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EFFECTIVENESS OF A STRUCTURED TELE-PHYSIOTHERAPY PROGRAM ON MUSCLE STRENGTH AND FUNCTIONAL MOBILITY IN OLDER ADULTS WITH TYPE 2 DIABETES: A RANDOMIZED CONTROLLED TRIAL

Original Research

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Acknowledgement: We thank all participants, Physiotherapists, and clinic staff who made this trial possible. We also acknowledge the methodological contributions of prior research in this field, including the foundational work by Kataoka et al.

Conflict of Interest: None Grant Support & Financial Support: None

ABSTRACT

Background: Diabetes Mellitus type 2 (DM) accelerates the sarcopenia and functional worsening in the elderly population. The most critical is exercise although barriers such as access and poor compliance are derailing the effectiveness of the exercise. Tele-physiotherapy can be used to overcome these obstacles. Purpose: The study objective was to determine the comparability of 24-week, therapist-provided, tele-physiotherapy and usual care in terms of their efficacy in improving the knee extension strength and functional mobility of older adults with type 2 DM.

Objective: To evaluate effectiveness of a 24-week tele-physiotherapy program on muscle strength and functional mobility in older adults with Type 2 diabetes.

Methods: It was a multicenter, assessor-blind randomized, controlled clinical trial. ninety community-dwelling adults aged 50 years with T2DM and mild functional limitation (Short Physical Performance Battery [SPPB] score 4-10) were selected random in an Intervention Group (IG, n=45) or Control Group (CG, n=45). The IG received safe video-based training twice per week, personalized, strength, balance, and aerobic training, and behavioral coaching. The CG was provided with standard care and general activity advice. Its significant outcome was that it changed the isometric Knee Extension Force (KEF, Nm/kg). Others included SPPB, Timed Up and Go (TUG), 6-Minute Walk Test (6MWT), HbA1c, and adherence as some secondary outcomes. The time measurements used were the baseline, 12, 24 (post-intervention) and 36 weeks (follow-up).

Results: Eighty-three (92 per cent of all the participants) of the subjects successfully completed the trial. IG showed a significant improvement compared to CG in KEF at 24 weeks (mean difference: +0.22 Nm/kg, 95% CI: 0.10-0.34, p<0.001). Better changes in the IG were also observed in the SPPB score (+ 1.8 points, p=0.002), TUG (-1.4 s, p=0.013), and 6MWT (+ 34 m, p=0.005). HbA1C was reduced considerably in both groups and was not different between the groups. Exercise session 84 compliance in IG, 52 compliances in CG (p<0.001). Relatively, there was an improvement in KEF and SPPB at 36 weeks of follow-up.

Conclusion: A 12-week tele-physiotherapy program was established to be considerably superior in terms of lower-limb strength and functional mobility among older adults with Type 2 DM, than conventional care, and also demonstrated increased adherence rates. A scaled method of managing functional degradation in this cohort is tele-physiotherapy, which is a viable management method.

Key Words: Effectiveness, Functional Mobility, Muscle Strength, Older Adults, randomized controlled trial, Structured Tele-Physiotherapy Program, Type 2 Diabetes.

