Effect of Task-Specific Hand Dexterity Circuit Training as an Adjunct to Conventional Physiotherapy on Pain and Functional Disability in Individuals with Rheumatoid Arthritis: A Quasi-Experimental Study

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ABSTRACT

Background: Rheumatoid arthritis (RA) is a chronic autoimmune inflammatory disorder predominantly affecting small joints of the hands, leading to pain, deformity, and functional disability. Conventional physiotherapy focuses primarily on pain relief and strengthening; however, structured task-specific dexterity training targeting functional hand activities remains underexplored.

Objective: To evaluate the effect of task-specific hand dexterity circuit training as an adjunct to conventional physiotherapy on pain and functional disability in individuals with rheumatoid arthritis.

Methods: A quasi-experimental comparative study was conducted over 12 months in a tertiary care teaching hospital. One hundred participants diagnosed with RA (ACR/EULAR 2010 criteria) were recruited through convenience sampling and allocated into experimental (n=50) and control (n=50) groups. Both groups received supervised physiotherapy sessions (40 minutes/day, 5 days/week) for four weeks. The control group received conventional physiotherapy, while the experimental group received 15 minutes of conventional therapy followed by 25 minutes of task-specific hand dexterity circuit training. Pain intensity was assessed using the Numeric Pain Rating Scale (NPRS) and functional disability using the Health Assessment Questionnaire Disability Index (HAQ-DI). Paired and independent t-tests were used for statistical analysis ($p<0.05$).

Results: Both groups showed significant within-group improvements ($p<0.001$). The experimental group demonstrated greater reduction in NPRS (6.9±1.2 to 3.1±0.9) compared to the control group (6.8±1.1 to 4.8±1.0). HAQ-DI scores improved significantly in the experimental group (1.86±0.38 to 1.15±0.26) compared to the control group (1.82±0.36 to 1.50±0.32) ($p<0.001$).

Conclusion: Task-specific hand dexterity circuit training combined with conventional physiotherapy provides clinically meaningful improvements in pain and functional disability in individuals with rheumatoid arthritis.

Keyword: Rheumatoid arthritis, hand dexterity, circuit training, Task-specific training.

INTRODUCTION

Rheumatoid arthritis (RA) is a chronic, systemic autoimmune inflammatory disorder primarily affecting synovial joints and leading to progressive articular destruction, deformity, and functional disability. It is characterized by persistent synovitis, symmetrical joint involvement, and systemic inflammatory manifestations. RA commonly involves the small joints of the hands and wrists, resulting in significant impairment of fine motor activities and reduced independence in activities of daily living (ADLs). Globally, RA affects approximately 0.5–1% of the adult population, with a higher prevalence among women than men (3:1 ratio) and peak incidence between 30

and 50 years of age. Indian epidemiological data report prevalence ranging from 0.3% to 0.7%, contributing substantially to long-term disability and socioeconomic burden.[1,2]

The etiology of RA is multifactorial, involving genetic susceptibility, environmental triggers, and immune dysregulation. Genetic associations, particularly HLA-DR4 alleles, increase disease susceptibility, while environmental factors such as smoking act as important triggers. The disease process is mediated by autoimmune mechanisms characterized by the presence of rheumatoid factor (RF) and anti-cyclic citrullinated peptide (anti-CCP) antibodies.[3] Persistent immune activation results in chronic synovial inflammation, synovial hypertrophy, and pannus formation. Pro-inflammatory cytokines including tumor necrosis factor-alpha (TNF-α), interleukin-1 (IL-1), and interleukin-6 (IL-6) play central roles in cartilage degradation and bone erosion. Progressive structural damage leads to ligament laxity, tendon imbalance, and classical deformities such as ulnar deviation, swan-neck deformity, and boutonnière deformity, particularly affecting the metacarpophalangeal and proximal interphalangeal joints.[4]

Clinically, patients present with prolonged morning stiffness exceeding one hour, symmetrical joint swelling, tenderness, reduced grip strength, fatigue, and progressive functional limitation. Hand dysfunction significantly interferes with essential ADLs such as dressing, feeding, grooming, and object manipulation. Functional disability in RA is commonly assessed using the Health Assessment Questionnaire Disability Index (HAQ-DI), which demonstrates high reliability (Cronbach's α 0.88–0.95; ICC >0.87) and responsiveness in RA populations.[5] Pain intensity is frequently evaluated using the Numeric Pain Rating Scale (NPRS), a valid and reliable measure for musculoskeletal pain assessment.[6]

