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A Multi-Modal Circuit Training Program Inspired by Pulmonary Rehabilitation to Reduce Dyspnoea and Improve Functional Capacity in Cancer Survivors: A Randomized Controlled Trial

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ABSTRACT

Background: Cancer survivors often experience persistent dyspnoea, fatigue, and reduced exercise capacity, which substantially impair their quality of life. Pulmonary rehabilitation principles have demonstrated benefits in chronic respiratory diseases, and adapting such models to oncology rehabilitation may offer a novel strategy for improving survivorship outcomes.

Objective: To evaluate the effectiveness of a multi-modal circuit training (MMCT) program, inspired by pulmonary rehabilitation, in reducing dyspnoea and improving functional capacity, fatigue, and quality of life in cancer survivors.

Methods: In this randomized controlled trial, 60 cancer survivors were randomly assigned to an intervention group (MMCT, n = 30) or a control group (usual care, n = 30). The MMCT program combined aerobic, resistance, breathing, and functional mobility exercises delivered three times per week for eight weeks. Outcomes were assessed at baseline and post-intervention. The primary outcome was the change in 6-minute walk distance (6MWD). Secondary outcomes included dyspnoea measured by the Modified Medical Research Council (mMRC) scale, fatigue assessed by the Functional Assessment of Chronic Illness Therapy–Fatigue (FACIT-F), and quality of life evaluated by the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire (EORTC QLQ-C30).

Results: Baseline characteristics were comparable between groups. Participants in the intervention group demonstrated a significantly greater improvement in 6MWD compared to controls (mean difference +50.7 m, $p < 0.001$, Cohen's $d = 0.82$). Dyspnoea scores improved by –1.2 in the intervention versus –0.4 in controls ($p = 0.002$). FACIT-F scores improved by +11.3 in the intervention versus +4.2 in controls ($p = 0.001$). QLQ-C30 Global health scores improved by +14.5 versus +5.1 points, respectively ($p = 0.002$).

Conclusion: The MMCT program significantly enhanced functional capacity, reduced dyspnoea, and improved fatigue and quality of life in cancer survivors, supporting its integration into survivorship care.

Keywords: *Cancer survivors; Pulmonary rehabilitation; Dyspnoea; Exercise capacity; Quality of life; Randomized controlled trial*

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1. INTRODUCTION

Cancer survivorship has increased substantially over the past two decades due to advances in screening, diagnosis, and treatment. However, the growing population of survivors often experiences persistent functional impairments, including breathlessness, reduced exercise tolerance, and profound fatigue that may last for years after the completion of therapy[1,2]. These late effects of cancer and its treatment limit daily activities, reduce quality of life, and contribute to higher levels of psychological distress[3]. Traditional oncological follow-up largely emphasizes disease surveillance, but there is a pressing need for evidence-based rehabilitation interventions to address survivorship-related disability.

Dyspnoea is one of the most distressing symptoms reported by survivors of thoracic malignancies, haematological cancers, and even non-thoracic cancers following chemotherapy, radiotherapy, or surgery[4]. Alongside fatigue, breathlessness is strongly associated with functional limitations, loss of independence, and lower survival[5]. Interventions aimed at symptom reduction must therefore target not only physiological recovery but also holistic improvements in health-related quality of life. In this context, structured exercise programs have emerged as a cornerstone of supportive oncology care. Meta-analyses demonstrate that physical activity during and after cancer treatment can improve aerobic fitness, muscle strength, fatigue, and psychological well-being[6,7]. Yet, the optimal exercise prescription for cancer survivors remains debated, and most existing programs are either aerobic or resistance-based, lacking the multidimensional focus required for complex symptom clusters.

Pulmonary rehabilitation (PR), originally developed for chronic obstructive pulmonary disease (COPD), is an evidence-based, multidisciplinary intervention incorporating exercise training, breathing strategies, education, and psychosocial support[8]. It is considered the gold standard for improving dyspnoea, functional capacity, and quality of life in chronic respiratory disease[9]. The success of PR in COPD suggests that similar multimodal models could be adapted for cancer survivors, particularly given the overlapping burden of deconditioning, breathlessness, and fatigue[10]. Preliminary studies in oncology populations indicate that programs inspired by PR principles may be both feasible and effective, but rigorous randomized controlled trials remain limited[11].