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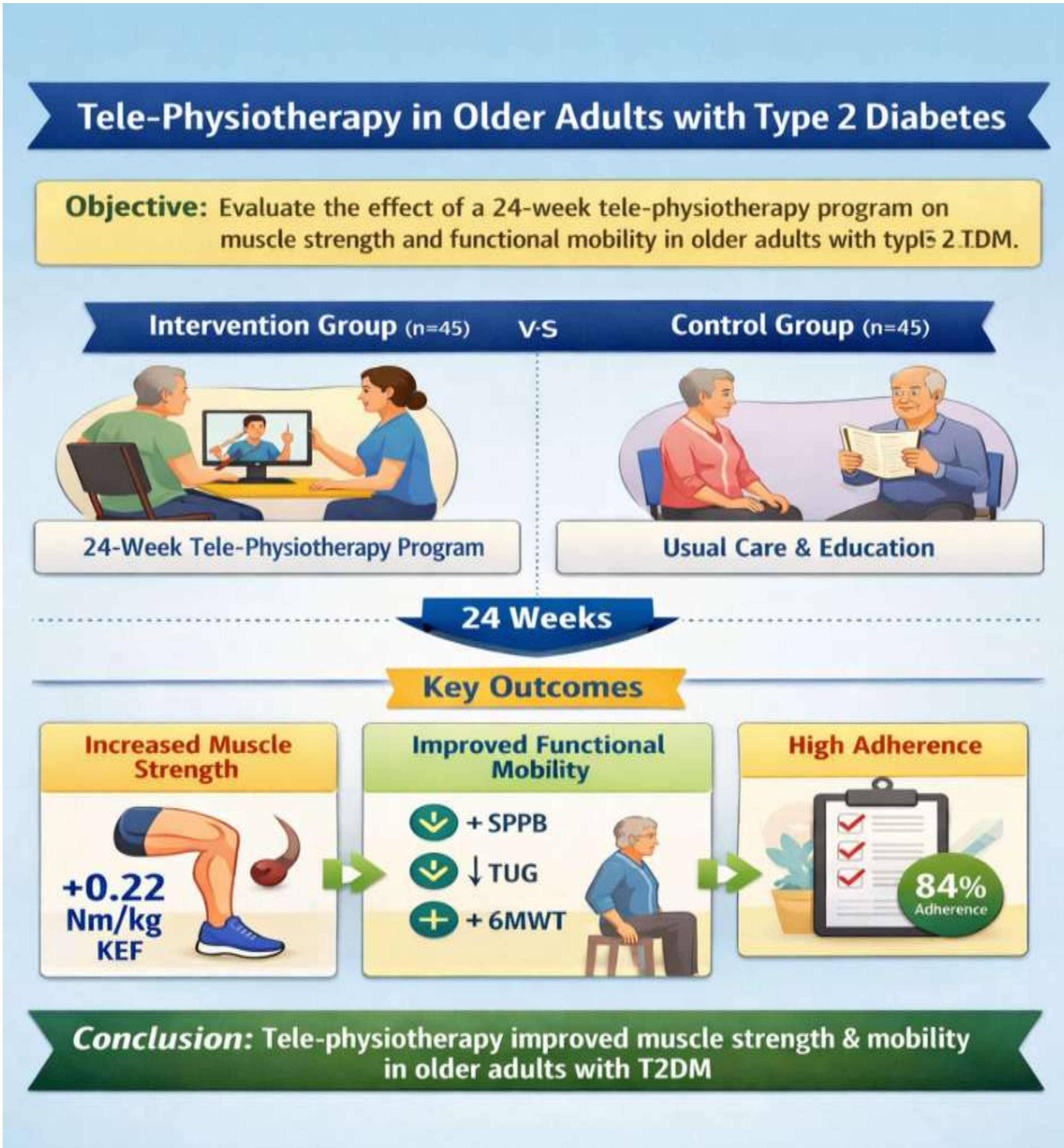

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INTRODUCTION

The unprecedented demographic transition toward an aging global population, coupled with the escalating prevalence of Type 2 Diabetes Mellitus (T2DM), represents a major public health challenge with profound functional implications (1). Currently, more than one-quarter of adults aged 65 years and older are living with diabetes, predominantly T2DM, a metabolic disorder increasingly recognized for its multisystem consequences beyond glycemic dysregulation. In older adults, T2DM accelerates sarcopenia, contributes to diabetic myopathy, impairs neuromuscular coordination, and diminishes aerobic capacity, collectively predisposing individuals to balance deficits, falls, frailty, and progressive disability (2–6). This constellation of impairments, often described as "diabetic disability," substantially compromises independence and health-related quality of life. Evidence indicates that chronic hyperglycemia, insulin resistance, and systemic inflammation contribute to muscle atrophy and reduced muscle quality, thereby amplifying functional decline in this vulnerable population (8). Despite advances in pharmacological therapies, functional deterioration remains inadequately addressed in routine diabetes care. Consequently, there is growing recognition that comprehensive management strategies must extend beyond metabolic targets to include interventions aimed at preserving physical performance, preventing disability, and sustaining autonomy among older adults with T2DM (4).

