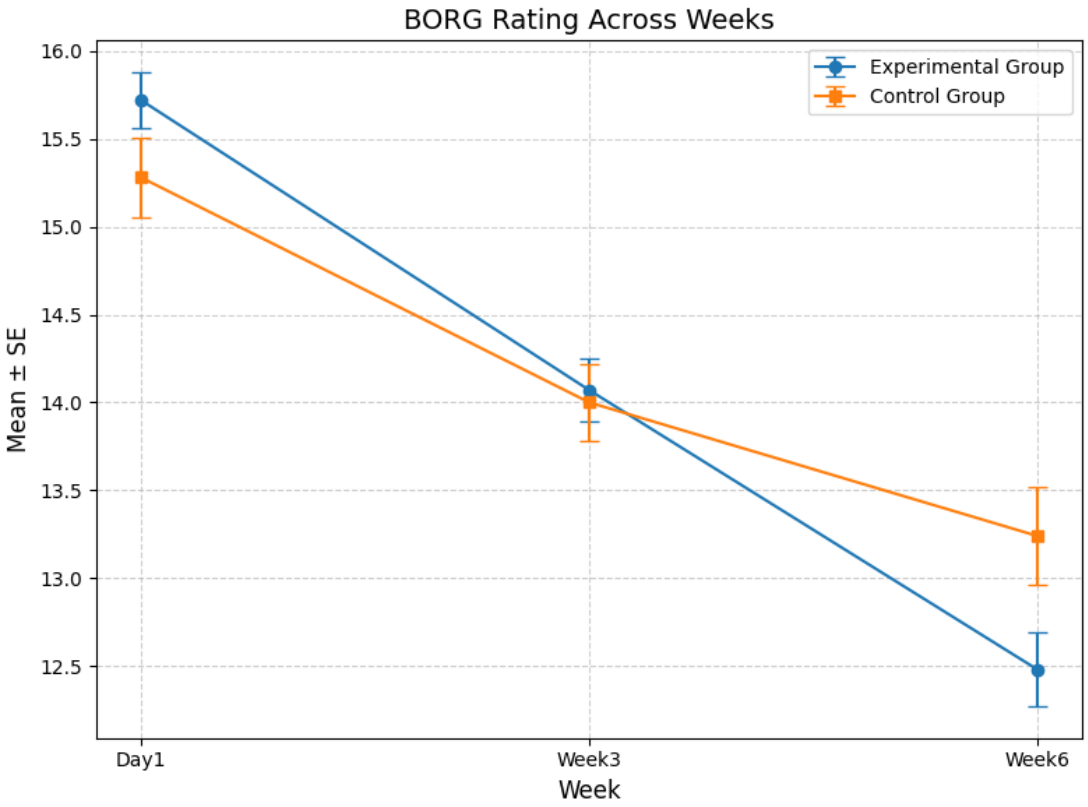


Figure 4.8:Borg Rating of Perceived Exertion (RPE) scores

Figure 4.8 illustrates the trend of Borg RPE scores for both the experimental and control groups over three assessment points (Day 1, Week 3, and Week 6). At baseline (Day 1), both groups reported relatively high perceived exertion, with mean RPE values of approximately 15.7 in the experimental group and 15.3 in the control group, corresponding to "hard" exertion levels. By Week 3, a marked reduction was observed in both groups, with scores dropping to around 14.1 and 14.0, respectively, indicating a shift toward more moderate levels of exertion. Importantly, by Week 6, the experimental group showed a marked decline in perceived exertion (mean ≈ 12.5) compared to the control group (mean ≈ 13.2). This pattern suggests that while both groups benefited from the intervention period, the experimental group showed a greater reduction in exercise-related strain. The error bars (representing the standard error) indicate minimal overlap at Week 6, further supporting the interpretation that the intervention had a stronger effect in alleviating exertion levels in the experimental group compared to the control group.

- Inferential Statistics: RM-ANOVA

The repeated-measures ANOVA shown in Table 4.30 revealed a highly significant main effect of time on Borg Rating scores across Day 1, Week 3, and Week 6 ($F(2,112) = 214.15$, $p < .001$, $\eta^2 = 0.46$, $\eta^2p = 0.79$). This indicates that participants perceived exertion decreased significantly over the intervention period, with a very large effect size (partial $\eta^2 = 0.79$), suggesting that time alone accounted for a substantial proportion of the variance in Borg scores. In contrast, the main effect of group (experimental vs. control) was not statistically significant ($F(1,56) = 0.09$, $p = 0.764$, $\eta^2 = 0.00$, $\eta^2p = 0.00$), demonstrating that when collapsed across time points, both groups had comparable exertion levels. However, the interaction between time and group was significant ($F(2,112) = 11.67$, $p < .001$, $\eta^2 = 0.03$, $\eta^2p = 0.17$), indicating that the trajectory of exertion reduction differed between groups. Specifically, the experimental group experienced a steeper and more pronounced decline in Borg ratings compared to the control group, highlighting the effectiveness of the intervention in reducing perceived exertion over time.

Table 4.30:Analysis of Repeated measure ANOVA for Borg Rating Score

	Sum of squares	df	Mean Squares	F	p	η^2	η^2_p
BORG Rating - Day 1, BORG Rating - Week 3, BORG Rating - Week 6	202.63	2	101.32	214.15	<.001	0.46	0.79
Group of Patient	0.28	1	0.28	0.09	0.764	0	0
RM Factor x Group of Patient	11.05	2	5.52	11.67	<.001	0.03	0.17
Residuals (Between Subjects)	173.01	56	3.09				
Residuals (Within Subjects)	52.99	112	0.47				

Bonferroni Post-hoc-Tests RM Factor (Borg rating score)

Tables 4.31 and 4.32 show Bonferroni-adjusted post-hoc comparisons revealed that Borg Ratings decreased significantly across all time intervals. From Day 1 to Week 3, there was a mean reduction of 1.47 points ($p < .001$, 95% CI [1.25, 1.68]), indicating a marked early improvement in perceived exertion. From Day 1 to Week 6, the reduction was even larger, with a mean difference of 2.64 points ($p < .001$, 95% CI [2.29, 2.98]), reflecting a substantial long-term improvement. Additionally, Borg Ratings continued to decline significantly between Week 3 and Week 6 (mean difference = 1.17, $p < .001$, 95% CI [0.91, 1.43]), suggesting that the intervention had a cumulative effect over time, with progressive reductions in perceived exertion throughout the six-week program.

Table 4.31: Bonferroni Post-hoc-Tests RM Factor for Borg rating score

		Mean diff.	Std. Error	t	p	95% CI lower limit	95% CI upper limit
BORG Rating - Day 1	BORG Rating - Week 3	1.47	0.108	13.593	<.001	1.25	1.68
BORG Rating - Day 1	BORG Rating - Week 6	2.64	0.172	15.369	<.001	2.29	2.98
BORG Rating - Week 3	BORG Rating - Week 6	1.17	0.13	8.986	<.001	0.91	1.43

Table 4.32: Bonferroni Post-hoc-Tests Group of Patients for Borg rating

	Mean diff.	Std. Error	t	p
B - Experimental Group-A - Control Group	-0.08	0.27	-0.3	0.764

Minimal Detectable Change (MDC) for Borg RPE

The Borg Rating of Perceived Exertion (RPE) does not have a validated MCID; therefore, Minimal Detectable Change (MDC) was used to evaluate meaningful change.

An MDC of 1 point was applied based on previously published reliability data. The experimental group showed a reduction of 3.24 points from Day 1 to Week 6, exceeding the MDC threshold. The control group demonstrated a reduction of 2.04 points, which also surpassed the MDC. These findings indicate that both groups experienced clinically meaningful reductions in perceived exertion, with a greater improvement observed in the experimental group, as shown in Table 4.33.

Table 4.33: Achievement of MDC for Borg Rating From Day 1 to Week 6

Group	Day 1 Mean ± SD	Week 6 Mean ± SD	Mean Change	MDC (1 point) Achieved?
Experimental	15.72 ± 0.84	12.48 ± 1.12	3.24	Yes
Control	15.28 ± 1.22	13.24 ± 1.50	2.04	Yes

The results demonstrated that participants who underwent the Dynamic Neuromuscular Stabilization (DNS) exercise program showed a significant improvement in functional capacity and reduction of symptoms compared to baseline, indicating the intervention's effectiveness in enhancing recovery in individuals with post-COVID syndrome. The Intervention group demonstrated greater improvement compared to the Control group, showing significant improvement in musculoskeletal pain, balance, and gait abnormalities, and rate of perceived exertion.

Collectively, these results indicate that DNS exercise leads to meaningful and clinically relevant improvements in study outcomes. It underscore the functional and neurological benefits of this training protocol for patients recovering from COVID-19.

Adverse Events management during Study protocol

Adverse events are considered a natural and expected component of clinical research, particularly during therapeutic and rehabilitation interventions. Careful monitoring and management of any of these events are necessary for maintaining participant safety, ethical standards, and to evaluate the overall risk–benefit of the intervention.Table 4.34 presents the adverse events experienced by participants during the study intervention sessions and the corresponding management strategies used to ensure participant safety and comfort. The commonly observed adverse events included

muscle soreness, muscle fatigue, joint pain, muscle cramps, dizziness, general fatigue, loss of balance, and anxiety. Appropriate preventive and therapeutic measures, such as rest between sessions, cryotherapy, stretching exercises, breathing and relaxation techniques, hydration, posture correction, counselling, reassurance, and visual or verbal feedback were provided whenever required. These management approaches helped in minimizing discomfort and enabled the safe continuation of the intervention program throughout the study period.

Table 4.34: Management of Adverse Events reported

Adverse event	**Action taken for management**
Muscle soreness (DOMS)	Cryotherapy, participant counselling, rest between sessions
Muscle fatigue	Rest between exercise sessions
Joint pain	Proper posture alignment, hydrocollateral pack application
Muscle cramps	Gentle stretching exercises, proper hydration (electron Glucose)
Dizziness	Breathing exercises, rest
General fatigue	Breathing, relaxation, rest between sessions
Loss of balance/instability	Correct positioning, support, verbal commands/visual feedback
Anxiety	Rest, counselling, reassurance, light music

CHAPTER - V

5 DISCUSSION

Overview

This chapter discusses the findings of the present study, which aimed to assess the prevalence and physiotherapeutic management for post-COVID-19 musculoskeletal complications, balance, and gait abnormalities. The interpretation and analysis of the result follow the objectives of the study. Key outcomes are examined for their clinical and practical significance, with a focus on the application of DNS exercises in the rehabilitation of individuals experiencing long-term post-COVID musculoskeletal symptoms, including balance and gait abnormalities. The chapter also addresses limitations of the present research, implications for clinical practice utility, and potential directions for future research.

5.1 Prevalence of Post-COVID-19 musculoskeletal problems

This study investigated the prevalence and physiotherapeutic management of musculoskeletal problems, balance, and gait impairments in individuals recovering from COVID-19. The findings revealed a substantial prevalence of post-acute musculoskeletal dysfunctions, accompanied by alterations in gait patterns and compromised balance control. The findings indicated a moderate prevalence of musculoskeletal complaints, including myalgia, balance, and gait impaired mechanics. These findings are consistent with the increasing body of evidence suggesting that SARS-CoV-2 infection has long-term effects on the neuromuscular and musculoskeletal systems(72)

The number of people recuperating from COVID-19 illness has increased since the start of the epidemic. Our research sheds light on the potential chronic symptoms that patients may develop after an acute infection. The rate of post-COVID-19 infection in our participant group was relatively high, with nearly 58.8%(n=224) showing features of moderate musculoskeletal involvement, 7.6%(n=29) severe, and

33.6%(n=128) with mild features of post-COVID-19 syndrome, having males 47%(n=179) and females 53%(n=202) respectively. The overall mean percentage score was found to be 59.75%. Our results are consistent with a meta-analysis done in 2024, which suggested the estimated prevalence was found to be highest in Asia, 49.79% (95% CI: 30.05%-69.54%) (31). The results are also consistent with another study conducted in China, which found that around two-thirds (68%) of participants had at least one symptom after recovering from acute coronavirus infection (198). The causes of these symptoms are diverse, ranging from degenerative and destructive conditions like osteoporosis and sports-related injuries to inflammatory processes affecting tissues surrounding the bones and joints, such as synovitis and bursitis. It is also a frequent clinical symptom observed in individuals with post-viral infections, including COVID-19. Systemic inflammatory response associated with COVID-19 may influence bone and joint tissue physiology. Several cytokines triggered by infection—such as CXCL10, IL-17, and TNF-α—are known to promote osteoclastogenesis while inhibiting osteoblast proliferation and differentiation, ultimately reducing bone mineral density (BMD). Additionally, IL-1β, IL-6, and TNF-α contribute to chondrolysis, which may cause joint pain or accelerate the development of early degenerative osteoarthritis in some patients. Likewise, IL-1β, IL-17, and TNF-α are thought to drive inflammation in tendinopathy, disrupting normal tenocyte function, impairing matrix remodeling, and potentially exacerbating degenerative disorders (6). The etiopathogenesis and causative factors that affect musculoskeletal system involvement are discussed under the following headings:

1. Receptors and enzymes: The ACE2 and serum transmembrane protease 2(TMPRSS2) present in synovium and bone tissue bind with the virus, which affects remodeling since osteoclasts express ACE2 receptors. This results in COVID-19-related muscle injury and bone loss.

2. Inflammation-cytokine storm: As discussed earlier, increased inflammatory cytokines promote proteolysis, which reduces protein synthesis, leading to muscle damage and

enhanced bone resorption through the nuclear factor kappa B-RANK-RANKL system. IL-1β and IL-6 induce muscle fibrosis, while IL-10 impairs mitochondrial functions in muscles.

3. Hypoxia: Hypoxia with inflammation causes anaerobic glycolysis and lactate dehydrogenase increased production. It promotes osteoclast activity because the balance between bone formation and resorption is disrupted, favoring increased bone breakdown. Production of ROS causes cell apoptosis and DNA damage.

4. Muscle catabolism: Sarcopenia results from inflammation, malnutrition, and muscle catabolism. Hypoxia, immobility, oxidative stress, and production of ROS can lead to sarcopenia and myofibrillar damage (9).

In contrast, a cross-sectional study conducted in Maharashtra, India, reported a prevalence of 17.5%, lower than reported by our findings (57). This variation could be due to differences in participant age ranges, which in their study spanned from 19 to 39 years, as well as the circulation of specific SARS-CoV-2 variants, such as the Alpha variant, that were prevalent in that region during 2020. On the other hand, our study was conducted during a time period dominated by the Omicron and Delta variants. The fact is also supported by another study done by study done in Bhuneshwar, India, which reported the prevalence of 29.2% at four weeks and six months of follow-up, respectively. Additionally, the study reported that those who had completed two doses of vaccination were significant predictors of Long COVID, in contrast to our findings, which showed non-significant results with the dosage of vaccination but significant results with the use of steroids ($p < 0.001$). Corticosteroids can induce oxidative stress and mitochondrial dysfunction, which aggravates fatigue and delay recovery. They suppress immune responses by inhibiting cytokine production (e.g., IL-2, IFN-γ), and T-cell proliferation, resulting in prolonged musculoskeletal and systemic symptoms. However, the vaccination dose and symptoms depend on numerous factors like:

- Time of acute infection vs. vaccination (waning immunity)
- Variant differences (immune escape potential),
- Or host factors such as age, comorbidities, and prior immune status.

Females are more affected than males because of hormones and increased production of IgG antibodies during the early stage of disease, which may contribute to hyperinflammation during the acute phase and persistence of disease symptoms(200). Our survey findings showed that COVID-19 was associated with an increased risk of long COVID symptoms, with no observable differences based on gender or time since acute infection, consistent with the meta-analysis and systematic review conducted in China (2024)(51).

Musculoskeletal problems, balance, and gait impairments following the pandemic are increasingly reported in studies worldwide, according to current findings.A study documented over 50 long-term effects, with tiredness/fatigue, reduced muscle strength, and joint pain among the most common(203). In our study conducted over 381 participants were surveyed, 88% reported the onset of musculoskeletal pain after infection, in contrast to only 11% who experienced such symptoms before infection. This supports the hypothesis that the infection is linked with the onset or aggravation of musculoskeletal symptoms in a large proportion of individuals. The results of our study are consistent with a study that reported a higher prevalence of MSDs after acute coronavirus infection(204).