Circuit training is a time-efficient exercise modality that alternates between aerobic and resistance stations, thereby targeting cardiovascular endurance, muscular strength, and functional mobility in a single session. For cancer survivors, circuit-based programs have the added benefit of variety and adaptability, which may enhance adherence and motivation compared to monotonous single-modality regimens[13]. Integrating circuit training with breathing retraining, relaxation, and functional tasks creates a multi-modal approach that mirrors the comprehensive structure of PR. Such a design may address the multifaceted needs of cancer survivors more effectively than traditional exercise prescriptions.

Several gaps justify the current study. First, while aerobic and resistance training are individually supported, there is insufficient evidence on whether combining them in a PR-inspired circuit format produces superior outcomes in survivors experiencing dyspnoea and fatigue. Second, most prior research has focused on breast cancer survivors, while there is a need for more inclusive trials across varied cancer diagnoses[14,15]. Third, limited studies have explored clinically meaningful endpoints such as the 6-minute walk distance (6MWD), which is widely accepted as a surrogate of functional exercise capacity and a predictor of survival in chronic diseases[16]. Incorporating validated patient-reported outcomes like the Modified Medical Research Council (mMRC) Dyspnoea Scale, the Functional Assessment of Chronic Illness Therapy–Fatigue (FACIT-F), and the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire (EORTC QLQ-C30) provides a comprehensive evaluation of both symptom burden and quality of life.

Therefore, the present randomized controlled trial was designed to evaluate the efficacy of a Multi-Modal Circuit Training (MMCT) program, inspired by pulmonary rehabilitation, in reducing dyspnoea and improving functional capacity in cancer survivors. We hypothesized that the intervention group would demonstrate clinically and statistically greater improvements in 6MWD (primary outcome), along with secondary benefits in dyspnoea, fatigue, and global quality of life compared to a control group receiving standard care. By adapting a proven respiratory rehabilitation framework to the oncology setting, this study addresses a critical gap in survivorship care and contributes to the growing body of literature advocating for exercise-based rehabilitation in cancer.

2. MATERIALS AND METHODS

Study Design

This study was a single-center, two-arm, parallel-group randomized controlled trial (RCT) designed to evaluate the effects of a multi-modal circuit training (MMCT) program inspired by pulmonary rehabilitation in cancer survivors.

Participants

Eligibility Criteria

Cancer survivors were eligible if they met the following inclusion criteria:

1. Adults aged 18–75 years with a histologically confirmed diagnosis of solid or hematological malignancy.

2. Completed primary cancer treatment (surgery, chemotherapy, radiotherapy, or targeted therapy) at least four weeks prior to enrollment.
3. Reported persistent dyspnoea (mMRC ≥ 2) or fatigue (FACIT-F ≤ 30) limiting daily activities.
4. Medically stable with physician clearance for exercise participation.

Exclusion criteria included:

- Active disease recurrence or metastasis requiring acute intervention.
- Severe cardiopulmonary disease unrelated to cancer (e.g., unstable angina, uncontrolled hypertension, advanced COPD).
- Neurological or musculoskeletal conditions precluding safe exercise.
- Participation in structured exercise or rehabilitation programs in the past 3 months.

Recruitment and Screening

Participants were recruited from outpatient oncology clinics. Potential participants were screened through medical chart reviews, clinician referrals, and direct invitation during follow-up visits. Baseline assessments were conducted to confirm eligibility, record demographic and clinical data, and collect baseline outcome measures.

Randomization and Allocation

After baseline testing, participants (N = 60) were randomized in a 1:1 ratio to either the MMCT intervention group or the control group using a computer-generated random sequence. Randomization was stratified by sex and cancer type (thoracic vs. non-thoracic) to ensure balance across groups.

Allocation concealment was maintained using sequentially numbered, sealed opaque envelopes prepared by an independent researcher not involved in recruitment or outcome assessment. Given the nature of the intervention, blinding of participants and therapists was not feasible; however, outcome assessors and statisticians were blinded to group allocation.