Structured exercise and physiotherapy constitute cornerstones of non-pharmacological diabetes management, demonstrating significant benefits in improving insulin sensitivity, glycemic control, muscle strength, and functional mobility (9). Resistance and balance training, in particular, have been shown to counteract sarcopenia and reduce fall risk in older individuals. However, real-world adherence to exercise programs in this age group remains persistently low, frequently falling below 50%, largely due to barriers such as limited access to specialized rehabilitation services, transportation challenges, financial constraints, comorbidities, and reduced self-efficacy (2,9). Traditional face-to-face physiotherapy services were further disrupted during the COVID-19 pandemic, highlighting systemic vulnerabilities and widening gaps in access to rehabilitative care (6,12,13). Older adults residing in rural or underserved areas are disproportionately affected by these barriers (14). These constraints underscore the need for innovative, accessible, and sustainable rehabilitation models that can effectively deliver structured exercise while addressing behavioral and logistical obstacles. Integrating technological solutions into rehabilitation frameworks offers a promising avenue to enhance continuity of care and long-term engagement in therapeutic exercise among older adults with chronic diseases (3).

Tele-physiotherapy, utilizing information and communication technologies such as videoconferencing and telephone-based platforms, has emerged as a viable alternative for delivering home-based rehabilitation (15). It encompasses assessment, exercise supervision, monitoring, education, and behavioral coaching, thereby enabling patient-centered care within the home environment. Evidence suggests that tele-physiotherapy can improve physical performance, balance, fall efficacy, activities of daily living, dyspnea management, and quality of life across a range of chronic conditions including heart failure, stroke, osteoarthritis, hip fracture, musculoskeletal disorders, and cognitive impairment (5,6,15). Randomized evidence, such as the study by Kataoka et al., demonstrated that weekly telephone guidance improved knee extension force (KEF) and adherence in older adults with T2DM; however, functional mobility outcomes did not significantly improve, potentially due to limited training specificity and low intervention intensity (8). While systematic reviews indicate promising outcomes in cardiovascular and neurological populations, high-quality randomized controlled trials specifically targeting both metabolic and functional endpoints in older adults with T2DM remain limited (2,17). Given the global rise in aging populations across regions including China, the United Kingdom, and the United States (10–12), scalable rehabilitation strategies are urgently required. Therefore, this study aims to determine whether a 24-week, bi-weekly, video-based tele-physiotherapy program incorporating progressive resistance, balance training, and structured behavioral coaching can produce superior improvements in lower-limb muscle strength and functional mobility compared to standard care in older adults with T2DM, and whether these benefits are sustained following intervention cessation (10).

METHODS

A prospective, multicenter, two-arm, parallel-group, assessor-blinded randomized controlled trial was conducted between January 2025 and June 2025 across three tertiary-care hospitals in Swat, Pakistan. The study comprised a 24-week intervention phase followed by a 12-week post-intervention follow-up, yielding a total study duration of 36 weeks for each participant. Ethical approval was obtained from the institutional review boards of the participating centers prior to commencement, and the trial was registered in a recognized clinical trial registry. All procedures were performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment. Community-dwelling older adults attending geriatric and endocrinology outpatient clinics were screened for eligibility. Individuals were included if they were aged ≥65 years, had a confirmed diagnosis of Type 2 Diabetes Mellitus (HbA1c 6.5–10.0%), demonstrated mild functional limitation defined by a Short Physical Performance Battery (SPPB) score of 4–10, were able to ambulate independently with or without an assistive device, had access to a smartphone, tablet, or computer with internet connectivity, and were willing to participate. Exclusion criteria comprised severe diabetic complications (e.g., advanced neuropathy with ulceration, proliferative retinopathy with recent hemorrhage), unstable cardiovascular disease, uncontrolled hypertension, significant cognitive impairment (Montreal Cognitive Assessment score <18), severe musculoskeletal or neurological disorders precluding safe exercise participation, or current engagement in structured resistance training programs.