Neck pain and low back pain have become the most common due to sedentary lifestyles and occupational demands. Prolonged bed rest, physical inactivity, and hospitalization during the acute phase often lead to muscle atrophy, weakness of spinal stabilizing muscles, and poor postural control, increasing the risk of mechanical low back pain. Psychological stress, anxiety, and sleep disturbances may further heighten pain perception. In our survey, most frequently reported pain sites were the neck (69%), upper back (62%), knee (59%), and lower back (51%), in contrast to the findings of a survey done in Bengaluru, in which maximum pain was reported in the lower back 54%, followed by neck pain, arthralgia, fatigue, and myalgia(12). Another study found that the most common region for musculoskeletal pain after COVID-19 was the lumbar area and shoulder girdle (50). Yet another study listed low back, muscular, and joint pain among the ten most common symptoms, suggesting possible mechanisms such as viral persistence, immune dysregulation, organ dysfunction, disruption in cellular energy production, mitochondrial malfunction, and reduced tissue oxygen availability,

supporting the findings of our prevalence study. Studies highlighting balance and mobility dysfunction as frequent features in PACS suggested the central nervous system and (115) vestibular involvement (205).Although the underlying pathophysiology of long COVID still needs to be further explored (51). Numerous prevailing studies align with the findings of our cross-sectional study results, with lumbar pain, knee pain, and neck pain as the most common prevailing post-COVID-19 symptoms (80).

36% of participants in our study reported swelling in joints, suggesting a possible inflammatory or autoimmune mechanism post-COVID. Literature has noted post-viral arthritis and reactive inflammatory conditions as a consequence of systemic viral infections, including SARS-CoV-2 (160). The widespread involvement may be linked to inflammation, immune response, or neuromuscular deconditioning. More than half of the respondents indicated fatigue and reported increased time needed for physical activity. These findings are similar to previous studies, which emphasize fatigue, malaise, and musculoskeletal pain as prevalent symptoms(5). Persistent fatigue is a common consequence of many viral infections and has also been widely documented in patients with COVID-19. According to WHO reports, fatigue occurs in approximately 38% cases. Early fatigue in these patients is primarily due to chronic viral persistence in the respiratory organs, mainly lungs, brain, adipose tissue, and other organs, in addition to the effects of the cytokine storm and compromised nutritional status (81). As discussed earlier, viral and host factors such as systemic inflammation, metabolic, endocrine, and endothelial malfunction, as well as tissue destruction by infection, lack of oxygen, intestinal infection, and dysfunction of the autonomic nervous system are key components underlying the condition. Other contributors include thrombotic endothelialitis, characterized by endothelial inflammation, hyperactivated platelets, and fibrinoid microclots (111).

The findings from the physician survey conducted as part of the study for evidence provided valuable insights into the post-COVID-19 burden of musculoskeletal complaints observed in clinical settings. A significant proportion of physicians (86%) reported an increase in musculoskeletal cases in outpatient departments, aligning closely with observations noted in the general population, where patients commonly report persistent myalgia, arthralgia, and early fatigue. Notably, 100% of physicians

agreed on the rise in myalgia, and 98% confirmed an increase in early fatigue symptoms—both of which were frequently reported in the population survey, reinforcing the validity of these clinical findings. While increases in arthritis pain (70%) and viral arthralgia (approximately 84%) were also prominent, responses regarding fractures and strain/sprain incidence were more varied, with a high degree of neutrality, indicating less perceived change in acute traumatic presentations.

The convergence of physician perspectives with population-reported symptoms highlights a consistent post-COVID-19 syndrome as a prevalent health problem persisting in the community, underscoring the need for management strategies in both clinical and community health frameworks.

Our study's prevalence survey directly addresses this gap by providing much-needed data on post-COVID musculoskeletal, balance, and gait abnormalities in a context where no clear consensus exists. Despite global vaccination efforts, the long-term functional impact of the pandemic remains unresolved, and existing studies offer inconsistent or incomplete estimates of these post-COVID complications. By generating population-specific prevalence data, the study contributes valuable evidence that clarifies the burden of musculoskeletal and functional impairments in underrepresented settings. This not only strengthens the global understanding of post-COVID sequelae but also supports the development of context-appropriate rehabilitation strategies for affected communities.

5.2 Prevalence of Post-COVID-19 balance and gait abnormalities.

The current survey-based study highlights a significant prevalence of balance disturbances reflecting persistent neuromotor impairments consistent with post-COVID-19 syndrome. Our findings demonstrate that dizziness is least commonly reported during sedentary activity (sitting, 15%) and increases with progressively demanding physical activities such as standing (27%), walking (37%), and most significantly during running (60%). This indicates that dynamic balance is more affected than static stability. These findings can be explained as SARS-CoV-2 ARS-CoV-2 may impact neural tissue directly through the olfactory bulb, infecting the central nervous system (CNS), or indirectly through associated vascular damage such

as vasculitis or vasculopathy. The third possible mechanism by which the virus impacts the central nervous system is post-infectious immune-mediated effects. These significant brain alterations may impair the CNS capacity for proprioceptive, vestibular, and visual sensations about dynamic postures, as explained in a study that examined the impact of the SARS-CoV-2 disease in community-dwelling older adults and found altered balance impairment and frequent falls among these subjects (206) .

Furthermore, a significant portion of our respondents reported balance disturbances during positional transitions due to autonomic dysregulation. Orthostatic intolerance and postural orthostatic tachycardia syndrome (POTS) are common in COVID-19 patients. These conditions can cause delayed or insufficient cardiovascular responses to changes in position, leading to dizziness, lightheadedness, and even presyncope during transitions such as standing up, especially in the sitting-to-standing and standing-to-walking phases(207). Other factors contributing to balance impairments include delayed anticipatory postural adjustments (APAs). In post-COVID individuals, involvement of the central nervous system, including cerebellar dysfunction or reduced corticospinal excitability, may delay or impair these APAs, resulting in imbalance or swaying(208). Similar findings regarding balance disorders have also been proposed in a review of movement disorders in patients with COVID-19(104).

The virus in the brain and the coronary arteries(extra-pulmonary sites) have been reported by some researchers. The SARS-CoV-2 virus causes fusion between neurons and glial cells, which may lead to compromised neuronal activity. Transient respiratory infection induces neuroinflammatory responses, activates microglial cells impairs neurogenesis.

This study reveals a significant prevalence of gait abnormalities following COVID-19 infection. Notably, 59% of participants reported a change in walking rhythm, while 57% experienced a decrease in walking speed. These findings are indicative of compromised motor control, neuromuscular coordination, or generalized deconditioning, commonly observed in individuals recovering from COVID-19. Other gait-specific disturbances included irregular foot placement, wide-based gait, difficulty in transitioning from standing to walking (38%), and difficulty taking short steps (38%)

and long steps (46%). The results are in support of the study that reported greater gait variation in individuals infected than in the participants who were not infected. The possible mechanism responsible is the effect of infection on the central and peripheral nervous systems, higher BMI, cardiovascular functions, skeletal muscle weakness, mainly the quadriceps, and exercise intolerance (78). Another study done in 2022 also reported an asymmetrical walking pattern after full recovery, supporting evidence for our research. A coordinated walking pattern occurs as a result of an intact central and peripheral nervous system. Studies reported changes in the peripheral nervous system after COVID-19; also, there were changes in the brain observed. The global size of the brain is found to be reduced due to thinning of grey matter and parahippocampal gyrus, which are the main structures for gait symmetry(100). Abnormalities are attributed to a combination of neuromuscular, neurological, autonomic, cognitive, and psychological factors. Prolonged immobilization, critical illness-related myopathy, and generalized deconditioning contribute to lower limb muscle weakness, resulting in reduced stride length, slower walking speed, and impaired balance(44). Moreover, involvement of the central and peripheral nervous systems—such as small fiber neuropathy, ataxia, and proprioceptive deficits- can disrupt coordination and motor control. The autonomic dysfunction, particularly postural orthostatic tachycardia syndrome (POTS), impairs cardiovascular regulation during postural changes and contributes to instability and unsteady gait (140). Cognitive impairments, commonly referred to as “brain fog,” affect executive function and motor planning, especially during dual-task activities, further altering walking patterns (209). Brain fog disrupts the blood-brain barrier in addition to neuroinflammation. The HPA axis is activated by BBB dysregulation, which releases norepinephrine and glucocorticoids, producing symptoms. White matter changes have been observed in the acute phase, which can be one of the contributing factors for producing cognitive dysfunctions, dizziness, and fatigue, as mentioned in a study on brain-structural abnormalities in patients with post-COVID-19 headache (225). Psychological factors such as anxiety, depression, and post-traumatic stress can lead to functional disturbances characterized by cautious, shuffling, or exaggerated, unsteady gait.

In summary, the present study reveals a significant prevalence of balance and gait abnormalities among individuals following COVID-19 infection. Commonly reported issues such as altered walking rhythm, decreased speed, wider base of support, and difficulty with step length and transitions suggest that post-COVID syndrome affects not only neuromuscular coordination but also broader aspects of functional mobility. These disturbances are likely influenced by underlying musculoskeletal complications like muscle weakness, joint pain, and stiffness over knee pain or low back pain, postural instability, and generalized fatigue. Together, these musculoskeletal and sensorimotor impairments contribute to altered patterns and reduced physical performance. The findings emphasize the importance of early screening for musculoskeletal dysfunction, balance, and gait abnormalities in the affected populations, with targeted rehabilitation interventions like Dynamic Neuromuscular Stabilization exercises protocol, targeted to improve stability, mobility, and overall quality of life.

The findings of this survey directly address the identified research gap by providing empirical evidence on the long-term musculoskeletal, balance, and gait abnormalities experienced by individuals infected with COVID-19. While previous research has mainly focused on the acute management of COVID-19, this study contributes to understanding its persistent musculoskeletal issues, especially in resource-limited settings such as Asia and Africa, where data are still limited. The results highlight the prevalence and types of musculoskeletal problems along with neurological issues like balance and gait disturbances, offering valuable insights into an underexplored aspect of the pandemic's aftermath. In doing so, the study not only emphasizes the need for targeted rehabilitation methods, such as Dynamic Neuromuscular Stabilization (DNS), but also supports the development of customized interventions to reduce these long-term effects—helping to close the existing knowledge gap outlined in the main research problem.

5.3 Implementation of DNS Exercise

DNS is a rehabilitation method grounded in developmental kinesiology. It focuses on re-establishing efficient movement patterns by involving the body's natural motor control mechanisms. Developed by Pavel Kolar at the Prague School of Rehabilitation,

DNS is predicated on the understanding that optimal postural and movement control is established during early childhood through central nervous system maturation. Based on the developmental stages, DNS aims to retrain the neuromuscular system to achieve optimal stabilization of the spine and joints during both static postures and dynamic activities. It focuses on optimal breathing exercise patterns by diaphragm stabilization and integrated mechanical activation of the spinal stabilization system before initiating movements in the extremities. The proposed DNS protocol is a holistic rehabilitative intervention for the management of post-COVID-19 syndrome. DNS aims to restore fundamental movement efficiency and functional capacity in affected individuals by promoting integrated motor control and functional breathing. It involves the integrated action of intrinsic muscles of the spine forming the Integrated Spinal Stabilization System (ISSS).

The present study aimed to study the effectiveness of the DNS exercise protocol for the management of musculoskeletal problems, balance, and gait impairments among COVID-19 recovered individuals. The outcome variables of the present research were pain measured by the NPRS, balance, and gait assessment by the Tinetti balance and gait assessment tool, and perceived exertion measured by the Borg scale. The results of the study showed a positive outcome for all variables between the groups.

5.4 Demographic Data

5.4.1 Age Distribution

The age range of 18 to 45 years ensures a more homogeneous study population in terms of musculoskeletal characteristics. This age group typically represents individuals with minimal age-related degenerative changes, without the confounding impact of age-associated comorbidities (212). Moreover, younger and middle-aged adults were among those significantly affected, especially in terms of persistent fatigue, musculoskeletal pain, and balance impairments, which impact daily functioning and quality of life. The 18–45 age group also tends to have higher levels of physical activity pre-COVID, making any decline in physical performance and intensity more perceptible and clinically relevant. This age range is also more likely to benefit from rehabilitation strategies like DNS due to greater neuroplastic potential and physical

adaptability compared to the older population (63). Thus, focusing on this demographic enables better assessment of the specific therapeutic outcomes of DNS in restoring postural control, gait mechanics, and activity levels post-COVID.

5.4.2 Gender Distribution

The relatively balanced distribution between males and females across both intervention and control groups minimized potential gender bias and helped ensure internal validity of the study outcomes. Although a slightly higher proportion of male participants was observed, this aligns with prevailing literature studies suggesting a higher prevalence of musculoskeletal and functional complaints in males, potentially due to differences in inflammatory responses, physical activity patterns, or occupational exposure.

5.4.3 Numeric Pain Rating Scale

- **Effect of TENS on the reduction of musculoskeletal pain:** Melzack and Wall proposed the gate control theory of pain in 1965, and it has been developed and altered ever since. The "T" (Transmission cells) cells are inhibited by the interneurons found in the SG-cells (cells of substantia gelatinosa rolandi) of the posterior horn of the spinal cord**.** Through the excitatory synapse, the SG cells are excited once the Aß large diameter fibers are activated electrically or by basic mechanical stimulation of the receptors in the joints, muscle, or skin. After receiving inputs from mechanoreceptors (Aß fibers) and nociceptors (A8 and C fibers), the SG cells integrate and modulate the activity of the pain fibers. By inhibiting the T-cells, they close the gate to pain transmission and stop nociceptive information from being transmitted to higher centers. This is additionally enabled by the excitatory input of the large-diameter afferents on the T-cells, which transmit data via the thalamus to the somatosensory cortex via mechanoreceptors. But when the nociceptive afferents (A and C fibers) are active, the SG (substantia gelatinosa rolandi) cells become inhibited. This lessens the presynaptic inhibition of the nociceptive afferent terminal, allowing nociceptive information to be sent to higher centers. When high-intensity, low-

frequency electrical pulses are applied to activate Aδ pain fibers, they cause impulses in the midbrain that return via the spinal cord and block C-system cells by secreting encephalin. The secretion of encephalin at the substantia gelatinosa Rolandi (lamina-Il) results in the analgesic effect of inhibiting the transmission of C fiber impulses to the central nervous system. The application of TENS helps achieve this (16). Studies have shown evidence of TENS for control of pain (190). Numerous studies have proposed the effectiveness of the transcutaneous electrical nerve stimulation modality on respiratory functions among COVID-19 patients. These studies proposed that TENS may be a promising and effective therapeutic method with few side effects compared to any other medication to relieve various symptoms and complications of COVID-19 patients(156). Similarly, another study emphasized the application of TENS in the management of low back pain, knee pain, fibromyalgia, and non-specific musculoskeletal pain. It was used in both groups for the treatment of musculoskeletal pain (157).

- **Effect of Isometric Exercises on the reduction of musculoskeletal pain**: strength training by isometric work targeting specific muscle groups—provides distinct, diverse advantages for the musculoskeletal system. It enhances structural qualities by promoting sarcomere addition and increasing the production of actin and myosin filaments, shifts muscle composition, and improves neural components such as neuromuscular coordination, while also regulating metabolic function(27). Ahmed. I (2022) have also explained the role of exercise in the treatment of symptoms like fatigue, myalgia, and improving quality of life after COVID-19 infection(148).An eight-week isometric exercise program was shown to lower inflammatory cytokines (IL-6, TNF-α, and CRP), with significant reductions in TNF-α and CRP observed in older females with grade 1 early knee osteoarthritis. The results of their study showed that ISOM with EMS has the best score among all groups(152). Exercise stimulates the activity of the body's natural opioids in both the central and peripheral nervous systems, producing feelings of euphoria while reducing pain. Rhyu. et al.,(2015) have also studied the effect of isometric exercises on low back pain and

concluded that LBP patients who performed isometric exercise may have a positive effect in reducing pain degree and increasing muscle activity (213). Isometric exercises, which involve muscle contraction without a change in muscle length or joint movement, promote pain reduction through several physiological mechanisms. Firstly, sustained muscle contraction activates the descending inhibitory pathways, which release endogenous opioids and serotonin, leading to analgesic effects. Secondly, it increases local blood circulation and removes harmful metabolites, helping to remove inflammatory mediators such as prostaglandins and bradykinin that sensitize nociceptors. It induces mechanoreceptor stimulation, which can modulate pain perception through the gate control theory. Additionally, regular isometric training enhances neuromuscular coordination and muscle strength, reducing mechanical stress on joints and tissues. It improves pain tolerance and reduces pain-related fear and central sensitization(31).