Conventional physiotherapy management in RA primarily focuses on pain reduction, joint protection strategies, range of motion exercises, and muscle strengthening. Evidence supports that strengthening and mobility exercises improve joint stability and reduce pain; however, most rehabilitation protocols emphasize impairment-based approaches rather than functional, task-oriented retraining.[7] Recent rehabilitation research highlights the importance of task-specific training based on motor learning principles, suggesting that repetitive, goal-directed activities enhance neuromuscular coordination and functional performance. Task-oriented interventions have demonstrated positive outcomes in neurological and musculoskeletal conditions, yet structured dexterity-focused circuit training programs remain underexplored in individuals with RA.[8]

Although hand involvement is one of the most disabling features of RA, limited evidence exists regarding short-term, structured hand dexterity interventions targeting real-life functional tasks. Most available studies emphasize pharmacological management and general exercise therapy, leaving a gap in functional rehabilitation literature. Therefore, there is a need to investigate low-cost, feasible, and clinically applicable task-specific training approaches that directly address hand dexterity and ADL performance. Hand dexterity circuit training, involving repetitive functional tasks such as object manipulation and grip activities, may provide meaningful improvements in functional independence and pain reduction. The present quasi-experimental study was therefore designed to evaluate the effect of task-specific hand dexterity circuit training on functional disability and pain in individuals with chronic rheumatoid arthritis.

METHODOLOGY

This quasi-experimental comparative study was conducted over a period of 12 months in the Department of Musculoskeletal Physiotherapy at a tertiary care teaching hospital. Ethical approval was obtained from the Institutional Ethics Committee prior to commencement of the study, and written informed consent was obtained from all participants in accordance with the Declaration of Helsinki.

The sample size was calculated using G*Power software (version 3.1), assuming a moderate effect size (d = 0.5), alpha level of 0.05, and statistical power of 80% for between-group comparisons. The minimum required sample size was 90 participants. To account for potential attrition, 100 participants were recruited using convenience sampling and allocated into two groups of 50 participants each (experimental group and control group).

Participants diagnosed with Rheumatoid arthritis according to the 2010 ACR/EULAR classification criteria were screened in the outpatient department. Individuals aged between 30 and 60 years with confirmed involvement of hand joints (metacarpophalangeal, proximal interphalangeal, or wrist joints), stable pharmacological management for at least four weeks, and mild to moderate functional disability (HAQ-DI score between 1 and 2.5) were included. Participants were excluded if they had severe fixed deformities preventing task performance, recent upper limb fracture or surgery within the past six months, neurological disorders affecting upper limb function, acute inflammatory flare-ups during recruitment, or associated advanced musculoskeletal conditions such as severe osteoarthritis.

Baseline assessment was performed prior to intervention. Pain intensity was measured using the Numeric Pain Rating Scale (NPRS), which served as the primary outcome measure. Functional disability was assessed using the Health Assessment Questionnaire Disability Index (HAQ-DI), which was considered the secondary outcome measure. Outcome measures were reassessed after completion of the 4-week intervention period.

Both groups underwent supervised physiotherapy sessions five days per week for four weeks, with each session lasting 40 minutes to ensure equal treatment duration and minimize performance bias. The control group received 40 minutes of conventional physiotherapy, which included active range of motion exercises for wrist and fingers, isometric and isotonic strengthening of intrinsic hand muscles, shoulder and scapular stabilization exercises to improve proximal control, and education regarding joint protection and energy conservation techniques.

The experimental group received 15 minutes of conventional physiotherapy (as described above) followed by 25 minutes of task-specific hand dexterity circuit training. The circuit training consisted of structured functional tasks including pegboard manipulation, coin transfer and sorting, buttoning and unbuttoning practice, sponge ball squeezing with graded resistance, therapy putty molding, and towel wringing activities. Each task was performed for approximately 4–5 minutes with short rest intervals. Progression was applied weekly by increasing repetitions, resistance, and task complexity.

Attendance and adherence were monitored throughout the intervention period.

Data were analyzed using SPSS version 25.0. The normality of distribution was assessed using the Shapiro–Wilk test. Within-group pre–post comparisons were performed using paired t-test, while between-group post-intervention comparisons were analyzed using independent t-test. The level of statistical significance was set at $p < 0.05$. Effect size (Cohen's d) was calculated to determine the magnitude of change.

RESULTS

A total of 100 participants completed the 4-week intervention period, with 50 participants allocated to the experimental group and 50 to the control group. No dropouts were reported. Baseline demographic and clinical characteristics were comparable between groups, with no statistically significant differences observed in age, disease duration, baseline pain intensity, or functional disability ($p > 0.05$), indicating homogeneity at baseline.