The required sample size was calculated a priori using G*Power version 3.1, based on an anticipated moderate-to-large effect size (Cohen's d = 0.65) derived from previous literature (8). To achieve 80% statistical power with a two-sided alpha of 0.05 for detecting between-group differences in the primary outcome, 39 participants per group were required. Allowing for an estimated 15% attrition rate, the target sample size was adjusted to 90 participants (45 per group). After baseline assessment, eligible participants were randomly allocated in a 1:1 ratio to either the intervention group or control group using a centralized, web-based randomization system with computer-generated permuted blocks of variable sizes (4 and 6), stratified by recruitment site and baseline SPPB score. Allocation concealment was ensured by restricting access to the sequence to an independent statistician not involved in recruitment. Outcome assessors and the data analyst remained blinded to group assignment throughout the trial. Due to the nature of the intervention, participant and therapist blinding was not feasible.

Participants allocated to the intervention group received therapist-supervised tele-physiotherapy sessions twice weekly for 24 weeks (48 sessions total), delivered through a secure, encrypted videoconferencing platform compliant with international data protection standards. Each 45-minute session consisted of a 10-minute warm-up emphasizing joint mobility and low-intensity aerobic movements; 20 minutes of progressive resistance training incorporating functional tasks such as sit-to-stand and step-ups using body weight and elastic resistance bands; 10 minutes of balance and gait training including static, dynamic, and dual-task activities (27); and a 5-minute cool-down with stretching and education. Exercise intensity was prescribed and progressed using the Borg Rating of Perceived Exertion scale, approximating 40–50% of one-repetition maximum (1RM) during initial weeks and advancing toward 60–70% as tolerated (29). Weekly motivational interviewing techniques and individualized goal-setting strategies were integrated to enhance adherence. Participants were additionally encouraged to perform a simplified home-based exercise routine one to two times per week. The control group continued to receive standard medical care from their treating physicians and attended a single baseline education session during which general advice regarding physical activity and a standardized exercise pamphlet were provided. No structured or supervised exercise sessions were delivered to this group during the trial period.

Outcome assessments were conducted at baseline (T0), 12 weeks (T1), 24 weeks post-intervention (T2), and 36 weeks (T3 follow-up). The primary outcome was isometric knee extension force (KEF), normalized to body weight (Nm/kg), measured using a belt-stabilized handheld dynamometer to enhance reliability and minimize tester bias (14,15). Secondary outcomes included functional mobility assessed by the SPPB, Timed Up and Go (TUG) test, and Six-Minute Walk Test (6MWT) (20); glycemic control measured by HbA1c; skeletal muscle mass assessed using bioelectrical impedance analysis under standardized hydration conditions; diabetes-specific quality of life measured by the Diabetes-39 questionnaire; and exercise self-efficacy evaluated using the Exercise Self-Efficacy Scale. Process measures included adherence (percentage of completed sessions), adverse events, and participant satisfaction collected through structured questionnaires.

Data were analyzed according to the intention-to-treat principle. Linear mixed-effects models were employed to examine Group × Time interactions while accounting for repeated measures and adjusting for stratification variables. Between-group differences at T2 and T3 were estimated with 95% confidence intervals. Assumptions of normality and homogeneity were verified prior to modeling. Per-protocol and sensitivity analyses were conducted to assess robustness of findings. Statistical significance was set at $p < 0.05$ (two-tailed), and analyses were performed using SPSS version 26.0.

RESULTS

Participant Flow and Baseline Characteristics: Figure 1 shows the CONSORT flow diagram. Ninety participants were randomized. Seven dropped out (4 IG, 3 CG), leaving 83 (92%) for the primary analysis. Baseline characteristics were balanced between groups.