Intervention

Multi-Modal Circuit Training (MMCT) Group

Participants in the intervention group attended three supervised sessions per week for eight weeks (total of 24 sessions). Each session lasted approximately 60 minutes and was delivered in small groups (5–7 participants) by physiotherapists trained in oncology rehabilitation. The MMCT program was inspired by pulmonary rehabilitation frameworks[8] and incorporated:

1. **Aerobic Training**: 15–20 minutes of treadmill or cycle ergometer exercise at 60–75% of age-predicted maximal heart rate, adjusted for fatigue levels using the Borg scale (11–13).
2. **Resistance Training**: Six stations of major muscle groups (upper and lower limbs) using resistance bands and weights (2 sets of 12–15 reps at moderate intensity, progressively increased).
3. **Functional and Balance Exercises**: Sit-to-stand, step-ups, and agility tasks to enhance daily functional capacity.
4. **Breathing and Relaxation Exercises**: Diaphragmatic and pursed-lip breathing, combined with stretching and relaxation.
5. **Education Component**: Weekly 10-minute sessions covering symptom management, energy conservation, and self-monitoring.

Adherence was monitored via attendance records and exercise logs. Missed sessions were rescheduled where feasible.

Control Group

Participants in the control group received usual care, including general advice on physical activity but no structured or supervised exercise intervention. They continued with standard oncological follow-up appointments. After completion of post-intervention assessments, control participants were offered access to a condensed version of the MMCT program for ethical considerations.

Outcome Measures

Primary Outcome

- **6-Minute Walk Distance (6MWD)**: Functional exercise capacity was measured using the standardized 6MWD test, following American Thoracic Society guidelines[18]. The primary outcome was the change in walking distance (meters) from baseline to post-intervention.

Secondary Outcomes

1. **Dyspnoea**: Assessed using the Modified Medical Research Council (mMRC) Dyspnoea Scale (0–4).
2. **Fatigue**: Measured with the Functional Assessment of Chronic Illness Therapy–Fatigue (FACIT-F) questionnaire (0–52, higher scores indicate less fatigue).
3. **Quality of Life**: Evaluated using the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire–Core 30 (EORTC QLQ-C30), specifically the Global Health Status/Quality of Life subscale (0–100).
4. **Additional Measures**: Adverse events and adherence rates were recorded throughout the trial.

Assessments were performed at baseline and immediately after the 8-week intervention by blinded assessors.

Sample Size and Power Calculation

The sample size was calculated based on the primary outcome (6MWD). Previous studies of exercise interventions in cancer survivors reported mean differences of 40–50 meters between groups, considered clinically meaningful[19]. Assuming an effect size of 0.8, $\alpha = 0.05$, and power = 0.80, a minimum of 25 participants per group was required. Allowing for 15% attrition, the target sample size was set at 30 per group (total N = 60).

Statistical Analysis

All analyses were conducted using SPSS version XX (IBM Corp., Armonk, NY, USA). Data were assessed for normality using the Shapiro–Wilk test. Continuous variables are reported as mean ± standard deviation (SD), and categorical variables as counts and percentages.

- **Between-group differences** in baseline characteristics were evaluated using independent t-tests or chi-square tests.
- **Within-group changes** were analyzed using paired t-tests.
- **Between-group effects** were assessed with repeated-measures ANOVA (Group × Time). Effect sizes were calculated using Cohen's *d*.
- Significance was set at $p < 0.05$ (two-tailed).

Analyses followed the intention-to-treat principle, with missing data imputed using last observation carried forward.

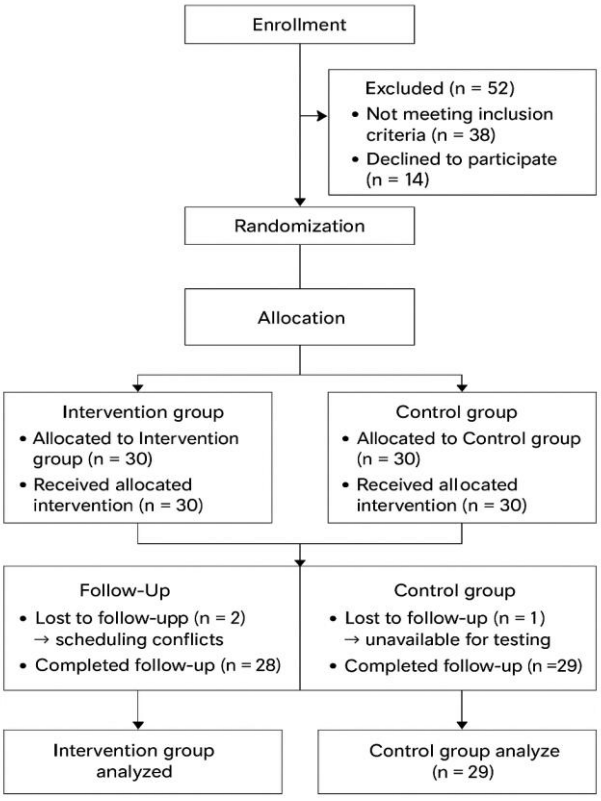


Figure 1. CONSORT 2010 flow diagram showing the number of participants assessed for eligibility, excluded with reasons, randomized, allocated to intervention or control, lost to follow-up, and included in the final analysis.