- **Effect of DNS Exercises on the reduction of musculoskeletal pain** : The results of our study indicated a greater improvement in pain following the application of the proposed three-level Dynamic Neuromuscular Stabilization (DNS) exercise in the experimental group B. In the present study, the interpretation of effect sizes provides important insight into the magnitude and practical relevance of the observed changes in NPRS scores following the DNS intervention. The repeated-measures ANOVA demonstrated an exceptionally large main effect of Time ($\eta p^2 = 0.81$), indicating that the progression from Day 1 to Week 3 and Week 6 accounted for a substantial proportion of the variance in pain reduction. This suggests that, irrespective of group allocation, participants experienced marked improvement in symptoms over the intervention period. Although the main effect of Group was not statistically significant and yielded only a small-to-moderate effect size ($\eta p^2 = 0.05$), this finding suggests that the two groups did not differ meaningfully in their overall baseline-to-end outcome levels. However, the significant Time × Group interaction produced a large effect size ($\eta p^2 = 0.21$), indicating that the pattern

and magnitude of improvement differed considerably between the groups. Specifically, the DNS group showed a more pronounced reduction in pain across the three time points compared with the control group, reflecting the added therapeutic benefit of the DNS exercises.

Taken together, these effect size values demonstrate that the changes observed in this study were not only statistically significant but also clinically meaningful. The very large effect of Time underscores the natural progression of recovery aided by exercise therapy, while the large interaction effect highlights the specific contribution of DNS in accelerating symptom improvement. These findings support the relevance of DNS as an effective intervention strategy for individuals experiencing post-COVID musculoskeletal symptoms.

DNS reduces pain by restoring ideal movement patterns derived from developmental kinesiology, enhancing core stability through the coordinated activation of deep stabilizing muscles such as the diaphragm and transversus abdominis. By promoting proper joint centration and neuromuscular control, DNS alleviates mechanical stress, muscle imbalances, and compensatory movements that often lead to pain. It also engages the central nervous system to correct faulty motor patterns and incorporates diaphragmatic breathing to manage intra-abdominal pressure and soothe the nervous system. Collectively, these effects enhance functional stability and efficiency of movement, ultimately decreasing pain and discomfort. This concept have been supported by previous literature on DNS. A considerable decrease in pain was noted in a study on the effects of 6 weeks of DNS exercise on extreme paddling force (PF) and pain perception in the shoulder among flatwater kayakers(167). In contrast, a case study examining the impact of 12 weeks of Vojta/Dynamic Neuromuscular Stabilization exercises on chronic migraines, concluded reduction in pain was noted(170) .

Another study investigated the effects of an eight-week DNS exercise in a two-month follow-up research on pain, functional impairment, and quality of life in subjects with non-specific chronic low back pain. It included 29 participants,

with 16 in the control group and 13 in the exercise group. The Visual Analog Scale (VAS), Oswestry Impairment Index, and SF-36 questionnaire were utilized to assess pain intensity, functional impairment, and quality of life before, immediately after, and two months following the intervention. Over eight weeks, the exercise group performed DNS exercises three times a week, while the control group continued their regular daily activities. The findings showed that an eight-week course of DNS exercises can relieve pain, improve functional activities, and quality of life in subjects with non-specific chronic low back pain. Pain, functional impairment, and quality of life were all improved in exercise group A(169).

One more study supported a hypothesis regarding the role of DNS in chronic neck pain. It described that DNS works to improve neck pain by enhancing the neurophysiological components of motion and builds upon the scientific principles of kinesiological and biomechanical development. Deep neck flexor activation is essential, which cannot be achieved solely through isometric strengthening and other stabilization exercises. Furthermore, the synchronization of muscle groups with the CNS and the regulation of IAP contribute to core stability. Consequently, DNS exercises are vital for treating individuals with persistent neck pain, thereby providing us with an evident explanation of the reduction of pain in the experimental group (172). The study of chronic non-specific low back pain provides evidence of the application of DNS with other physiotherapeutic management like TENS(187). The present sudy's findings on pain reduction following DNS intervention align with previous research demonstrating that DNS effectively decreases musculoskeletal pain by enhancing core stability, postural control, and neuromuscular coordination. Similar to earlier studies, the observed pain relief can be attributed to improved activation of deep stabilizing muscles and normalization of muscle tone, which reduces abnormal loading and nociceptive input. These results further support existing evidence that DNS facilitates both biomechanical correction and central modulation of pain perception, reinforcing its therapeutic role in musculoskeletal rehabilitation. The Minimal Clinically

Important Difference (MCID) analysis for pain intensity further supports the effectiveness of the DNS intervention (227). Using the two commonly accepted MCID thresholds for the NPRS—a 2-point reduction and a 30% improvement from baseline—the experimental group demonstrated a clinically meaningful decrease in pain (with a mean reduction of 2.66 points) from Day 1 to Week 6. This improvement exceeded both MCID criteria, indicating that participants receiving DNS experienced a meaningful and perceptible reduction in pain. In contrast, the control group showed a mean reduction of 1.58 points, which did not meet either MCID threshold. These findings highlight that, beyond statistical significance, the DNS protocol produced clinically relevant improvements in pain intensity, whereas the control intervention did not yield meaningful change. The MCID outcomes, therefore, reinforce the clinical value of DNS as an effective approach for pain reduction in post-COVID rehabilitation. The results are supported by RCT, which showed improvement in motor performance and quality of life by incorporating DNS exercises in post covid-19 patients' rehabilitation (164).

DNS reducing pain helps fill the research gap by offering evidence for a targeted, mechanism-based intervention at a time when effective treatments for post-COVID musculoskeletal symptoms are limited. It provides early data supporting DNS as a structured, clinically applicable approach to improving pain and function—areas where current post-COVID rehabilitation protocols remain insufficiently defined.

5.4.4 Tinetti balance score

Possible mechanism for change in Tinetti balance score readings

- Effect of TENS on the improvement of balance:

Transcutaneous Electrical Nerve Stimulation (TENS) has shown effectiveness in improving balance by improving proprioceptive feedback and reducing pain, which affects postural control. It stimulates cutaneous and afferent nerve fibers, leading to improved sensorimotor integration and increased excitability of motor pathways, thereby facilitating better muscle coordination and joint stability(214).

Furthermore, by modulating pain perception through the gate control theory and endogenous opioid mechanisms, it allows individuals to engage more confidently in movement without guarding or compensatory behaviors that disrupt balance(215). Studies have demonstrated that TENS applied to the lower limbs can lead to improvements in static and dynamic balance, particularly in populations with neurological or musculoskeletal impairments(216), suggesting its utility as a supportive modality in balance rehabilitation programs. Studies proposed that it can be used for the management of musculoskeletal pain in COVID-19 recovered patients. They highlighted the effectiveness of exercise in reducing shortness of breath, increasing muscle power, balance, and coordination, reducing stress, and pain. It reduces acute and chronic pain, yet its use has to be explored through more research work done on this (17). Addressing the research gap, the application of this modality adds new evidence for its application in the rehabilitation of post-COVID-19 individuals with balance impairments, along with pain reduction.

- Effects of isometrics on the improvement of balance:

Neurological and vestibular impairments from COVID-19 can affect balance. Balance training, proprioceptive exercises, and functional movement drills enhance stability and reduce fall risk. A study revealed the effects of Pilates exercises on core muscle endurance and trunk balance in people with COVID-19. This has resulted in an improvement in the quality of movement patterns, along with the quality of life(154). Another study on incorporating stretching and low-load isometric strengthening exercises into rehabilitation programs for long COVID patients found improvements in overall function and exercise tolerance because it enhances core stability, flexibility, muscular strength, muscle coordination, and breathing capacity. During Pilates exercises, multiple muscle groups are activated, including the respiratory muscles involved mainly in exhalation. These muscle contractions are maintained throughout both inhalation and exhalation phases, which may contribute to improved pulmonary function(211). Additionally, a randomized controlled trial demonstrated that pilates exercises, which include isometric components, significantly improved core muscle endurance and static balance in young adults recovering from COVID-19. These findings support our

study that isometric strengthening exercises can be an effective component of rehabilitation programs aimed at enhancing balance and functional capacity in post-COVID-19 patients(217). The results are similar due to the underlying mechanism that isometric exercises improve balance by increasing joint stability and enhancing neuromuscular control without requiring movement. By strengthening the deep stabilizing muscles that maintain posture, they help the body resist sway, improve proprioception, and create a more stable base for dynamic tasks. However, previous studies on post-COVID-19 rehabilitation have reported mixed findings regarding cognitive outcomes. Several studies demonstrated significant balance and cognitive improvements following physical exercise–based rehabilitation programs or multidisciplinary interventions. In contrast, other studies did not observe significant improvements in cognitive function, health-related quality of life (HRQoL), grip strength, walking capacity, or balance after rehabilitation interventions. For example, a 6-week rehabilitation program consisting of aerobic and resistance exercises showed significant improvements in fatigue, anxiety, depression, symptom severity, functional disability, and dyspnea, but failed to demonstrate meaningful changes in cognitive function like grip strength, walking capacity, and balance (231). These contradictory findings highlight the need for further high-quality randomized controlled trials to better understand the effectiveness of multidisciplinary and exercise-based rehabilitation approaches in managing post-COVID-19 conditions. However, the findings of the present study support the effectiveness of exercise rehabilitation, demonstrating positive effects on balance, cognition, gait, and functional outcomes among individuals with post-COVID syndrome.

- Effect of DNS exercises on improvement of balance:

In our study, improvement in balance is shown in experimental group B, where the DNS exercise protocol for post-COVID-19 syndrome was implemented, as recorded in the Tinetti balance score. The findings indicate that balance, as measured by the Tinetti Assessment, improves with time duration, with a very large effect ($\eta p^2 = 0.66$), highlighting the effectiveness of the intervention across all participants.

Although there was no statistically significant difference between patient groups, the significant time × group interaction ($\eta p^2 = 0.19$) suggests that the rate of improvement varied between groups. This medium effect indicates that certain groups may respond more favorably to the intervention, emphasizing the importance of considering patient-specific factors in rehabilitation planning. These results align with previous research showing that dynamic neuromuscular stabilization (DNS) exercises can enhance balance and postural stability in post-COVID patients. The large effect of time demonstrates the clinical significance of balance improvements, while the interaction effect underscores the potential need to tailor interventions to optimize outcomes for different patient subgroups (the time × group interaction was significant, $F(2, 112) = 13.14$, $p < .001$, $\eta^2 = 0.03$, $\eta p^2 = 0.19$, indicating that the pattern of balance improvement over time differed between groups). During dynamic limb movement, the DNS is connected to postural stability in reaction to internal or external disturbances. As discussed earlier, the feedforward process enables the diaphragm, abdominal muscles, pelvic floor muscles, and spinal extensors to cooperate to provide the ideal IAP. It entails strengthening the muscular system as well as the neurological system and activating spinal stabilizers for improving dynamic as well as static stability. Our study results are in accordance with a previous study done on DNS exercises to assess their effectiveness on balance and gait function in the aged population. The results showed variation in outcome between the control and exercise groups after applying the exercise intervention of 6 weeks. More improvement was noted by DNS training on balance and gait function in the elderly (23). An RCT aimed to investigate the effectiveness of a DNS intervention on postural stability, pulmonary function, motor performance, and quality of life in COVID-19-recovered patients weaning from ventilators. It found it effective in improving postural stability and balance. By activating deep core stabilizers (transverse abdominis/internal oblique) and facilitating diaphragmatic movement, the technique can effectively improve balance and gait performance. The beneficial effects may be explained by better neuromuscular coordination, especially through greater activation and improved performance of the diaphragm—the main muscle involved in breathing—which also plays an important role in maintaining postural stability together with other

respiratory muscles. It restores and strengthens essential movement patterns by activating important sensory and motor pathways within the central nervous system. These processes influence functional motor programs that are vital for maintaining balance and coordinating neuromuscular responses with the surrounding environment. As a result, it can improve both static and dynamic balance. These improvements are likely associated with greater recruitment of neuromuscular units and adaptive changes within the sensorimotor cortex. Additionally, increased synaptic efficiency, enhanced neural stimulation, decreased resistance within neural pathways, and reduced inhibitory activity all contribute to more effective sensorimotor signal transmission, thereby improving overall balance performance (164). Another study proved that trainers and therapists could adapt DNS exercises since it appears to lower the risk of falls and improve lower limb strength, thereby showing significant effects on static and dynamic balance(218).

The technique of DNS could be used to improve functional movements, which improves stability(174). Thus, numerous studies support the findings of DNS improvement on balance. DNS targets deep stabilizing muscles, including the diaphragm, which is the prime muscle for pulmonary functions mainly affected by the SARS-CoV-2 virus, and optimizes intra-abdominal pressure regulation, leading to improved postural control and balance. This consistent neuromuscular re-education mechanism explains the comparable outcomes across studies.

The use of MDC (minimal detectable change) indicates whether observed changes in balance exceed potential measurement error. In the present study, the experimental group exceeded the MDC of 3 points for the Tinetti Balance score, reflecting a genuine improvement in postural stability following DNS training, as previously discussed in the results chapter. Conversely, the control group did not reach the MDC, suggesting that their improvement may reflect natural variation or minor adaptation rather than a clinically meaningful enhancement in balance (228). These findings support the effectiveness of DNS in improving functional balance in individuals with post-COVID symptoms. The findings indicated that only the DNS intervention produced a change in balance performance that exceeded

measurement error and can therefore be considered a true, meaningful improvement for post-COVID rehabilitation.

5.4.5 Tinetti Gait Score.

Possible mechanism for change in Tinetti gait score readings

- Effect of TENS on the improvement of gait:

Transcutaneous Electrical Nerve Stimulation (TENS) has shown effectiveness in improving gait among patients recovering from COVID-19, particularly those experiencing long-COVID symptoms in our study, as measured by the Tinetti gait assessment tool. TENS shows improvement through a combination of pain modulation, neuromuscular facilitation, and enhanced sensory feedback. By stimulating large-diameter sensory fibres, it inhibits nociceptive signals via the gate control mechanism, reducing pain that often limits mobility. Additionally, motor-level TENS can activate underlying muscles, improving the strength and coordination needed for a coordinated symmetrical lower limb pattern. Repetitive stimulation may also promote neuroplasticity, aiding motor relearning in patients with COVID-related deconditioning or neurological impairments. Furthermore, it stimulates proprioceptive stimulation, providing improved balance and postural control, and may reduce muscle spasm in cases of post-viral neuromuscular involvement. These combined effects contribute to more efficient, symmetrical, and stable walking patterns during post-COVID rehabilitation. A pilot randomized clinical trial demonstrated that daily high-dose TENS therapy over four weeks led to significant enhancements in gait parameters, including stride time, cadence, and a 12% reduction in the double-support phase during dual-task walking. These improvements suggest that TENS can positively influence walking efficiency, stability, and dynamic balance in post-COVID-19 individuals (219). Another case report described the application of direct peripheral nerve TENS in a patient with post-COVID-19 Guillain–Barré syndrome and acute transverse myelitis. The patient experienced substantial reductions in neuropathic pain and improvements in motor function, indicating that the modality may be effective in more complex neuromuscular complications of COVID-19. This supports the broader applicability of TENS beyond typical musculoskeletal presentations (220) Previous research has

demonstrated that Transcutaneous Electrical Nerve Stimulation (TENS) can improve gait parameters by influencing motor control and movement patterns in conditions such as stroke, osteoarthritis, or neuropathic pain, but very less have studied it specifically targeting neuromuscular re-education in this population. Although it has been shown to improve gait in other clinical populations, demonstrating the potential for neuromuscular modulation to enhance movement, there is a lack of evidence on structured neuromuscular stabilization approaches, such as DNS, along with the application of electrotherapy modality for improving gait and functional performance in individuals with post-COVID syndrome. This study aims to address that gap.