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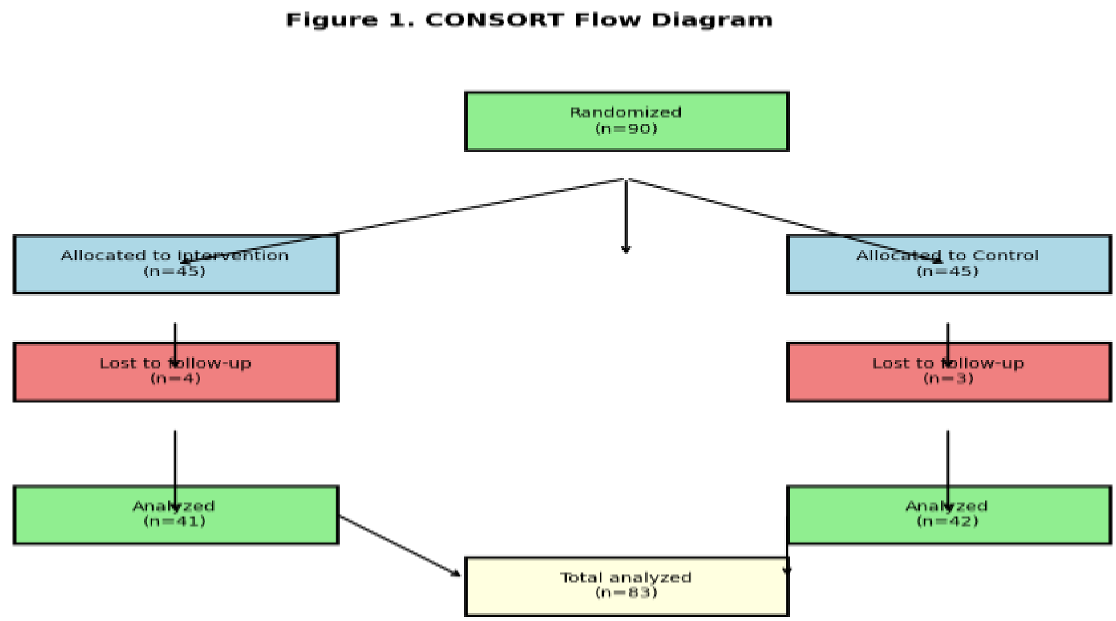