Within-Group Comparisons

In the experimental group, a statistically significant reduction in pain intensity was observed following intervention. The mean Numeric Pain Rating Scale (NPRS) score decreased from 6.9 ± 1.2 at baseline to 3.1 ± 0.9 post-intervention ($p < 0.001$), demonstrating a large effect size (Cohen's $d = 1.10$). The reduction exceeded the minimal clinically important difference of 2 points, indicating clinically meaningful improvement.

In the control group, pain intensity also showed significant improvement, with mean NPRS scores decreasing from 6.8 ± 1.1 to 4.8 ± 1.0 ($p < 0.001$). However, the magnitude of change was smaller compared to the experimental group, with a moderate effect size (Cohen's $d = 0.65$).

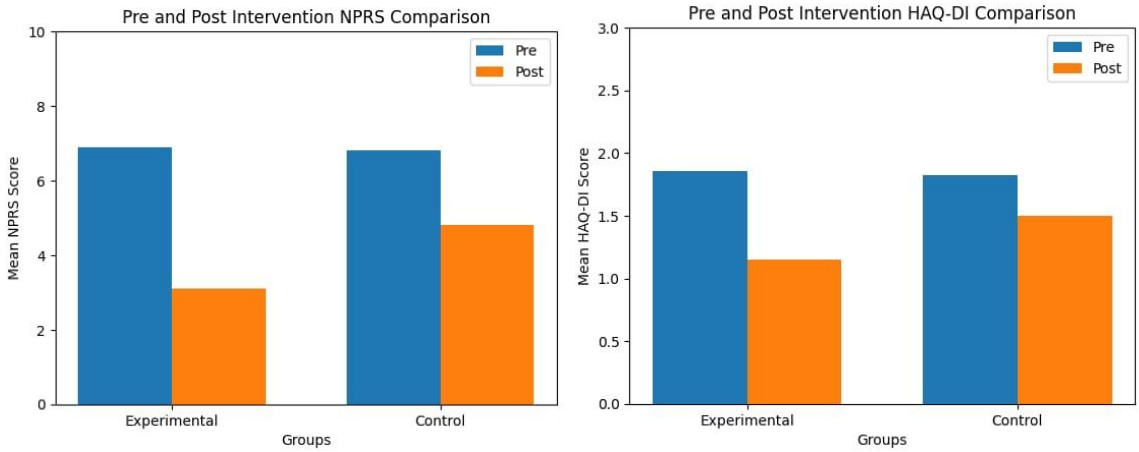
Functional disability significantly improved in both groups. In the experimental group, the mean Health Assessment Questionnaire Disability Index (HAQ-DI) score decreased from 1.86 ± 0.38 at baseline to 1.15 ± 0.26 post-intervention ($p < 0.001$), with a large effect size (Cohen's $d = 0.92$). In the control group, HAQ-DI

scores improved from 1.82 ± 0.36 to 1.50 ± 0.32 ($p < 0.01$), reflecting a small to moderate effect size (Cohen's $d = 0.48$).

Between-Group Comparisons

Post-intervention comparison revealed statistically significant differences between groups. The experimental group demonstrated significantly lower NPRS scores compared to the control group at the end of 4 weeks (3.1 ± 0.9 vs 4.8 ± 1.0; $p < 0.001$).

Similarly, post-intervention HAQ-DI scores were significantly lower in the experimental group compared to the control group (1.15 ± 0.26 vs 1.50 ± 0.32; $p < 0.001$).



DISCUSSION

The present study demonstrated that task-specific hand dexterity circuit training combined with conventional physiotherapy resulted in significantly greater reductions in pain and improvements in functional disability compared to conventional physiotherapy alone in individuals with Rheumatoid arthritis. Although both groups showed improvement, the magnitude of change was substantially higher in the experimental group, indicating the additive therapeutic value of structured, goal-directed dexterity training.

These findings are consistent with recent evidence supporting exercise-based rehabilitation in inflammatory arthritis. A systematic review by Rausch Osthoff et al.[9] concluded that therapeutic exercise improves pain, physical function, and muscle strength in individuals with inflammatory arthritis without exacerbating disease activity. Similarly, Metsios et al.[10] reported that appropriately prescribed physical activity reduces systemic inflammation and enhances functional capacity in Rheumatoid arthritis populations. The present results align with these findings, reinforcing the safety and clinical efficacy of supervised exercise interventions.