- Effect of Isometric exercises on the improvement of gait:

Isometric exercises of the quadriceps, back, and neck muscles play a crucial role in enhancing gait among COVID-19 recovered patients by reducing pain, improving muscle strength, and neuromuscular control. Prolonged inactivity and systemic inflammation during COVID-19 infection result in muscle atrophy and weakness, particularly in postural and locomotor muscles. Isometric exercises help in rebuilding muscle strength without exerting a significant cardiovascular load in individuals with compromised respiratory function. For instance, isometric quadriceps strengthening has been shown to improve knee joint stability and reduce pain, thereby facilitating better gait mechanics. Isometric strengthening of the back muscles enhances postural control, needed for maintaining balance and proper gait mechanics. For the neck muscles, isometric exercises improve neck muscle dysfunctions associated with neck pain, gaining improved head posture and balance during ambulation. It stimulates the release of myokines, such as irisin, that have systemic anti-inflammatory effects and may contribute to improved pulmonary function, highlighting a potential "muscle-lung cross-talk" mechanism beneficial in post-COVID rehabilitation. The mechanism has been explained by a study that discussed the role of exercise on skeletal muscle with minimal lung involvement. It evaluated the effectiveness of exercise regime on the rehabilitation of COVID-19 individuals and “muscle–lung cross-talk” as a mechanism for COVID-19 treatment (221). Another review study discussed the role of physiotherapy, including exercises, on symptoms, complications, and management of post-COVID symptoms, thus supporting the evidence of our study (13).

- Effect of DNS Exercises on the improvement of gait:

DNS improves core stability, muscle recruitment, and breathing efficiency based on developmental kinesiology principles, joint centration, and the stabilization of diaphragm. It activates the superficial and deep spinal stabilizers and restores optimal IAP regulation. It optimizes movement by reducing the excessive load on joints and the spine. Elevated intra-abdominal pressure contributes to enhanced spinal stability. This is achieved by integrated action and co-contraction of the diaphragm, pelvic floor, and abdominal muscles. DNS aims to improve breathing patterns and core stabilization and provides a stable base with centered joints during static and dynamic movement. It facilitates the activation of deep stabilizing muscles, including the transversus abdominis and multifidus, which are essential for trunk stability and efficient gait mechanics. It is based on subconscious activation of specific zones that reflexively engage the diaphragm and other core stabilizers, enhancing overall movement awareness. Dynamic Neuromuscular Stabilization (DNS) contributes to rehabilitation by facilitating activation of the deep core musculature and improving diaphragmatic function, which helps enhance balance, gait ability, and respiratory performance. Furthermore, DNS supports recovery not only at the physical level but also by positively influencing psychological well-being and social participation, thereby providing a holistic rehabilitation strategy (164).

Based on Jena's Principle of dynamic neuromuscular stability, DNS exercises provide an important component of spinal stabilization and abdominal stabilization before dynamic movement. It restores more stable movement patterns by combining natural developmental posture and neuromuscular control(18) (165).

Based on this mechanism, findings of our research are corroborated by earlier investigations that examined the impact of DNS training in comparison to traditional core exercises on core muscle contractility and postural control in individuals suffering from chronic low back pain. The study results indicate that DNS is more effective than conventional core exercises at improving core muscle contractility and standing postural control in chronic low back pain patients. These findings suggest that DNS may play a meaningful role in reducing pain and improving functional disability."(222) Another review study provided evidence that DNS exercises showed an improvement in spasticity, trunk control, balance, frequency of fall, walking, and ADLs in individuals

with neurological problems like MS and CP. The technique causes marked improvement in muscle thickness and activation, balance, and gait pattern (223). Grounded in concepts from neurodevelopmental kinesiology and reflex-based core stabilization mechanisms. This method emphasizes the subconscious activation of targeted body regions, especially around the thoracic area, to promote automatic engagement of the diaphragm and associated core stabilizing musculature. Such an approach is especially beneficial for individuals who experience reduced somatosensory perception or limitations in movement control (164).

Another RCT was conducted on multiple Sclerosis patients over balance and trunk function and found that 5 weeks of DNS showed effective improvement. Thus, the technique demonstrated strong efficacy in individuals with somatosensory or movement impairments (19). By retraining breathing patterns and trunk control, it promotes better coordination and weight transfer during walking. However, the extent of gait improvement may depend on participants' baseline impairments, training duration, and adherence, highlighting the need for standardized protocols and long-term follow-up to confirm sustained benefits. There is a lack of evidence-based tailored physiotherapy exercise protocols. Investigating the role of Dynamic neuromuscular stabilization (DNS) exercises on gait and balance provides valuable insights into the potential benefits for managing post-COVID musculoskeletal, balance, and gait complications, addressing the existing research gap. The present study aims to provide an evidence-based intervention protocol for physiotherapy rehabilitation services in managing post-COVID syndrome prevailing in the community. The results of our study demonstrate that Tinetti Gait scores improved significantly over time, with a very large effect ($\eta p^2 = 0.69$), indicating that the intervention had a substantial impact on gait function among participants. Although there was no significant overall difference between patient groups, the significant time × group interaction ($\eta p^2 = 0.09$) suggests that the trajectory of gait improvement varied between groups. This moderate interaction effect indicates that some patient subgroups responded more favorably to the intervention, emphasizing the importance of tailoring rehabilitation strategies. These findings align with previous research showing that dynamic neuromuscular stabilization (DNS) exercises can improve gait and mobility in post-COVID patients. The large effect of time highlights the clinical relevance of the intervention, while the

interaction effect underscores the potential need for individualized approaches to optimize functional recovery. Unlike the balance subscale, neither group exceeded the MDC for the Tinetti Gait score. This indicates that the observed improvements in gait were modest and may reflect normal variability rather than a clinically important functional gain.

The DNS intervention produced slightly larger improvements than the control group; however, the magnitude was insufficient to surpass the MDC, suggesting that DNS may influence balance more strongly than gait in the early phase of intervention.

5.4.6 Physical Activity Intensity Level

- Effect of TENS on the improvement of perceived exertion:

The results of our study signify that Transcutaneous Electrical Nerve Stimulation (TENS) has emerged as a promising non-pharmacological intervention to alleviate fatigue and enhance the functional level of physical activity in COVID-19 recovered patients. The modulation of pain pathways may contribute to reduced fatigue levels. Also, by stimulating peripheral nerves, TENS may improve muscle activation and coordination, potentially counteracting the neuromuscular impairments observed in long COVID patients.As discussed earlier, improvements in gait metrics indicate that TENS may effectively reduce fatigue, thereby aiding in fall prevention and enhancing physical activity levels(220). Cracium(2021) has also mentioned in his chapter the application of TENS as physiotherapy management of COVID-19, thus providing strong foundations for the findings of our study (24).

- Effect of Isometric exercises on the improvement of perceived exertion:

Isometric training has been associated with neuromuscular function, improving muscle strength and endurance without giving significant stress on the heart. Furthermore, engaging in regular isometric exercises may support mitochondrial health, promoting better energy production at the cellular level, which is crucial to help reduce fatigue. It may improve autonomic nervous system function, which is often dysregulated in post-

COVID-19 conditions, leading to better regulation of heart rate and blood pressure during physical activity, thereby improving physical activity intensity level. In another RCT to study the effectiveness of comprehensive rehabilitation training, such as aerobic training, respiratory training, strength training, and stretching, in post-COVID symptoms resulted in improvements (196). Another study by Almazan et al. (2021) has reviewed the therapeutic benefits of exercise in the rehabilitation of post-COVID-19 conditions (27)

- Effect of DNS exercises on the improvement of perceived exertion:

The findings of our study showed that BORG Rating scores changed significantly over time, with a very large effect ($\eta p^2 = 0.79$), indicating that the intervention substantially reduced perceived exertion among participants. These results align with prior research showing that structured rehabilitation programs can decrease perceived exertion and improve tolerance to activity in post-COVID patients. The large effect of time demonstrates the clinical significance of the intervention, while the interaction effect points to the importance of personalized rehabilitation strategies. Joint centration in DNS refers to the optimal alignment and positioning of a joint to allow for maximal stability and efficient force transfer during movement. Optimal central nervous system control in combination with balanced muscular activation ensures optimal joint centration in both movement and resting positions. This joint centration is a dynamic neuromuscular principle that provides a mechanical advantage by reducing excessive load over joints throughout the range. As a result of this principle, there is optimal transfer of the load over the joint, creating optimal functioning of the open and closed kinetic chain movement. This diverts the maximum loading across soft tissue structures like ligaments and tendons, causing the least strain and protecting the joint structure during the tension phase. Also, if any one segment of the ISSS stabilizing system is disturbed, it affects the stabilizing system as a whole, affecting the quality of purposeful movement. The DNS exercises integrate the optimal functioning of the ISSS mechanism by activating the diaphragm, pelvic girdle, and abdominals, along with back extensors of the lower thoracic and lumbar regions. The outcome of joint centration is reduced mechanical stress on relevant structures, causing overactivation of the muscles. This improves the physical activity intensity level (18). A study was conducted to

evaluate the effectiveness of a physical exercise–based rehabilitation program in survivors of severe COVID-19. A randomized clinical trial was conducted with 30 participants. The intervention sessions were performed three times per week for 40–60 minutes over a period of six weeks. Outcome measures included quality of life, physical activity level, functional status, physical capacity, dynamic balance, neuromuscular fitness, and respiratory muscle strength, which were assessed before and after the intervention. Exercise intensity during resistance training was monitored using an analog perceived exertion scale ranging from 0 (no exertion) to 10 (maximal effort). The findings demonstrated that multicomponent physical rehabilitation resulted in significant improvements in physical activity level, functional capacity, balance, respiratory muscle strength, neuromuscular fitness, and overall quality of life. Greater respiratory strength may reduce perceived exertion during daily activities. The integration of inspiratory muscle training (IMT) with aerobic exercise has been shown to enhance respiratory muscle performance, leading to notable improvements in maximal inspiratory pressure (PImax), as documented in previous studies. Additionally, this combined approach provides cardiovascular advantages, particularly among individuals with hypertension. Pulmonary rehabilitation programs have also been found to decrease dyspnea, enhance exercise tolerance, and reduce fatigue levels. The greater perception of breathlessness compared to lower-limb fatigue suggests that pulmonary impairment remains a major factor contributing to functional limitations following COVID-19. These findings emphasize the importance of incorporating aerobic exercise, resistance training, and respiratory muscle conditioning into comprehensive rehabilitation protocols(83).

A 3-level eight-week DNS exercise improved fatigue, walking speed, endurance, and quality of life parameters in patients with multiple sclerosis, and can be utilized as a corrective strategy to enhance physical function and quality of life. The current findings demonstrate a substantial impact of endurance training on increasing average walking distance. A study evaluated the effects of DNS exercises on postural stability, pulmonary function, motor performance, and QOL and found a good effect of these exercises on fatigue and respiratory functions(164).

Another study done on the treatment of patients with posterior cortical atrophy (PCA) by DNS showed 60% improvement in ADL, especially in QOL and

musculoskeletal functions(175). Similarly, DNS training enhanced functional movement, torso stability, and dynamic stability, which in turn improved fatigue level. Regardless of age or gender, trainees who need safe and efficient posture correction can benefit from DNS training(176). Numerous studies support the hypothesis that DNS is effective at improving perceived exertion. Thus, the above study successfully provides evidence for the application of the proposed Dynamic Neuromuscular Stabilization Exercise protocol for the management of musculoskeletal problems, balance, and gait impairments in individuals with post-COVID-19 infection. Since no established MCID exists for the Borg RPE scale, MDC was used to identify meaningful change beyond measurement error. Both groups exceeded the MDC threshold of 1 point, indicating real improvement in perceived exertion over the intervention period. The experimental group showed a marked reduction in exertion levels compared with the control group, suggesting that the DNS intervention may have contributed to greater improvements in exercise tolerance and perceived physiological effort.

The findings of this study successfully address the outlined rationale by providing essential evidence on the long-term musculoskeletal, balance, and gait impairments experienced by post-COVID individuals—thereby contributing to the global understanding of COVID-19's persistent health burden. By documenting the prevalence and nature of these abnormalities, the study offers valuable information on the long-term effects of COVID-19, helping bridge the existing gap in patient care after the acute phase of infection. Furthermore, the demonstrated efficacy of DNS in reducing pain and improving balance and gait function, as measured by scales used in the study, provides a strong evidence-based rehabilitation approach that supports holistic recovery and enhances quality of life. The possible mechanisms responsible. for bringing out the desired result has been discussed in the above section. These outcomes also contribute valuable guidance for physiotherapy practice, aiding clinical decision-making and supporting the development of structured rehabilitation protocols for affected populations. Ultimately, by integrating both prevalence assessment and therapeutic intervention, this study fills a critical gap in current research and establishes a foundation for future studies in post-COVID rehabilitation and public health.

5.5 Limitations

During the Survey, bias in the self-administered questionnaire responses could potentially influence the results or may give skewed results. participants themselves reported their symptoms based on their experiences after COVID-19; this can create bias or potential errors in responses. Secondly, research has not been conducted on the validity and reliability of the self-administered questionnaire. The questionnaire was modified from the previous research questionnaire and verified. Although we presume that the Omicron and Delta variants were predominant during the study period, we lack definitive evidence to confirm this. Finally, it is crucial to remember that musculoskeletal symptoms are complex and multifactorial, including social, physical, and psychological ones, several of which were beyond the control of this investigation. The intervention part of the study was limited to a small geographical area, and long-term follow-ups of the subjects were not done.

5.6 Clinical Implications

To date, there is no standard line of management available for individuals suffering from post-COVID-19 syndrome. Most research efforts have predominantly concentrated on the management of the initial phase of the infection and its prevention. Consequently, there is a critical demand to implement an interdisciplinary rehabilitation program aimed at addressing post-COVID-19 complications. Symptomatic management should consist of both physical and psychological rehabilitation programs, including patient counselling. Performance of exercises, physical or sports activity, and individual education can reduce symptoms of pain, fatigue, and exertional dyspnea, and can gradually improve exercise tolerance and physical capacity of patients experiencing long COVID-19. Non-pharmaceutical interventions and specially designed physiotherapy interventions, along with electrotherapy techniques, can help manage these complications. Tailored and supervised training exercises may be an effective multisystemic therapeutic approach (26). In addition to traditional exercise protocols that emphasize resistance, endurance, and balance training, it is essential to incorporate a novel approach known as Dynamic Neuromuscular Stabilization into the

physiotherapy intervention program. The technique is derived from developmental kinesiology, proposed by Professor Pavel Kolar (27).

Although the technique is applied for sports and neurological rehabilitation but its implications for post-COVID-19 populations in the treatment of musculoskeletal symptoms can be of potential benefit. DNS exercises are beneficial not only for the functional treatment of musculoskeletal system syndromes characterized by pain but also for enhancing exercise capacity. It improves spinal stability, trunk balance, and fear of falling (28). Based on evidence, it is found to be an effective protocol for reducing musculoskeletal pain, improving respiratory function, and strengthening core muscles. In addition, TENS may be an effective electrotherapeutic tool used by physiotherapists for relieving the acute and chronic pain associated with post-COVID-19 infection, such as arthralgia, myalgia, and fatigue (29).

The strength of the study can be summarized as:

1. Combined epidemiological and interventional approach: The study not only identifies the prevalence and symptoms of post-COVID syndrome in India but also tests the effectiveness of a targeted intervention (DNS), offering both descriptive and experimental value.

2. Use of an evidence-based physiotherapy rehabilitation method: Dynamic Neuromuscular Stabilization is a scientifically supported novel technique. Its inclusion enhances the methodological rigor and reinforces the clinical relevance of the findings for the targeted affected population.

3. Potential for Practical Clinical Application: The results can directly improve rehabilitation strategies for post-COVID patients, making the study highly relevant for physiotherapists and healthcare providers managing post-COVID sequelae after future waves of this respective viral infection.

5.7 Future Recommendations

In the DNS methodology, core body muscles and respiratory muscles are engaged concurrently, setting it apart from other methods. This simultaneous activation may offer distinct advantages; however, the beneficial effects of these exercises may

diminish following a period of detraining. Thus, more studies should be conducted on the long-term efficacy of DNS exercises. The study should be conducted over a more diverse population. The proposed Copyright DNS protocol can be applied to children and the elderly population having musculoskeletal complications of post-COVID-19 syndrome.