Figure 1 Consort Flow Diagram

Baseline Characteristics of Participants

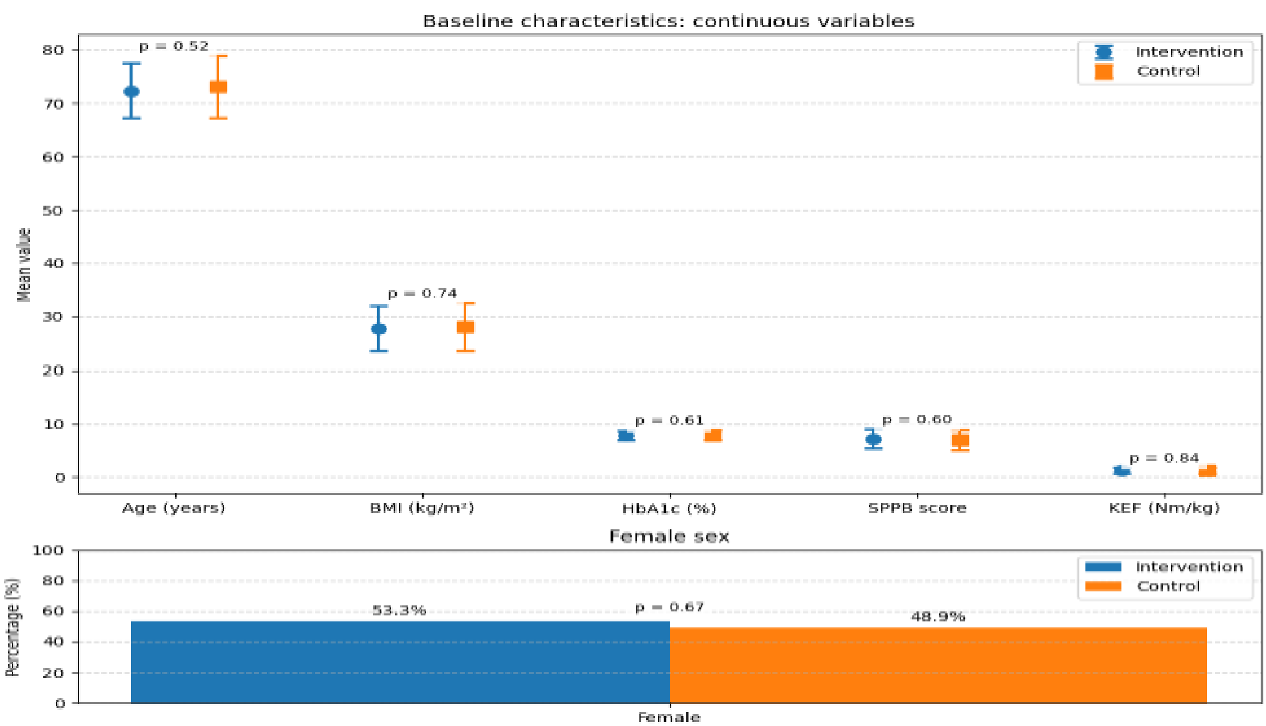

Figure 2 Baseline Characteristics: Continuous Variables

Baseline Characteristics: The baseline characteristics of the study participants are given in Table 1. Ninety participants were recruited, and 45 participants in each side were randomly chosen (including the intervention group and the control group). The average age of the respondents was comparable in the intervention and the control groups (72.4 +- 5.1 years vs. 73.1 +- 5.8 years, respectively). Most participants in both groups were women (53.3% and 48.9%, respectively). There was a similarity between mean BMI (27.8 +- 4.2 kg/m2 vs. 28.1 +- 4.5 kg/m2) and glycemic control (HbA1c 7.8 +- 0.9 vs. 7.9 +- 1.0). There were no differences between groups in physical function measured by the Short Physical Performance Battery (SPPB) score (7.2 +- 1.8 vs. 7.0 +- 1.9), and knee extensor strength (KEF: 1.31 +- 0.48 Nm/kg vs. 1.29 +- 0.51 Nm/kg). No statistically significant differences between the groups were mentioned in all the variables of the baseline (p > 0.05) which means that the process of randomization was effective in balancing groups at the beginning of the research**.**

Table 01: Data are presented as mean ± SD or n (%).

Characteristic	Intervention Group (n=45)	Control Group (n=45)	p-value
Age, years	72.4 ± 5.1	73.1 ± 5.8	0.52
Female, n (%)	24 (53.3%)	22 (48.9%)	0.67
BMI, kg/m²	27.8 ± 4.2	28.1 ± 4.5	0.74
HbA1c, %	7.8 ± 0.9	7.9 ± 1.0	0.61
SPPB score (0–12)	7.2 ± 1.8	7.0 ± 1.9	0.60
KEF, Nm/kg	1.31 ± 0.48	1.29 ± 0.51	0.84

Primary Outcome: Knee Extension Force: A significant Group × Time interaction was found for KEF (F=12.47, p<0.001). At 24 weeks, the IG showed a significantly greater increase in KEF compared to the CG (mean between-group difference: +0.22 Nm/kg, 95% CI: 0.10–0.34, p<0.001). This benefit was partially retained at 36 weeks (+0.15 Nm/kg, 95% CI: 0.03–0.27, p=0.012).

Secondary Outcomes

Functional Mobility: The IG demonstrated significantly greater improvements in SPPB (+1.8 points, p=0.002), TUG (–1.4 s, p=0.013), and 6MWT (+34 m, p=0.005) at 24 weeks compared to the CG. These functional gains were maintained at 36 weeks for SPPB (p=0.023) and 6MWT (p=0.038), but not for TUG (p=0.089).