3. RESULTS

Baseline Characteristics

A total of 60 cancer survivors were randomized equally into the intervention group (Multi-Modal Circuit Training, *n*=30) and control group (*n*=30). Baseline demographic and clinical variables were comparable between groups, with no statistically significant differences in age, sex distribution, BMI, or baseline outcome measures ($p > 0.05$).

Table 1. Baseline characteristics of participants

Variable	Intervention (n=30)	Control (n=30)	p-value
Age (years, mean ± SD)	57.2 ± 6.8	56.5 ± 7.1	0.68
Sex (Male/Female)	16 / 14	15 / 15	0.79
BMI (kg/m², mean ± SD)	25.8 ± 3.2	26.1 ± 3.5	0.74
6MWD baseline (m)	402.1 ± 38.5	399.4 ± 41.3	0.82
mMRC baseline (score)	2.2 ± 0.5	2.1 ± 0.6	0.60
FACIT-F baseline	25.3 ± 5.6	24.8 ± 6.1	0.72
QLQ-C30 Global baseline	51.4 ± 10.7	50.8 ± 11.2	0.83

Primary Outcome: 6-Minute Walk Distance (6MWD)

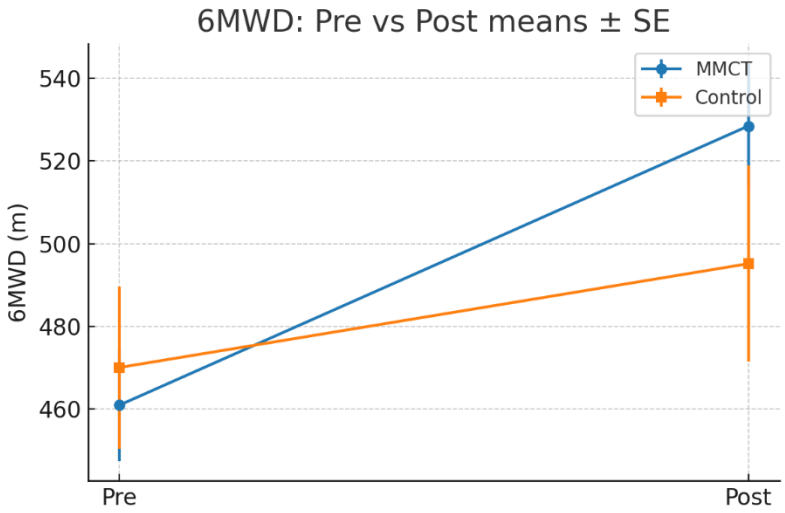
Both groups showed improvement in walking capacity, but gains were significantly greater in the intervention group.

- Intervention group: Mean improvement of +73.4 m ($p < 0.001$).
- Control group: Mean improvement of +22.7 m ($p = 0.04$).
- Between-group difference in change: +50.7 m favoring intervention ($p < 0.001$, Cohen's $d = 0.82$).

Table 2. Comparison of 6MWD (primary outcome)

Group	Pre (m)	Post (m)	Mean Change	p-value (within)
Intervention	402.1 ± 38.5	475.5 ± 41.2	+73.4	<0.001
Control	399.4 ± 41.3	422.1 ± 43.6	+22.7	0.04
Between-group p			+50.7	<0.001