CHAPTER - VI

6 CONCLUSION

Millions of people have been impacted by post-COVID-19 conditions since the pandemic began. The SARS-CoV-2 virus, responsible for COVID-19, remains prevalent, and the conditions that arise following COVID-19 pose a considerable risk and persistent challenge to public health worldwide. Currently, there is limited research on the management of post-COVID-19 syndrome. In line with this perspective, the present study aimed to examine the prevalence of post-COVID-19 syndrome and evaluate the effectiveness of Dynamic Neuromuscular Stabilization (DNS) exercises as a rehabilitation intervention. The results of the study showed that 88% (337) of the subjects were affected by musculoskeletal problems after being infected with COVID-19, with the most prevalent pain reported as , neck, low back and knee pain, respectively. A higher prevalence of fatigue has also been reported in 61% (231) of the affected population.

Providing combined prevalence and intervention data in the same study, this dual design of the present study makes it novel by providing a direct translation from problem identification to solution testing, showing how a specific subset of impairment responds to a specialized intervention.

According to established clinical rehabilitation guidelines for post-COVID syndrome, rehabilitation programs should focus on individualized assessment, gradual exercise progression, respiratory rehabilitation, balance and cognitive rehabilitation, fatigue management, and restoration of functional capacity. **Guidelines published by the World Health Organization** recommend comprehensive rehabilitation interventions by a hybrid approach across all levels of health care, emphasizing the management of arthralgia, post-exertional symptoms exacerbation (PESE), breathing and cognitive impairments, fatigue management, psychological symptoms like anxiety and depression, and physical exercise training for orthostatic intolerance, respectively. It should include breathing exercises, physical activity training, patient education, and

monitoring of persistent symptoms such as fatigue, dyspnea, and reduced endurance (229). Similarly, **the National Institute for Health and Care Excellence (NICE)** has given COVID-19 rapid guidelines: managing long-term effects of COVID-19 that advise core team healthcare professionals like occupational therapists and physiotherapists, to implement multidisciplinary rehabilitation approaches with careful pacing of activities and individualized treatment planning to prevent symptom exacerbation of fatigue, balance, and respiratory care (230). In line with these recommendations, the findings of the present study suggest that Dynamic Neuromuscular Stabilization (DNS) exercises can be effectively incorporated into post-COVID rehabilitation protocols due to their role in improving diaphragmatic breathing, postural stability, neuromuscular coordination, and overall functional performance. Therefore, physiotherapists and rehabilitation professionals should consider integrating DNS-based interventions into routine clinical practice as part of evidence-based rehabilitation strategies for individuals experiencing post-COVID syndrome.

The Proposed Dynamic Neuromuscular Stabilization Exercise Protocol was designed to manage musculoskeletal, balance, and gait abnormalities post-COVID-19 infection. Intra-group comparisons show significant improvements in all the outcome measures, such as pain, balance and gait abnormalities, and perceived exertion in both Control Group A and Experimental Group B. Inter-group comparisons demonstrate a more significant improvement in all parameters for Experimental Group B. Thus, the results of the study conclude that the proposed Dynamic Neuromuscular Stabilization Exercise, when used in conjunction with conventional physiotherapy treatment, represents a comprehensive integrated management approach for the management of post-COVID-19 complications. The findings of our study, therefore, provide strong evidence for the future application of the DNS technique by physiotherapists for the management of post-COVID-19 complications.

The study provides a novel contribution by applying a developmental-based motor control rehabilitation method to post-COVID-19 syndrome, offering new evidence on breathing mechanics, postural stability, and functional recovery that has not been previously tested in this population. It quantifies the true prevalence of gait and balance impairments in a population where they are under-recognized.

COVID-19 can result in prolonged illness and persistent symptoms, even in young adults and persons with no underlying medical conditions who were hospitalized or home quarantined. Much is still unknown about how it affects people over time. More time and research are needed to understand the newly evolved viral disease. Most rehabilitation studies focused on aerobic training, respiratory therapy, or general physiotherapy. There is almost no evidence on interventions targeting motor control, deep core activation, or developmental movement patterns. The findings of this study help fill the existing research gaps by providing current evidence on the prevalence and characteristics of musculoskeletal, balance, and gait impairments among individuals recovered from COVID-19 infection, where current literature remains limited mainly in developing countries like India.By documenting musculoskeletal problems, balance and gait impairments, and how they affect functional mobility, the study contributes foundational epidemiological data that is essential for understanding the scope of post-COVID physical dysfunction. Furthermore, the study evaluated the effectiveness of physiotherapy, specifically the Dynamic Neuromuscular Stabilization (DNS) approach, offering early evidence on a targeted rehabilitation strategy where the benefits of post-COVID rehabilitation are still unclear. DNS, through its focus on restoring optimal neuromuscular control and postural stability, demonstrates potential improvements in pain, balance, and gait mechanics, thereby addressing the lack of research on intervention outcomes for this population. An intervention grounded in developmental kinesiology provides the first evidence that motor-control approaches based on the ISSS model may be effective for post-COVID-19 patients. The work may be the first to systematically test the novel approach on this population, establishing it as a potentially effective rehabilitation framework.

The findings of the present study may extend beyond individuals with post-COVID syndrome and could have broader clinical implications for more diverse populations, including patients with Chronic Obstructive Pulmonary Disease (COPD), asthma, and those recovering from prolonged mechanical ventilation, as well as other conditions associated with impaired breathing mechanics and reduced functional capacity that require respiratory rehabilitation. Because the proposed technique emphasizes diaphragmatic activation, postural stabilization, and efficient respiratory patterns, its

principles may be beneficial across various cardiopulmonary rehabilitation settings. Therefore, DNS-based interventions may serve as a valuable adjunct to conventional physiotherapy programs and need further investigation in diverse respiratory populations. Despite these encouraging outcomes, further research involving larger and more diverse populations is recommended to establish the long-term efficacy and broader generalizability of Dynamic Neuromuscular Stabilization (DNS) as a rehabilitation strategy for post-COVID syndrome and other respiratory rehabilitation populations.

Clinical Relevance

• DNS exercises markedly reduced pain and discomfort in individuals with post-COVID-19 syndrome.
• Enhanced postural control and neuromuscular coordination improved balance and reduced the risk of falls during functional activities.
• Improvements in gait performance indicated better mobility, walking efficiency, and functional independence following DNS-based rehabilitation.
• Lower scores on the Borg Rating of Perceived Exertion (RPE) reflected decreased exercise-related fatigue and improved tolerance for physical activity.
• The findings support incorporating DNS exercises into evidence-based physiotherapy and cardiopulmonary rehabilitation programs to optimize functional recovery and quality of life in post-COVID patients.

Overall, the study bridges gaps in both knowledge of impairment prevalence and evidence-based physiotherapy management, supporting more informed clinical decision-making for post-COVID rehabilitation across future COVID-19 waves. This study delivers insights with direct relevance to global health and human functioning, supporting rehabilitation approaches that strengthen not only individuals but the resilience of society as a whole.

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Signature of Scholar with date

(Vijayshree Singh)

Date:

Remarks of the Supervisor/ Co-Supervisor.

Certification by the Supervisor/ Co-Supervisor:

1) It is hereby certified that the information and details presented above are true to the bestof my knowledge.
2) The performance and progress of research work of the candidate is satisfactory.

Supervisor

Dr. Zaki Anwer (Ph.D), UID – 28776
Professor, Dept. of Physiotherapy, LPU

Co-Supervisor

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ANNEXURE – 1 (Paper Publication)



Natural Resources for Human Health
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Original Research

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KEYWORDS:
Long COVID, Dynamic Neuromuscular Stabilization, balance, gait, Rehabilitation

Neuromuscular Rehabilitation for Balance and Gait Impairments in Long COVID Condition: A Randomized Controlled Trial

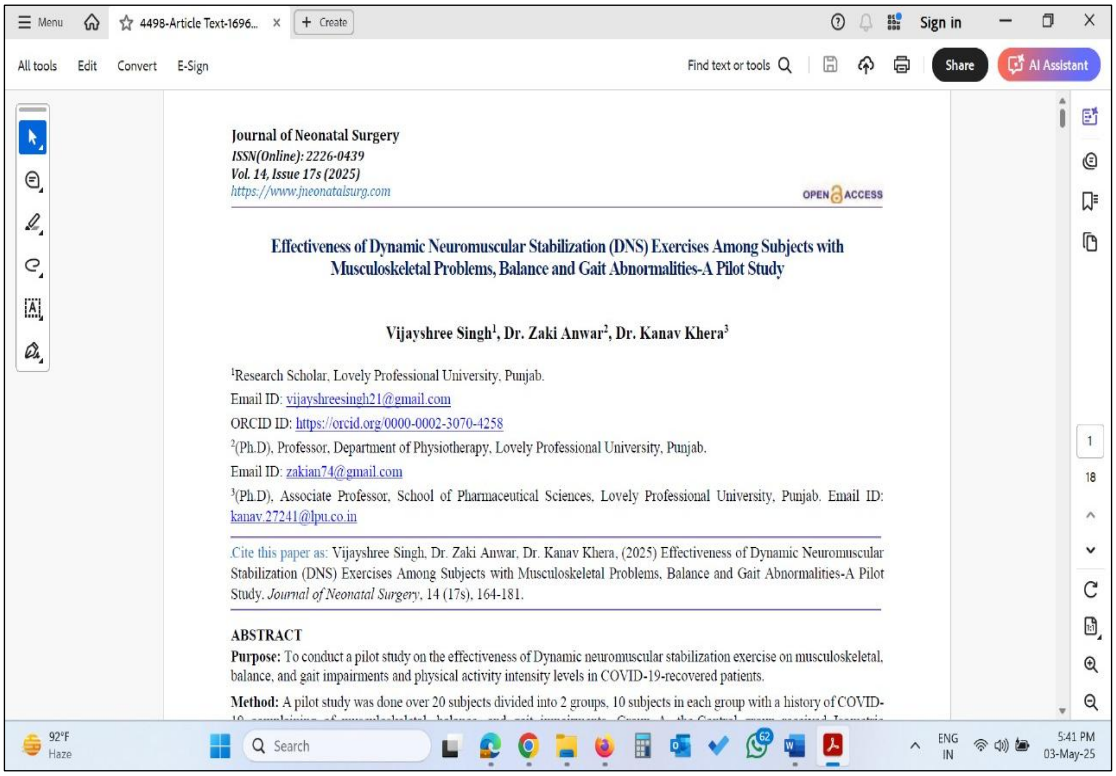
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ABSTRACT:

Introduction: The World Health Organization (2026) defines ongoing/long COVID as Symptoms that persist beyond the initial infection phase, including cognitive difficulties like brain fog.

Current rehabilitation emphasizes integrated strategies targeting neuromuscular control and breathing–posture coordination. Dynamic Neuromuscular Stabilization, grounded in developmental kinesiology, addresses these mechanisms; however, evidence for its effectiveness remains limited. This RCT investigated the effectiveness of Dynamic Neuromuscular Stabilization (DNS) in people with post-COVID condition, focusing on



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Effectiveness of Dynamic Neuromuscular Stabilization (DNS) Exercises Among Subjects with Musculoskeletal Problems, Balance and Gait Abnormalities-A Pilot Study

Vijayshree Singh[1], Dr. Zaki Anwar[2], Dr. Kanav Khera[3]

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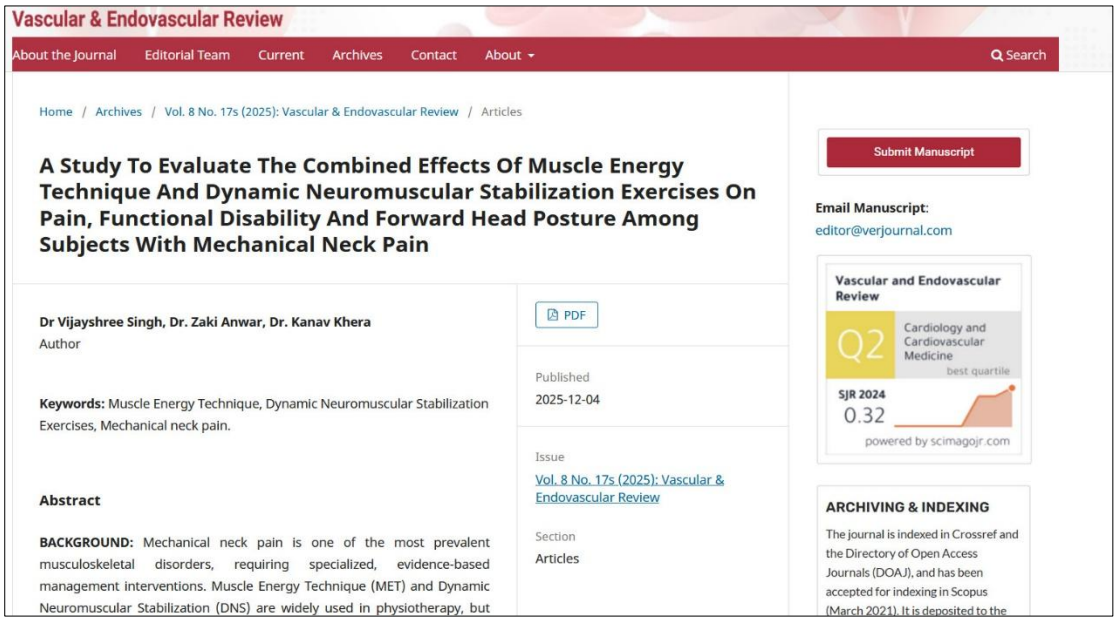
Cite this paper as: Vijayshree Singh, Dr. Zaki Anwar, Dr. Kanav Khera, (2025) Effectiveness of Dynamic Neuromuscular Stabilization (DNS) Exercises Among Subjects with Musculoskeletal Problems, Balance and Gait Abnormalities-A Pilot Study. *Journal of Neonatal Surgery*, 14 (17s), 164-181.

ABSTRACT

Purpose: To conduct a pilot study on the effectiveness of Dynamic neuromuscular stabilization exercise on musculoskeletal, balance, and gait impairments and physical activity intensity levels in COVID-19-recovered patients.

Method: A pilot study was done over 20 subjects divided into 2 groups, 10 subjects in each group with a history of COVID-

Paper Publication



Vascular & Endovascular Review

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A Study To Evaluate The Combined Effects Of Muscle Energy Technique And Dynamic Neuromuscular Stabilization Exercises On Pain, Functional Disability And Forward Head Posture Among Subjects With Mechanical Neck Pain

Dr Vijayshree Singh, Dr. Zaki Anwar, Dr. Kanav Khera
Author

PDF

Keywords: Muscle Energy Technique, Dynamic Neuromuscular Stabilization Exercises, Mechanical neck pain.