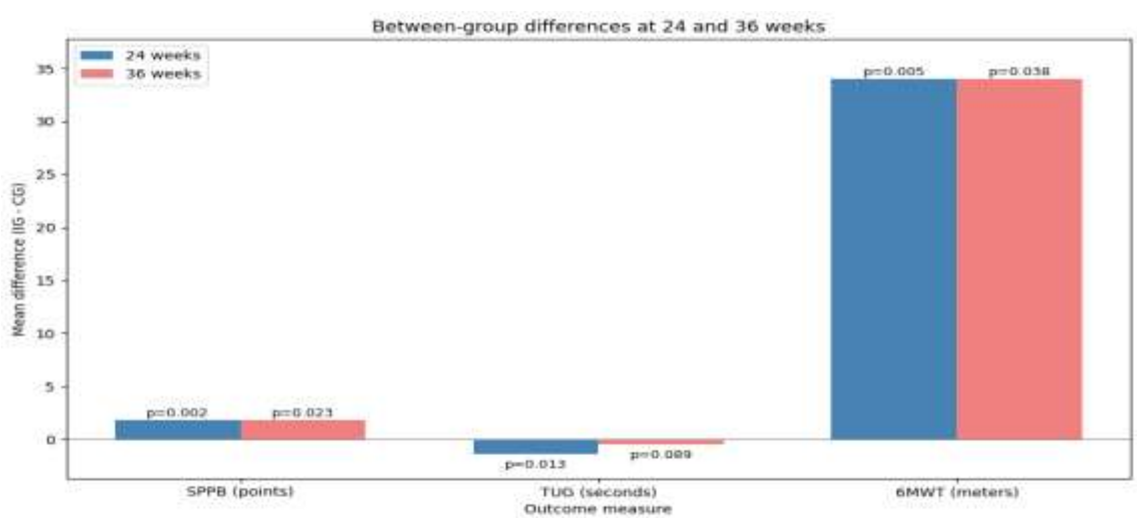

Figure 3 Between-Group Differences at 24 and 36 weeks

Glycemic Control and Body Composition: HbA1c decreased significantly in both groups (IG: –0.6%, CG: –0.5%), with no significant between-group difference (p=0.42). Skeletal muscle mass did not change significantly in either group.

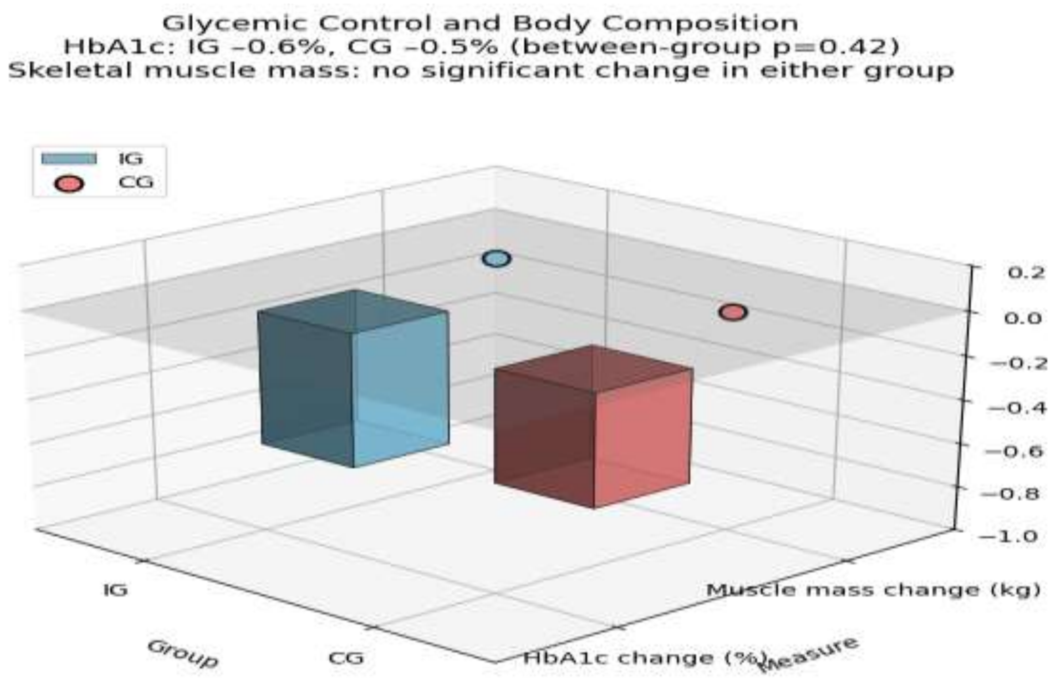

Figure 4 Glycemic Control and Body Composition

Patient-Reported Outcomes: The IG reported greater improvement in Diabetes-39 quality of life (p=0.02) and exercise self-efficacy (p=0.004) at 24 weeks.