Hand-specific rehabilitation programs have demonstrated promising outcomes in RA management. Williams et al.[11] reported significant improvements in grip strength and hand function following structured hand exercise programs. Furthermore, Lamb et al.[12], in the extended SARAH trial, confirmed sustained improvement in hand function with structured exercise compared to usual care. However, most previous studies have primarily focused on strengthening protocols. In contrast, the present study incorporated a circuit-based task-specific dexterity model emphasizing repetitive, functional, and goal-directed tasks. This functional integration may explain the larger effect sizes observed in both pain reduction and disability improvement.

The significant reduction in pain observed in the experimental group may be explained by both peripheral and central mechanisms. Exercise-induced hypoalgesia is mediated through activation of descending inhibitory pathways and increased release of endogenous opioids and endocannabinoids[13]. Repetitive joint movement enhances synovial fluid circulation, improves cartilage nutrition, and reduces joint stiffness, thereby decreasing mechanical nociceptive input. Additionally, regular physical activity has been associated with reduction in pro-inflammatory cytokines such as TNF-α and IL-6, which contribute to nociceptive sensitization in Rheumatoid

arthritis[14]. These mechanisms collectively may account for the clinically meaningful reduction in NPRS scores observed in the experimental group.

Improvement in functional disability, as measured by HAQ-DI, can be attributed to motor learning and task-specific training principles. Repetitive, goal-oriented functional tasks promote cortical plasticity and improved sensorimotor integration[15]. Task-specific dexterity exercises enhance coordinated activation of intrinsic hand muscles and improve precision grip control necessary for daily activities such as dressing, grooming, and object manipulation. Furthermore, incorporation of shoulder and scapular stabilization likely enhanced distal hand performance through improved proximal stability and kinetic chain optimization[16].

Pain and functional disability are closely interrelated in Rheumatoid arthritis. Reduction in pain likely facilitated increased engagement in functional tasks, breaking the cycle of pain, fear-avoidance, disuse, and progressive disability. Contemporary rehabilitation models emphasize function-centered approaches rather than impairment-based treatment alone[17]. The large effect sizes observed in the experimental group support the clinical relevance of incorporating structured dexterity circuits into routine physiotherapy programs.

The presence of a control group receiving equal-duration conventional physiotherapy strengthens the internal validity of the present study. The significantly greater improvements observed in the experimental group suggest that task-specific dexterity training provides benefits beyond standard rehabilitation. However, as the study employed a quasi-experimental design with convenience sampling, randomization was not performed, which may limit generalizability. Future randomized controlled trials with long-term follow-up are recommended to evaluate sustained benefits and comparative effectiveness[18].

Overall, the findings support the integration of task-specific hand dexterity circuit training as an effective adjunct to conventional physiotherapy in the management of Rheumatoid arthritis.

CONCLUSION

Task-specific hand dexterity circuit training combined with conventional physiotherapy resulted in significantly greater reductions in pain and improvements in functional disability compared to conventional physiotherapy alone in individuals with Rheumatoid arthritis. The structured, goal-directed intervention demonstrated clinically meaningful improvement in both primary (pain) and secondary (functional disability) outcomes over a 4-week period.

LIMITATIONS

Despite the significant findings, certain limitations must be acknowledged. First, the study employed a quasi-experimental design with convenience sampling, which limits randomization and may introduce selection bias. Second, the intervention duration was limited to four weeks; therefore, long-term sustainability of improvements in pain and functional disability could not be determined. Third, outcome measures were primarily patient-reported scales (NPRS and HAQ-DI), which, although valid and reliable, may be influenced by subjective perception. Objective measures such as grip strength dynamometry or dexterity tests were not included. Additionally, disease activity indices and inflammatory biomarkers were not assessed, which could have provided further insight into physiological changes associated with the intervention. Finally, the study was conducted in a single tertiary care center, which may limit generalizability to broader populations

FUTURE RECOMMENDATIONS

Future research should employ randomized controlled trial designs to establish stronger causal inference and minimize selection bias. Studies with longer follow-up periods are recommended to evaluate the sustainability of improvements and potential effects on disease progression. Incorporating objective outcome measures such as grip strength, hand function performance tests, and inflammatory biomarkers would provide a more comprehensive evaluation of intervention effectiveness. Comparative studies examining task-specific dexterity training against other structured hand rehabilitation protocols may further clarify optimal therapeutic strategies.

Multicenter trials with diverse populations are also recommended to enhance external validity and support broader clinical implementation.

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