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Section
Articles

Abstract

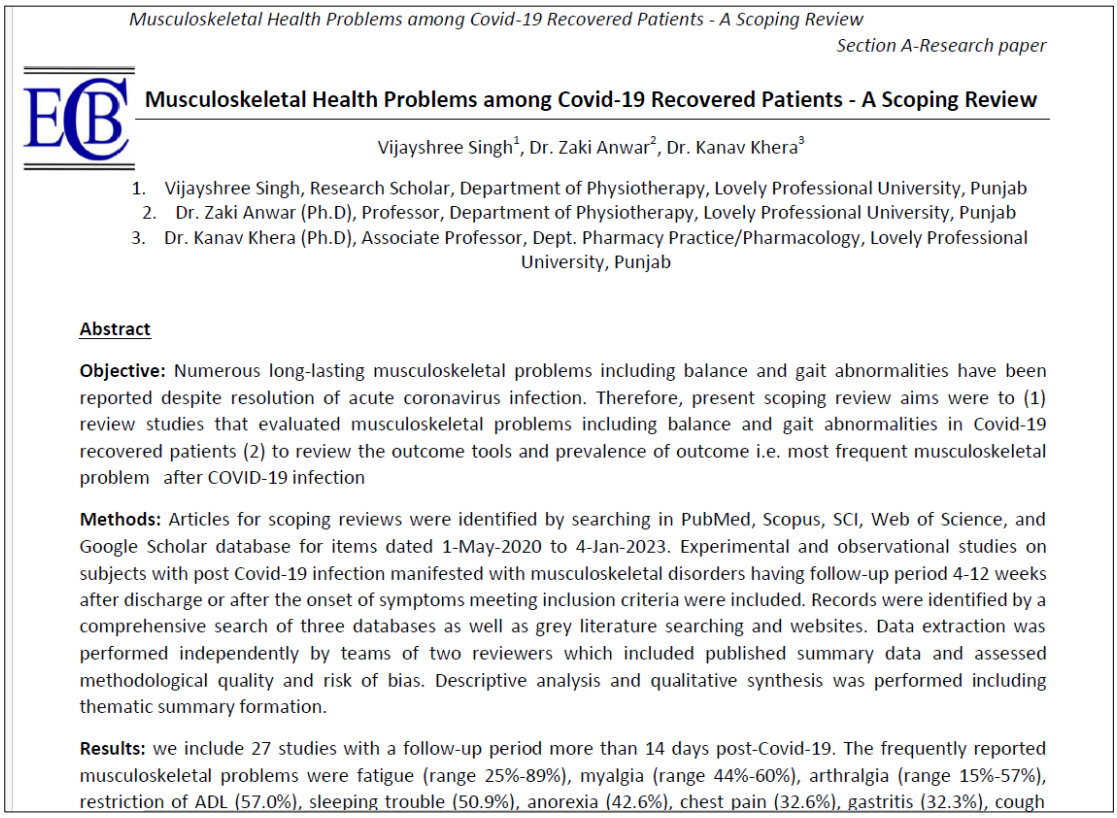
BACKGROUND: Mechanical neck pain is one of the most prevalent musculoskeletal disorders, requiring specialized, evidence-based management interventions. Muscle Energy Technique (MET) and Dynamic Neuromuscular Stabilization (DNS) are widely used in physiotherapy, but

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Musculoskeletal Health Problems among Covid-19 Recovered Patients - A Scoping Review

Vijayshree Singh[1], Dr. Zaki Anwar[2], Dr. Kanav Khera[3]

1. Vijayshree Singh, Research Scholar, Department of Physiotherapy, Lovely Professional University, Punjab
2. Dr. Zaki Anwar (Ph.D), Professor, Department of Physiotherapy, Lovely Professional University, Punjab
3. Dr. Kanav Khera (Ph.D), Associate Professor, Dept. Pharmacy Practice/Pharmacology, Lovely Professional University, Punjab

Abstract

Objective: Numerous long-lasting musculoskeletal problems including balance and gait abnormalities have been reported despite resolution of acute coronavirus infection. Therefore, present scoping review aims were to (1) review studies that evaluated musculoskeletal problems including balance and gait abnormalities in Covid-19 recovered patients (2) to review the outcome tools and prevalence of outcome i.e. most frequent musculoskeletal problem after COVID-19 infection

Methods: Articles for scoping reviews were identified by searching in PubMed, Scopus, SCI, Web of Science, and Google Scholar database for items dated 1-May-2020 to 4-Jan-2023. Experimental and observational studies on subjects with post Covid-19 infection manifested with musculoskeletal disorders having follow-up period 4-12 weeks after discharge or after the onset of symptoms meeting inclusion criteria were included. Records were identified by a comprehensive search of three databases as well as grey literature searching and websites. Data extraction was performed independently by teams of two reviewers which included published summary data and assessed methodological quality and risk of bias. Descriptive analysis and qualitative synthesis was performed including thematic summary formation.

Results: we include 27 studies with a follow-up period more than 14 days post-Covid-19. The frequently reported musculoskeletal problems were fatigue (range 25%-89%), myalgia (range 44%-60%), arthralgia (range 15%-57%), restriction of ADL (57.0%), sleeping trouble (50.9%), anorexia (42.6%), chest pain (32.6%), gastritis (32.3%), cough

ANNEXURE – 2 (Conference Certificates)



International Conference on Physical Therapy, Sports Medicine

Certificate

OF PRESENTATION

BioLEAGUES

International Conference on

Physical Therapy and Sports Medicine

21st & 22nd September 2023 | Virtual Conference

This is to certify that Ms/Mr/Mrs/Dr **Vijayshree Singh** of Lovely Professional University delivered their **Oral Presentation** titled Effectiveness of Dynamic Neuromuscular Stabilization (DNS) Exercises on Musculoskeletal Manifestations of Post-Covid 19 Patients in the "**International Conference Physical Therapy and Sports Medicine**" organized by BioLEAGUES on the 21st & 22nd September 2023

Jarapla Srinivas Nayak, Organizing Chairperson, ICPTSM

Dr. Shah Sarfraznawaz Fakiyoddin, Organizing Secretary, ICPTSM

Mr. Rudra Bhanu Satpathy, Founder & CEO, BioLEAGUES



Certificate of Presentation

Dr. Vithalrao Vikhe Patil Foundation, Ahmednagar

DVVPF's, College of Physiotherapy, Ahmednagar

Affiliated to Maharashtra University of Health Sciences, Nashik, Approved by Govt. of Maharashtra
Recognized by Maharashtra State O.T.P.T. Council, Mumbai and Indian Association of Physiotherapist,
Accredited with NAAC Grade "A" & Recognized by UGC 2 (F)

Department of Musculoskeletal Physiotherapy

In association with

Ahmednagar District IAP Branch and Indian Association of PT Women Cell

Organised

International Conference on Arthritis 2023 (Virtual)

WORLD ARTHRITIS DAY 12 OCTOBER

This is to certify that

Dr. Vijayashree Singh

has presented a paper titled ***To study the effect of isometric quadriceps strengtheniing exercise on pain, disability, quadricep strength and proprioception in unilateral knee OA among subject with post covid 19 syndrome*** *in category* ***Professional*** *at the* ***"International conference on Arthritis (Virtual) 2023"*** *conducted on Thursday 12th October 2023.*

Director (Medical) VIMS, Ahmednagar

Organizing Chairman

Organizing Secretary

Co-ordinator IAPWC

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ANNEXURE – 3 (Questionnaire – Physician Survey)

Survey to study the prevalence of musculoskeletal, Balance and Gait impairments in post Covid-19 patients.

Demographic Data

Name:	**Date:**
Name of the Organization:	**Designation:**
Specialization:	
Contact No.	
Email Id:	

Characteristics of musculoskeletal disorders among Covid-19 recovered patients (age: 18 to 45 Years)

S. No	Questionnaire	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	Is there an increase in number of patients with Musculoskeletal problems in OPD after Covid-19.					
2	Is there an increase in incidence of fracture after Covid-19.					
3	Is there an increase in evidence of strain/sprain after Covid-19.					
4	Is there an increase in prevalence of viral arthralgia after Covid-19.					
5	Is there an increase in prevalence of myalgia after Covid-19.					
6	Is there an increase in prevalence of arthritis pain after Covid-19.					
7	Is there an increase in incidence of symptoms of early fatigue after Covid-19.					
8	Is there any decrease in the physical activity on mild exertion after Covid-19.					
9	Is there an increase in incidence of new onset of backache after Covid-19.					
10	Is there an increase in incidence of new onset of neck pain after Covid-19.					
11	Is there an increase in Incidence of new onset of hip/knee pain after Covid-19.					
12	Is there an increase in history of frequent fall and Gait abnormalities after Covid-19.					
13	Is there an increase in history of Balance impairment after Covid-19.					
14	Is there an increase in evidence of frequency of joint pain after Covid-19.					
15	Is there an increase in frequency of swelling in and around joints after Covid-19.					
16	Is there an increase in prevalence of decrease in Ca+ and Vitamin D levels after Covid-19.					
17	Is there an increase in incidence of radiological evidence of degeneration changes present among targeted age group population (18 to 45 years).					

Seal & Signature: _____

ANNEXURE – 4 (Questionnaire – Public Survey)

Questionnaire for Musculoskeletal Dysfunction

Name:	**Aadhaar Card No.:**
Date of Assessment:	**Date of Birth:** **Age:**
Marital Status: Married ( ) Single ( ) Divorced ( ) Widowed ( )	
Gender: Male ( ) Female ( ) Other ( )	**Mobile No:**
Email id:	

Address: _____

_____

General Awareness/Biometric:

- **Occupation:** Student ( ) Professional ( ) Own Business ( ) Housewife ( )
- **Time of having Covid-19 Infection:** Less than 6 Months ( ) 6 to 12 months ( ) More than 1 Year ( )
- **Mode of recovery:** Home quarantine ( ) Hospitalized ( )
- **Steroids taken:** Yes ( ) No ( )
- **Dosage of Vaccination:** Dosage 1 ( ) Both ( ) Booster ( )

Questionnaire				
Category	**S. No.**	**Question**	**Yes**	**No**
General Questions	1	Having addiction of Smoking/Alcohol before Covid-19 infection		
	2	**Medical Condition:**		
		• presence of any underline disease before Covid-19 infection		
		• Without Any medical condition before Covid-19		
	3	**Onset of Musculoskeletal pain:**		
		• Before getting Covid-19 Infection		
		• After getting Covid-19 infection		
	4	**Location of musculoskeletal pain:**		
		• Neck Pain		
		• Upper Back		
		• Lower Back		
		• Arm		
		• Fore Arm		
		• Wrist/Hand		
		• Hips/Thigh		
		• Knee		
		• Ankle/Foot		
	5	Swelling in joints post Covid-19 infection		
	6	Amount of time taken for any physical activity has increased after Codiv-19 infection		
	7	Do you get tired easily, while doing daily routine work?		
	8	Do you have pain in Chest/between ribs?		
	9	**Shortness of breath after Covid-19 infection, while**		
		• Taking Rest		
		• Doing Activity		
	10	Increased muscle cramps after Covid-19 Infection		

Questionnaire for Musculoskeletal Dysfunction

GAIT related Questions	11	Change in walking rhythm after Covid-19 infection		
	12	Irregular foot placement after Covid-19 infection		
	13	Walk with wide based after Covid-19 infection		
	14	Decrease in Walking Speed after Covid-19 infection		
	15	Do you face any difficulty while shifting position from standing to walking?		
	16	Do you feel any difficulty in taking short steps while walking?		
	17	Do you feel any difficulty in taking long steps while walking?		
Balance related Questions	18	**Experience dizziness during:**		
		• Siting		
		• Standing		
		• Walking		
		• Running		
	19	Do you feel any disturbance in balance while changing position from sitting to standing?		
	20	Do you feel any disturbance in balance while changing position from standing to sitting?		
	21	Do you feel any disturbance in balance while changing position from standing to walking?		

Name & Signature: _____

ANNEXURE – 5 (Informed Consent Form – Public Survey)

INFORMED CONSENT FORM

(APPROVED BY INSTITUTIONAL ETHICS COMMITTEE, LOVELY PROFESSIONAL UNIVERSITY)
(ANNEXURE 15)

Title: PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL, BALANCE ANDF GAIT IMPAIRMENTS IN INDIVIDUALS WITH POST - COVID-19 INFECTION

Invitation for participation: You are invited to participate in a research study on PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL, BALANCE AND GAIT IMPAIRMENTS IN INDIVIDUALS WITH POST - COVID-19 INFECTION.

Purpose of the study: To find out the musculoskeletal problems faced by people post Covid-19 infection and their physiotherapeutic management.

Explanation of the procedure:

Subjects who agree to give their consent are required to fill this survey.

Risk of participation:

There is no risk in the procedure.

Financial implication:

All this procedure will be done free of cost.

Assurance of confidentiality:

Any information obtained in connection with this survey will be kept confidential. If information in this study will be published in appropriate journals or presented at professional meeting, then your identity will be kept strictly confidential.

Withdrawal from the study:

Participation in this study is voluntary. Even if you decide to participate in the study, you are free to withdraw and discontinue at any time during the study.

Consent of participation: I have voluntarily decided to participate in this research study. I have been explained by the researcher about the study. I have read and understood the information presented. I certify that I have voluntarily decided to participate in the study.

Kindly give you consent for the survey:

- Yes ( )
- No ( )

ANNEXURE – 6 (Patient Information Sheet – Public Survey)

PATIENT INFORMATION SHEET
(APPROVED BY INSTITUTIONAL ETHICS COMMITTEE,
LOVELY PROFESSIONAL UNIVERSITY)

Myself Vijayshree Singh, a Ph.D research scholar in Physiotherapy at Lovely Professional University, Phagwara, Punjab;under the Supervision Dr. Zaki Anwar, Professor, Department of Physiotherapy, Lovely Professional University, Phagwara, Punjab and co-supervisor Dr. Kanav Khera, Professor, Department of Pharmacy Practice, School of Pharmaceutical Sciences, Lovely Professional University, Phagwara.

I am conducting a survey on the title "PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL, BALANCE AND GAIT IMPAIRMENTS IN INDIVIDUALS WITH POST - COVID-19 INFECTION." in DAV Institute of Physiotherapy & Rehabilitation, Jalandhar.

I am going to give you information and would like to invite you to be part of this survey. I am going to ask you questions related to your problems like pain in joints, any changes in walking pattern or balance which you might have faced after recovery from Covid-19.

Before you decide, you can talk to anyone you feel comfortable with about the study. Please ask me to stop as you go through the information, and I will take the time to explain. If you have questions later you can ask them to me.

Procedure: If you agree to participate in the survey then you will be interviewed for 5-10 minutes regarding the joints pain, walking and balance faced by you after recovering from Covid-19. You'll be asked to fill out a form or answer some questions on paper related to your health after recovery from covid-19 infection. Your answers will help us learn more about certain topics. Your participation will be a big help, and we appreciate you taking the time to share with us.

Potential benefits: There may or may not be a direct benefit to you if you participate in this survey but it may help you to understand the impact of understanding the health-related information after recovering from Covid-19.

Confidentiality of Information: we ensure you that your data will be kept confidential and your name will not be disclosed to anyone. This data will be used for academic purposes or can be used for publication.

Voluntary participation: Your participation in this survey is entirely your choice whether to participate or not. If you choose not to participate all the services, you receive here will continue and nothing will change. You may change your mind later and stop participating even if you agreed earlier.

Whom to contact in case of any question: If you have any questions, you may ask now or later. If you wish to ask questions later, you may contact me at below mentioned address.

- Contact Person: Vijayshree Singh
- Mobile no.: 9340118147
- Email id: vijayshreesingh21@gmail.com
- Address: Department of Physiotherapy, Lovely Professional University.

ANNEXURE – 7 (Informed Consent Form – Intervention Study)

INFORMED CONSENT FORM

(APPROVED BY INSTITUTIONAL ETHICS COMMITTEE, LOVELY PROFESSIONAL UNIVERSITY)
(ANNEXURE 15)

- **Study Title:** PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL, BALANCE AND GAIT IMPAIRMENTS IN INDIVIDUALS WITH POST - COVID-19 INFECTION.
- **Study Number:** _____

Subject's Full Name: _____

Date of Birth/Age: _____

Address: _____

1. I confirm that I have read and understood the information sheet dated _____for the above study and have had the opportunity to ask questions.

OR

I have been explained the nature of the study by the Investigator and had the opportunity to ask questions

2. I understand that my participation in the study is voluntary and that I am free to withdraw at any time, without giving any reason and without my medical care or legal rights being affected.

3. I understand that the sponsor of the clinical trial/project, others working on the Sponsor's behalf, the Ethics Committee and the regulatory authorities will not need my permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the trial. However, I understand that my identity will not be revealed in any information released to third parties or published.

4. I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s)

5. I agree to take part in the above study

Signature (or Left Thumb impression) of the Subject/Legally Acceptable Representative:

Signatory's Name: Date:

Signature of the Witness: Date: Name of the Witness:

Signature of the Investigator: Date: Study Investigator's Name:

ANNEXURE – 8 (Patient Information Sheet – Intervention Study)

PATIENT INFORMATION SHEET

(APPROVED BY INSTITUTIONAL ETHICS COMMITTEE, LOVELY PROFESSIONAL UNIVERSITY)

CTRI/2023/03/050962 [Registered on: 22/03/2023]

Myself Vijayshree Singh, a Ph.D research scholar in Physiotherapy at Lovely Professional University, Phagwara, Punjab; under the Supervision Dr. Zaki Anwar, Professor, Department of Physiotherapy, Lovely Professional University, Phagwara, Punjab and Co-supervisor Dr. Kanav Khera, Professor, Department of Pharmacy Practice, School of Pharmaceutical Sciences, Lovely Professional University, Phagwara. I am conducting a study on the Title "**PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL, BALANCE AND GAIT IMPAIRMENTS IN INDIVIDUALS WITH POST - COVID-19 INFECTION.**" in DAV Institute of Physiotherapy & Rehabilitation, Jalandhar.