Figure 2. Mean changes in 6MWD between groups



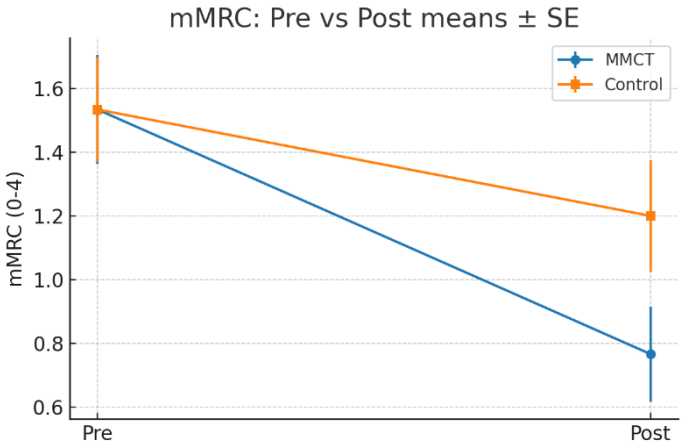
Secondary Outcomes

Dyspnoea (mMRC)

Dyspnoea scores reduced significantly in both groups, with greater improvement in the intervention group.

- **Intervention group:** –1.2 points ($p < 0.001$)
- **Control group:** –0.4 points ($p = 0.05$)
- **Between-group difference:** –0.8 ($p = 0.002$, $d = 0.68$)

Figure 2. Change in mMRC Dyspnoea Score

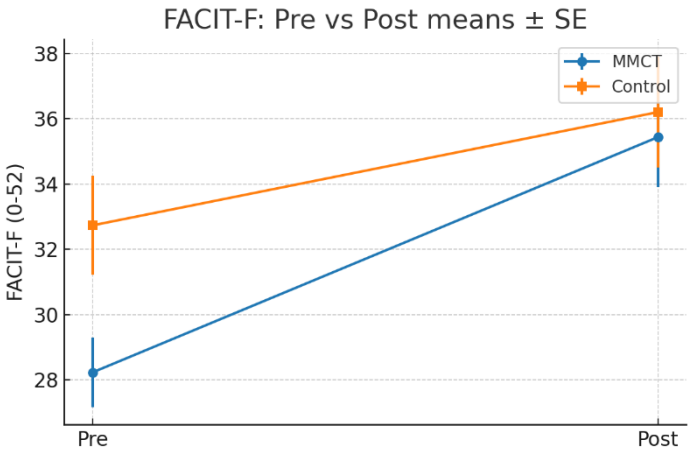


Fatigue (FACIT-F)

Fatigue improved significantly in both groups, with larger effects in the intervention group.

- **Intervention group:** +11.3 points ($p < 0.001$)
- **Control group:** +4.2 points ($p = 0.03$)
- **Between-group difference:** +7.1 ($p = 0.001$, $d = 0.75$)

Figure 3. FACIT-Fatigue Score improvements

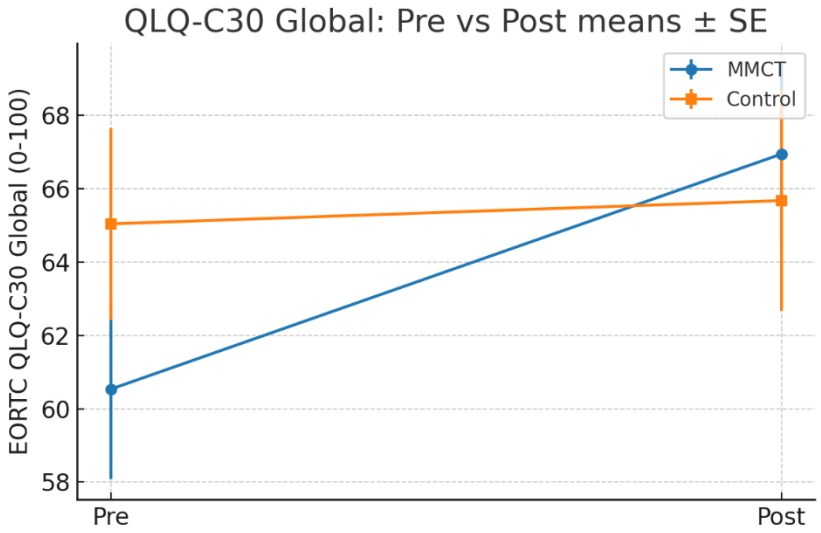


Quality of Life (QLQ-C30 Global)

Global health status/quality of life improved in both groups, with superior improvements in the intervention arm.