I am going to give you information and would like to invite you to be part of this study. I am going to ask you questions related to pain and disturbances in balance and walking pattern, which you might have faced after recovery from Covid-19 and will give you physiotherapy treatment to improve these problems.

Before you decide, you can talk to anyone you feel comfortable with about the study. I will explain you the procedure of treatment. Please ask me to stop as you go through the information, and I will take the time to explain. If you have questions later, you can ask them to me.

PROCEDURE:

You are invited to participate in a research study called a randomized controlled trial (RCT). This study aims to evaluate the effectiveness of a new treatment or intervention compared to the current standard of care. If you agree to participate in this study, you will be randomly assigned to one of two groups. Each group will receive a different treatment or intervention. The allocation to each group will be determined randomly, YOU WILL BE ASKED QUESTIONS REGARDINS MUSCLE AND JOINT PAIN, DEVIATION FROM NORMAL WALKING PATTERN INCLUDING BALANCE DISTURBANCES. AFTER DETAIL ANALYSIS OF YOUR COMPLAINTS, TREATMENT WILL BE GIVEN TO YOU WHICH WILL INCLUDE:

- **AN ELECTRIC THERAPY NAMED TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION (TENS):**

  It is a treatment that uses a small device to deliver electrical impulses to certain parts of your body, typically through electrodes placed on your skin. These impulses can help to relieve pain by interfering with the pain signals that travel from your nerves to your brain. It will be given for time duration 20 minutes with pre- set parameters.

- **EXERCISES- THESE INCLUDES:**

  ✓ Strength training exercises where you will contract your muscles without moving your joints. Instead of lifting or lowering weights, you will hold a position to build your muscle strength. (Isometric exercises).

- ✓ Exercises focusing on activating the natural movement patterns that we developed as infant's exercises (DNS). It will be done at 3 levels using resistance bands and gym ball. It is 40 min exercises with 5-minute warm-up by static sycling and 5 min cool-down; 2 weeks will be for each level exercise training session. Pictorial hand-outs will be given to learn the correct pattern of exercises.

EXPECTED DURATION PARTICIPATION IN THE STUDY:

You will attend treatment sessions five days a week, Monday through Friday, for a total of six weeks. Consistency is important for maximizing the effectiveness of your treatment.

THE POSSIBLE BENEFIT OF PARTICIPATION IN THE RESEARCH TO THE SUBJECT:

By taking part in this research, you might help us find new ways to treat or even prevent certain health conditions. By application of treatment interventions, the patient pain may get relieved. There can also be improvement in balance and altered walking pattern which is still affecting your health after recovery from covid-19. Also there can be improvement in your daily task-based functional activities.

REIMBURSEMENT:

There will be no monetary compensation provided to participants for their participation in this study.

CONFIDENTIALITY OF INFORMATION:

We ensure you that your data will be kept confidential and your name name will not be siaclosed to any one and will not be included in any documents.

VOLUNTARY PARTICIPATION:

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. If you choose not to participate all the services, you receive here will continue and nothing will change. You may change your mind later and stop participating even if you agreed earlier. It is your choice and all of your rights will still be respected.

WHOM TO CONTACT IN CASE OF ANY QUESTION: If you have any questions, you may ask now or later. If you wish to ask questions later, you may contact me at below mentioned address.

- Contact Person: Vijayshree Singh
- Mobile no.: 9340118147
- Email id: vijayshreesingh21@gmail.com
- Address: Department of Physiotherapy, Lovely Professional University.

ANNEXURE – 9 (LPU – Ethical Committee Approval)

LOVELY PROFESSIONAL UNIVERSITY
Transforming Education Transforming India

INSTITUTIONAL ETHICS COMMITTEE (IEC)
(Registration No: EC/NEW/INST/2022/3110)

Ref: LPU/IEC-LPU/2024/2/5
Date: 12.04.24

Dear Vijayshree Singh

The Institutional Ethics Committee, Lovely Professional University (IEC-LPU) reviewed and discussed your application to conduct the study entitled **"Prevalence and physiotherapeutic management for musculoskeletal, balance and gait impairments in individuals with post-COVID-19 infection".**

The following documents were reviewed:
(a) Application form
(b) Research Protocol
(c) Patient information sheet and informed consent form in English or vernacular language.
(d) Principal investigator's current Curriculum Vitae.
The following members of the ethics committee were present at the meeting held on 28.03.24

Sr. No	Name	Designation as per IEC
1	Dr. Shivani Tandon	Chairperson
2	Dr. Navneet Khurana	Member Secretary
3	Dr. Kanav Khera	Alternate Member Secretary
4	Dr. Anil Malhotra	Clinician-I
5	Dr. Naresh Kundra	Clinician-II
6	Dr. Meenu Chopra	Legal expert
7	Mr. Sumesh Mathew	Social scientist/Philosopher/Ethicist/Theologian
8	Dr. Rajan Kumar Sharma	Layperson

The Ethics committee **approved** the study to be conducted in its presented form subject to the condition of

- Researchers conducting studies beyond a 50 km radius of LPU must ensure they obtain local ethical approval and comply with any applicable regulations
- The principal investigator and all members of the project shall ensure compliance with current regulatory provisions (as per New Drug Clinical Trial Rules 2019 and ICH-GCP), Ethical Guidelines for Biomedical Research on Human Participants by ICMR, and the standard operating procedure of IEC including timely submission of Interim Annual Report and Final Closure Report.
- Participant Information Sheet and a copy of signed Informed Consent shall be given to every research participant.
- Inform IEC in case of any proposed amendments (change in protocol/procedure, site / Investigator, etc).
- Inform IEC immediately in case of any Adverse Events and Serious Adverse Events.
- Members of the IEC have the right to monitor any project with prior intimation.

Yours sincerely,

Chairperson/Member secretary/Alternate member secretary, IEC-LPU

12/04/24
dd/mm/yyyy

Member Secretary
Institutional Ethics Committee
Lovely Professional University
Phagwara-Punjab-144411

NAAC GRADE A++

Jalandhar-Delhi G.T. Road, Phagwara, Punjab (India) - 144411
Ph : +91-1824-444039 E-mail : ms_ieclpu@lpu.co.in website : www.lpu.in

ANNEXURE – 10 (DAV – Institutional Ethical Committee Approval)



D.A.V. INSTITUTE OF PHYSIOTHERAPY & REHABILITATION

Mahatma Hans Raj Marg, G.T. Road, Jalandhar-144 008 (Pb.) INDIA

Communication of Decision of the Institutional Ethics Committee(IEC)

IEC No.Phd- 2021-2024

Presentation Date:15.10.2022

Protocol Title	PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL , GAIT AND BALANCE IMPAIRMENTS IN INDIVIDUALS WITH POST- COVID-19 INFECTION .
Principal Investigator	VIJAYSHREE SINGH
Co-Investigator	DR. POONAM CHATURVEDI
Name of the department	Department Orthopedic Physiotherapy
New review	Yes
Date of review Date of Previous review if revised application	15.10.2022
Decision of IEC • Approved • Approved with suggestions • Revision • Rejected	Approved
Suggestions/ Reason/Remarks	
Recommended for a period of	5 Years

- *The information is only for the period mentioned above*
- *Inform IEC in case of any amendments to the protocol ,change of study procedure, site and investigator with reason along with the summary*
- *Inform IEC immediately in case of any adverse events and serious adverse events within 48 hours*
- *Member of IEC have right to monitor the trial / study with prior intimation.*

Dr. Jitendra Sharma: Chairperson

Dr. Shilpy Jetly : Member

Sr. Ram Babu: Member

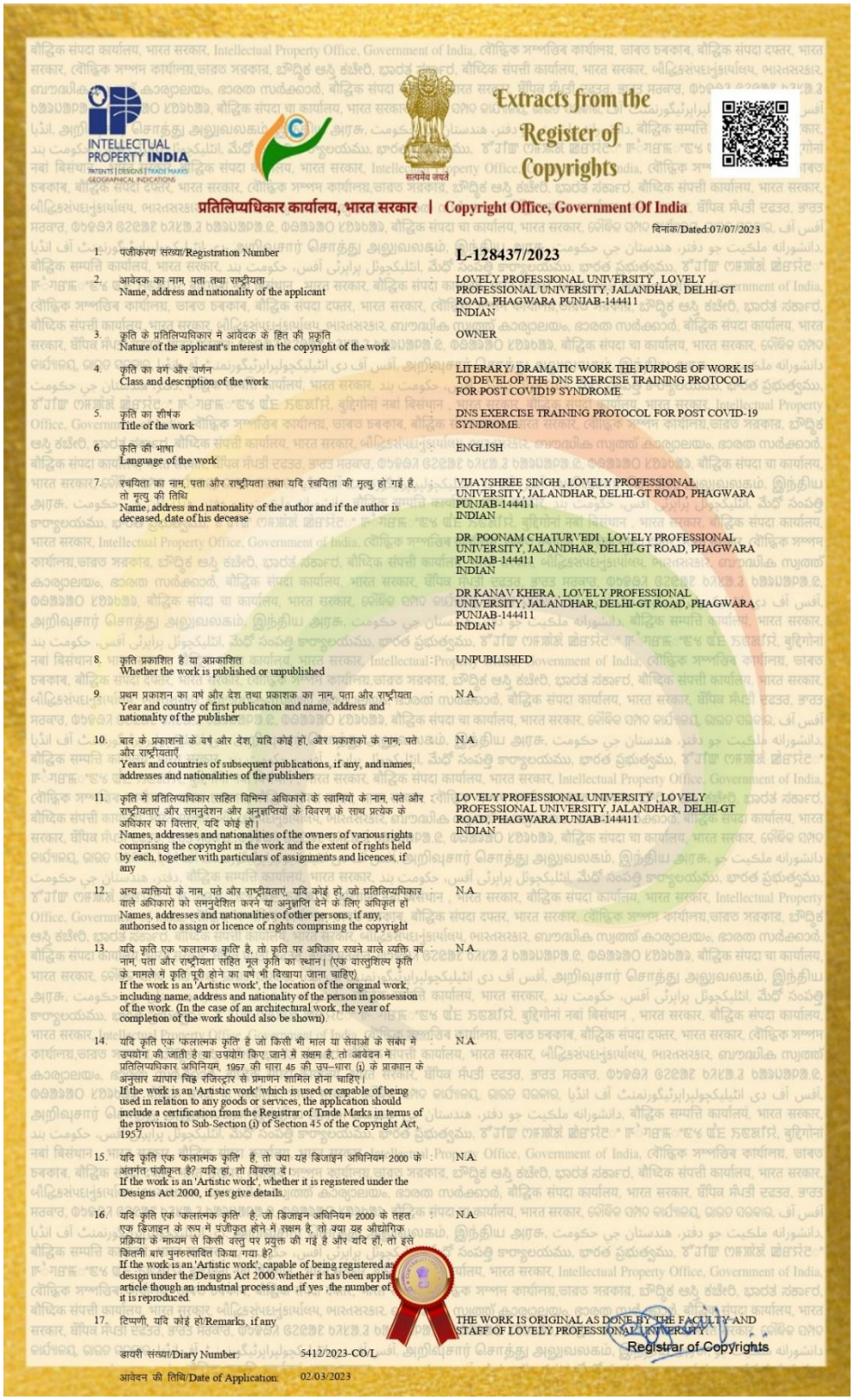
Dr. Yash Partap : Member

Dr. Manika Saxena: Member

2023-2-18 16:05

Tel.: (+91)181-2208021, 2209228 E-Mail: info@davrehabilitation.ac.in, davrehab_jal@hotmail.com

ANNEXURE – 11 (Copyright Certificate Title: DNS EXERCISE TRAINING PROTOCOL FOR POST COVID-19 SYNDROME)



INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

Extracts from the Register of Copyrights

प्रतिलिप्यधिकार कार्यालय, भारत सरकार | Copyright Office, Government Of India

दिनांक/Dated:07/07/2023

1.	पंजीकरण संख्या/Registration Number	**L-128437/2023**
2.	आवेदक का नाम, पता तथा राष्ट्रीयता Name, address and nationality of the applicant	LOVELY PROFESSIONAL UNIVERSITY , LOVELY PROFESSIONAL UNIVERSITY, JALANDHAR, DELHI-GT ROAD, PHAGWARA PUNJAB-144411 INDIAN
3.	कृति के प्रतिलिप्यधिकार में आवेदक के हित की प्रकृति Nature of the applicant's interest in the copyright of the work	OWNER
4.	कृति का वर्ग और वर्णन Class and description of the work	LITERARY/ DRAMATIC WORK THE PURPOSE OF WORK IS TO DEVELOP THE DNS EXERCISE TRAINING PROTOCOL FOR POST COVID19 SYNDROME.
5.	कृति का शीर्षक Title of the work	DNS EXERCISE TRAINING PROTOCOL FOR POST COVID-19 SYNDROME.
6.	कृति की भाषा Language of the work	ENGLISH
7.	रचयिता का नाम, पता और राष्ट्रीयता तथा यदि रचयिता की मृत्यु हो गई है तो मृत्यु की तिथि Name, address and nationality of the author and if the author is deceased, date of his decease	VIJAYSHREE SINGH , LOVELY PROFESSIONAL UNIVERSITY, JALANDHAR, DELHI-GT ROAD, PHAGWARA PUNJAB-144411 INDIAN DR. POONAM CHATURVEDI , LOVELY PROFESSIONAL UNIVERSITY, JALANDHAR, DELHI-GT ROAD, PHAGWARA PUNJAB-144411 INDIAN DR KANAV KHERA , LOVELY PROFESSIONAL UNIVERSITY, JALANDHAR, DELHI-GT ROAD, PHAGWARA PUNJAB-144411 INDIAN
8.	कृति प्रकाशित है या अप्रकाशित Whether the work is published or unpublished	UNPUBLISHED
9.	प्रथम प्रकाशन का वर्ष और देश तथा प्रकाशक का नाम, पता और राष्ट्रीयता Year and country of first publication and name, address and nationality of the publisher	N.A.
10.	बाद के प्रकाशनों के वर्ष और देश, यदि कोई हो, और प्रकाशकों के नाम, पते और राष्ट्रीयताएँ Years and countries of subsequent publications, if any, and names, addresses and nationalities of the publishers	N.A.
11.	कृति में प्रतिलिप्यधिकार सहित विभिन्न अधिकारों के स्वामियों के नाम, पते और राष्ट्रीयताएं और समनुदेशन और अनुज्ञप्तियों के विवरण के साथ प्रत्येक के अधिकार का विस्तार, यदि कोई हो। Names, addresses and nationalities of the owners of various rights comprising the copyright in the work and the extent of rights held by each, together with particulars of assignments and licences, if any	LOVELY PROFESSIONAL UNIVERSITY , LOVELY PROFESSIONAL UNIVERSITY, JALANDHAR, DELHI-GT ROAD, PHAGWARA PUNJAB-144411 INDIAN
12.	अन्य व्यक्तियों के नाम, पते और राष्ट्रीयताएं, यदि कोई हों, जो प्रतिलिप्यधिकार वाले अधिकारों को समनुदेशित करने या अनुज्ञप्ति देने के लिए अधिकृत हों Names, addresses and nationalities of other persons, if any, authorised to assign or licence of rights comprising the copyright	N.A.
13.	यदि कृति एक 'कलात्मक कृति' है, तो कृति पर अधिकार रखने वाले व्यक्ति का नाम, पता और राष्ट्रीयता सहित मूल कृति का स्थान। (एक वास्तुशिल्प कृति के मामले में कृति पूरी होने का वर्ष भी दिखाया जाना चाहिए) If the work is an 'Artistic work', the location of the original work, including name, address and nationality of the person in possession of the work. (In the case of an architectural work, the year of completion of the work should also be shown).	N.A.
14.	यदि कृति एक 'कलात्मक कृति' है जो किसी भी माल या सेवाओं के संबंध में उपयोग की जाती है या उपयोग किए जाने में सक्षम है, तो आवेदन में प्रतिलिप्यधिकार अधिनियम, 1957 की धारा 45 की उप–धारा (i) के प्रावधान के अनुसार व्यापार चिह्न रजिस्ट्रार से प्रमाणन शामिल होना चाहिए। If the work is an 'Artistic work' which is used or capable of being used in relation to any goods or services, the application should include a certification from the Registrar of Trade Marks in terms of the provision to Sub-Section (i) of Section 45 of the Copyright Act, 1957.	N.A.
15.	यदि कृति एक 'कलात्मक कृति' है, तो क्या यह डिजाइन अधिनियम 2000 के अंतर्गत पंजीकृत है? यदि हां, तो विवरण दें। If the work is an 'Artistic work', whether it is registered under the Designs Act 2000, if yes give details.	N.A.
16.	यदि कृति एक 'कलात्मक कृति' है, जो डिजाइन अधिनियम 2000 के तहत एक डिजाइन के रूप में पंजीकृत होने में सक्षम है, तो क्या यह औद्योगिक प्रक्रिया के माध्यम से किसी वस्तु पर प्रयुक्त की गई है और यदि हाँ, तो इसे कितनी बार पुनरुत्पादित किया गया है? If the work is an 'Artistic work', capable of being registered as design under the Designs Act 2000 whether it has been applied article though an industrial process and ,if yes ,the number of it is reproduced.	N.A.
17.	टिप्पणी, यदि कोई हो/Remarks, if any	THE WORK IS ORIGINAL AS DONE BY THE FACULTY AND STAFF OF LOVELY PROFESSIONAL UNIVERSITY.

डायरी संख्या/Diary Number: 5412/2023-CO/L

आवेदन की तिथि/Date of Application: 02/03/2023

Registrar of Copyrights

ASSESSMENT FORM

Name: _____

Age / Sex: _____

Occupation: _____

Address: _____

Chief Complaint: _____

_____

Present History: _____

_____

Medical History & Medicines Prescribed: _____

_____

Surgical History: _____

_____

H/o of Covid-19 Infection: Yes [ ] No [ ]

Duration since Covid-19 Infection: Less than 6 Months [ ] More than 6 Months [ ]

No. of Fall/Frequent Injury: Yes [ ] No [ ]

On Observation:

- Built – Ectomorphic / Mesomorphic / Endomorphic
- Assistive Device: Yes/No
- GAIT
- Oedema
- Deformity
- Colour of Skin/Texture

On Palpation:

- Warmth
- Tenderness
- Pitting/ Non Pitting Oedema
- Passive Movement Contracture

Motor Examination:

- ROM

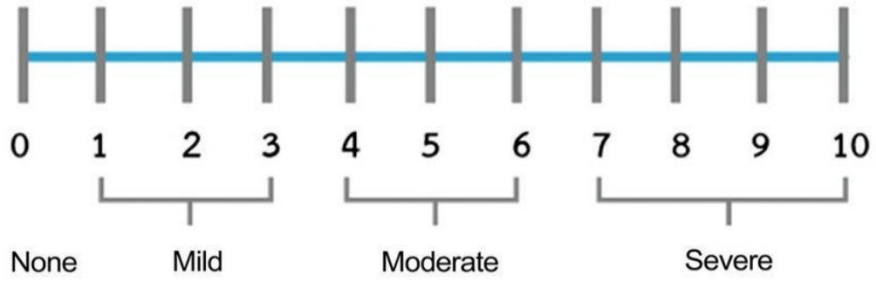
Functional Evaluation:

- Borg Rating of Perceived Exertion
- Tinetti Gait and Balance Assessment Tool

Investigation Report:

- Vitamin D
- X-Ray / Bone Scan
- Total and Ionoc calcium
- Blood Examination

NPRS Score:



TINETTI ASSESSMENT TOOL: BALANCE

RESIDENT NAME: _____

Initial Instructions: Subject is seated on a hard, armless chair. The following maneuvers are tested.

TASK	DESCRIPTION OF BALANCE	Possible	Score	Date	Score	Date	Score	Date
1. SITTING BALANCE	Leans or slides in chair	0						
	Steady, safe	1						
2. RISES FROM CHAIR	Unable without help	0						
	Able, uses arms to help up	1						
	Able without using arms	2						
3. ATTEMPTS TO RISEFROM CHAIR	Unable without help	0						
	Able, requires > 1 attempt	1						
	Able to rise in 1 attempt	2						
4. IMMEDIATE STANDING BALANCE(first 5 seconds)	Unsteady (swaggers, moves feet, trunk sways)	0						
	Steady but uses walker or other support	1						
	Steady without walker or other support	2						
5. STANDING BALANCE	Unsteady	0						
	Steady but wide stance (heels 4 inches apart) and uses cane or other support	1						
	Narrows stance without support	2						
6. NUDGED (subjectat max position with feet as close together as possible, examiner pushes lightly on subject's sternum with palm of hand 3 times)	Begins to fall	0						
	Staggers, grabs, catches self	1						
	Steady	2						
7. EYES CLOSED (atmax position – see #6 above)	Unsteady	0						
	Steady	1						
8. TURNING 360DEGREES	Discontinuous steps	0						
	Continuous steps	1						
	Unsteady (grabs, swaggers)	0						
	Steady	1						
9. SITTING DOWN	Unsafe (misjudged distance, falls into Chair)	0						
	Uses arms or not a smooth motion	1						
	Safe, smooth motion	2						
	BALANCE SCORES:			**RATE 1**		**RATE 2**		**RATE 3**

DATE OF ASSESSMENT	ASSESSOR SIGNATURE AND TITLE	LOCATION DURING ASSESSMENT
1.		
2.		
3.		

TINETTI ASSESSMENT TOOL: GAIT

RESIDENT NAME: _____

Initial Instructions: Subject stands with examiner, walks down the hallway or across the room, first at "usual" pace, then back at "rapid but safe" pace. Use usual walking aid.

TASK	DESCRIPTION OF BALANCE	Possible	Score	Date	Score	Date	Score	Date
10. INITIATION OF GAIT (immediately after told to "go)	Any hesitancy or multiple attempts to start	0						
	No hesitancy	1						
11. STEP LENGTHAND HEIGHT	RIGHT swing food does not pass left stance foot with step	0						
	RIGHT foot passes left stance foot	1						
	RIGHT foot does not clear floor completely with step	0						
	RIGHT foot completely clears floor	1						
	LEFT swing foot does not pass right Stance foot with step	0						
	LEFT foot passes right stance foot	1						
	LEFT foot does not clear floor Completely with step	0						
	LEFT foot completely clears floor	1						
12. STEP SYMMETRY	RIGHT AND LEFT step length not equal (estimate)	0						
	RIGHT AND LEFT step appear equal	1						
13. STEP CONTINUITY	Stopping or discontinuity between steps	0						
	Steps appear to continue	1						
14. PATH (estimated in relation to floor tiles,12-inch diameter. Observe excursion of 1foot over about 10 feet of the course)	Marked deviation	0						
	Mild/moderate deviation or uses walking aid	1						
	Straight without walking aid	2						
15. TRUNK	Marked sway or uses walking aid	0						
	No sway – but flexion of knees or back, or spreads arms out while walking	1						
	No sway, no flexion, no use of arms, and no use of walking aid	2						
16. WALKING STANCE	Heels apart	0						
	Heels almost touching while walking	1						
	Score – GAIT:							
	Score – BALANCE:							
	Score: BALANCE & GAIT:							
				RATE 1		**RATE 2**		**RATE 3**

DATE OF ASSESSMENT	ASSESSOR SIGNATURE AND TITLE	LOCATION DURING ASSESSMENT
1.		
2.		
3.		

ANNEXURE – 15 (BORG RPE Scale)

RATING OF PERCEIVED EXERTION BORG RPE SCALE		
6	Very, Very light	How you feel when lying in bed or sitting in a chair relaxed. Little or no effort
7		
8	Very Light	
9		
10	Fairly Light	
11		
12	Somewhat Hard	Target Range: How you should feel with exercise or activity
13		
14	Hard	
15		
16		
17	Very Hard	How you felt with the hardest work you have ever done Don't work this hard
18	Very, Very Hard	
19		
20	Maximum Exertion	

ANNEXURE – 16 (Individual Data Collection Report)

DATA COLLECTION FORM

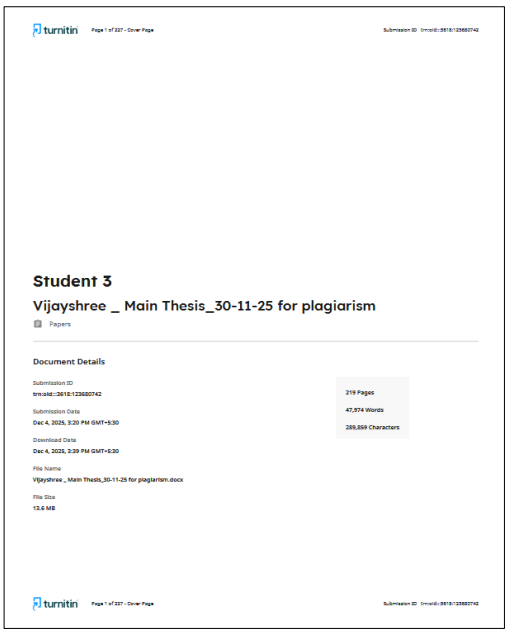
FORM SERIAL NO.:
_____

Patient Name:
_____
_

Age: _____ Mobile No. _____

Outcome Parameters	Day 1 pre-intervention	3rd week post-intervention	6th week post-intervention
NPRS Score (on scale of 0 to 10)			
TINETTI ASSESSMENT TOOL: BALANCE (on scale of 0 to 16)			
TINETTI ASSESSMENT TOOL: GAIT (on scale of 0 to 12)			
BORG Rating (on scale of 6 to 20)			

ANNEXURE – 17 (Plagiarism Report)



turnitin Page 1 of 227 - Cover Page Submission ID trn:oid:::3618:123680742

Student 3

Vijayshree _ Main Thesis_30-11-25 for plagiarism

Papers

Document Details

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Submission Date
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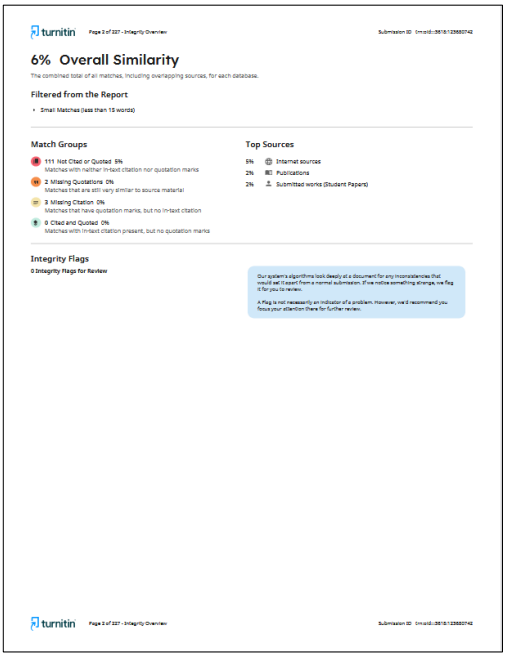
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File Name
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File Size
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219 Pages
47,874 Words
289,859 Characters

turnitin Page 1 of 227 - Cover Page Submission ID trn:oid:::3618:123680742



turnitin Page 2 of 227 - Integrity Overview Submission ID trn:oid:::3618:123680742

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Matches with in-text citation present, but no quotation marks

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Integrity Flags

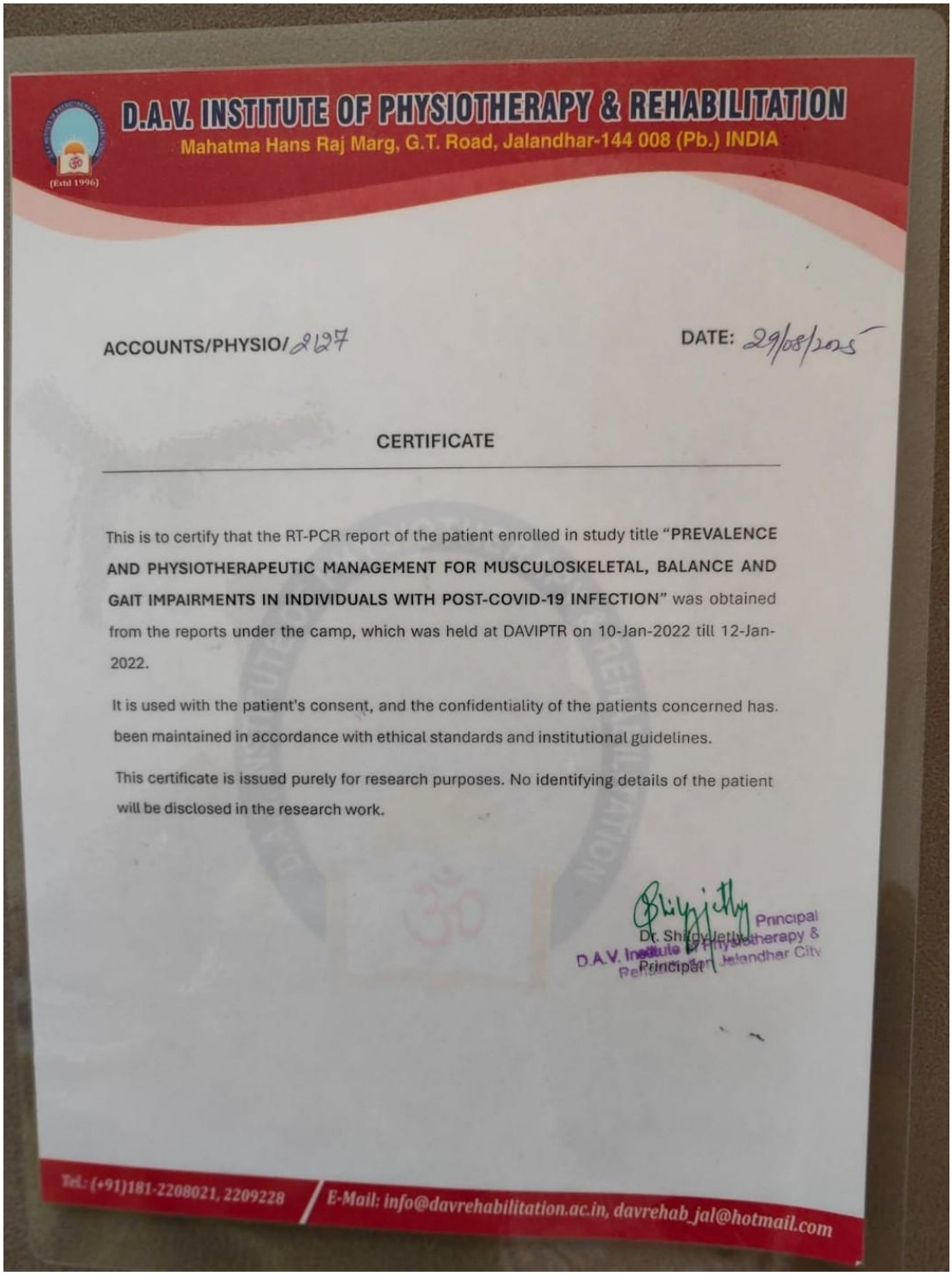
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A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.

turnitin Page 2 of 227 - Integrity Overview Submission ID trn:oid:::3618:123680742

ANNEXURE – 18 (RT-PCR Certificate)



D.A.V. INSTITUTE OF PHYSIOTHERAPY & REHABILITATION

Mahatma Hans Raj Marg, G.T. Road, Jalandhar-144 008 (Pb.) INDIA

(Estd 1996)

ACCOUNTS/PHYSIO/2127 DATE: 29/08/2025

CERTIFICATE

This is to certify that the RT-PCR report of the patient enrolled in study title "**PREVALENCE AND PHYSIOTHERAPEUTIC MANAGEMENT FOR MUSCULOSKELETAL, BALANCE AND GAIT IMPAIRMENTS IN INDIVIDUALS WITH POST-COVID-19 INFECTION**" was obtained from the reports under the camp, which was held at DAVIPTR on 10-Jan-2022 till 12-Jan-2022.

It is used with the patient's consent, and the confidentiality of the patients concerned has been maintained in accordance with ethical standards and institutional guidelines.

This certificate is issued purely for research purposes. No identifying details of the patient will be disclosed in the research work.

Dr. Shilpy Jethy
Principal
D.A.V. Institute of Physiotherapy & Rehabilitation, Jalandhar City

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