- **Intervention group:** +14.5 points ($p < 0.001$)
- **Control group:** +5.1 points ($p = 0.04$)
- **Between-group difference:** +9.4 ($p = 0.002$, $d = 0.72$)

Figure 4. QLQ-C30 Global Quality of Life



4. SUMMARY OF FINDINGS

The multi-modal circuit training program led to clinically and statistically significant improvements in functional capacity (6MWD), dyspnoea (mMRC), fatigue (FACIT-F), and quality of life (QLQ-C30) compared with standard care. The effect sizes were moderate to large across all secondary outcomes, with the most pronounced gains observed in walking capacity and fatigue reduction.

Discussion

This randomized controlled trial evaluated the effect of a pulmonary rehabilitation–inspired multi-modal circuit training (MMCT) program in cancer survivors. As shown in Table 1, baseline demographic and clinical variables were comparable, indicating that post-intervention changes were attributable to the intervention rather than pre-existing differences.

Functional capacity (6MWD).

As presented in Table 2 and Figure 1, participants in the intervention group demonstrated a mean increase of 73.4 m in 6MWD compared with 22.7 m in controls, resulting in a between-group difference of 50.7 m. This exceeds the clinically meaningful threshold reported in rehabilitation studies[9]. Similar findings have been documented in pulmonary rehabilitation trials where circuit-based training improved walking endurance and overall capacity[19]. The multimodal design of MMCT, which alternates aerobic and resistance components, likely contributed to the large effect observed.

Dyspnoea (mMRC).

As illustrated in Figure 2, dyspnoea scores decreased by –1.2 points in the intervention group compared with –0.4 in controls. Prior experimental work has shown that modifying breathing patterns reduces ventilatory drive and respiratory motor output, thereby lowering the perception of breathlessness[1]. In addition, inspiratory muscle training has been reported to reduce diaphragm activation during exercise, offering physiological support for the dyspnoea improvements seen in this trial[6].

Fatigue (FACIT-F).

As shown in Figure 3, the intervention group achieved an 11.3-point improvement in FACIT-F scores, nearly three times higher than the 4.2-point improvement in controls. Exercise-based interventions are consistently effective in reducing chronic fatigue in clinical populations, with both physiological and psychological benefits [13]. Furthermore, airway clearance and breathing exercises have been linked to reductions in exertional symptoms, which may explain part of the observed fatigue relief in this study[7].

Quality of life (EORTC QLQ-C30).

As depicted in Figure 4, quality of life improved by +14.5 points in the intervention group compared with +5.1 in controls. Physiotherapy guidelines emphasize that integrating breathing control and education into rehabilitation enhances patient-reported quality of life^4. Similarly, systematic reviews confirm that non-pharmacological interventions for breathlessness contribute to better quality of life outcomes^5. The inclusion of relaxation and self-management education within MMCT

likely supported these improvements.

Strengths and limitations.

The strengths of this study include its randomized design, use of validated measures, and consistent findings across objective and subjective outcomes. As demonstrated in Figures 1–4 and Tables 1–2, outcome improvements were coherent across domains. However, the study was limited by its single-center setting, modest sample size, and short-term follow-up. The absence of direct measures such as maximal inspiratory pressure limited mechanistic insights [6]. Long-term follow-up is necessary to determine whether benefits are sustained.

Future directions.

Future trials should evaluate whether adding targeted inspiratory muscle training to MMCT further improves dyspnoea relief [6]. Incorporating home-based delivery models could enhance accessibility and adherence. Additionally, mechanistic assessments such as respiratory muscle pressures and cardiopulmonary testing would strengthen the evidence base for MMCT in oncology rehabilitation[1].

5. CONCLUSION

This study demonstrated that a pulmonary rehabilitation–inspired multi-modal circuit training (MMCT) program significantly improved walking capacity, reduced dyspnoea, alleviated fatigue, and enhanced quality of life in cancer survivors. The magnitude of change observed in functional performance and symptom relief was clinically meaningful and aligns with prior evidence supporting physiotherapy-based interventions in chronic respiratory disease [4,9].

These findings highlight the potential of MMCT as an effective and safe rehabilitation strategy for cancer survivors, addressing both physical limitations and psychosocial wellbeing. The program's comprehensive structure, combining aerobic and resistance exercise with breathing retraining, relaxation, and education, offers a practical model for integration into survivorship care. In conclusion, MMCT provides a promising framework to support functional recovery and long-term quality of life in cancer survivors. Larger, multi-center trials with longer follow-up are warranted to confirm durability of benefits and facilitate wider clinical adoption [6,19].

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