Adherence, Safety, and Feasibility: Adherence to tele-sessions in the IG was 84% (mean 40 of 48 sessions). Self-reported exercise days were higher in the IG (3.2 days/week vs. 1.8 in CG, p<0.001). No serious adverse events related to the intervention occurred. Minor events (e.g., transient muscle soreness) were similar between groups. Satisfaction in the IG was high (mean score 4.5/5).

DISCUSSION

This multicenter randomized controlled trial demonstrated that a structured, bi-weekly, video-based tele-physiotherapy program delivered over 24 weeks produced significant improvements in lower-limb muscle strength and functional mobility in older adults with Type 2 Diabetes Mellitus. The intervention resulted in a clinically meaningful increase in isometric knee extension force, which was partially sustained at 12-week follow-up, indicating durability of neuromuscular adaptations beyond the supervised period. In parallel, improvements in SPPB scores, Timed Up and Go performance, and six-minute walk distance reflected enhanced balance, gait efficiency, and functional endurance. These findings expand upon earlier work that reported gains in muscle strength through low-intensity telephone guidance but limited impact on mobility outcomes (18). By integrating real-time video supervision, progressive resistance training, and structured balance and dual-task exercises, the present trial addressed training specificity and intensity progression more comprehensively, which likely contributed to the broader functional benefits observed (19,20). The magnitude of SPPB improvement exceeded the threshold considered clinically meaningful in geriatric populations, reinforcing the practical relevance of the intervention for reducing disability risk. The maintenance of strength and selected mobility gains at follow-up further suggested that participants internalized exercise behaviors and sustained engagement, reflecting successful behavioral integration into daily routines.

The absence of a significant between-group difference in glycemic control, despite modest reductions in HbA1c in both groups, was consistent with prior tele-rehabilitation trials in diabetic populations (21,22). Pharmacological optimization and routine endocrinology care likely exerted the dominant influence on metabolic parameters, thereby attenuating the incremental glycemic effect attributable to exercise alone. These findings supported the conceptualization of tele-physiotherapy as a complementary modality primarily targeting functional decline rather than serving as a stand-alone glycemic intervention. Similarly, skeletal muscle mass did not demonstrate significant change, aligning with evidence indicating that hypertrophic adaptations in older adults with metabolic disease require either higher intensities, longer durations, or combined nutritional strategies to overcome anabolic resistance (23,24). Nonetheless, neuromuscular strength gains occurred independently of measurable increases in muscle mass, reflecting improved motor unit recruitment and neural adaptation, phenomena frequently documented in early-phase resistance training (25). Importantly, the intervention achieved high adherence (84%) and strong participant satisfaction, outcomes that compared favorably with traditional facility-based programs where long-term adherence often declines below 50% (26). The incorporation of motivational interviewing and goal-setting techniques, grounded in established behavioral change frameworks, likely enhanced self-efficacy and contributed to sustained engagement (27). Improved Diabetes-39 and exercise self-efficacy scores further substantiated the psychosocial benefits of the program.

Several strengths enhanced the internal validity and translational relevance of this study. The assessor-blinded, multicenter design reduced detection bias and improved generalizability across clinical settings. The relatively long intervention duration, compared with many prior telehealth trials, allowed sufficient time for progressive overload and behavioral adaptation. The inclusion of both objective performance-based measures and patient-reported outcomes provided a multidimensional evaluation of treatment effects. Furthermore, the follow-up assessment enabled examination of sustainability, an aspect frequently overlooked in tele-rehabilitation research (28). However, certain limitations warranted consideration. Participants required access to digital technology and basic technological literacy, potentially limiting applicability to socioeconomically disadvantaged populations. The control group received minimal contact, which did not fully control for attention effects; therefore, part of the observed benefit may have been influenced by therapist interaction rather than exercise content alone. Although the 24-week duration was longer than many comparable trials, it may still have been insufficient to induce measurable hypertrophy in this age group characterized by anabolic resistance (23,24). Additionally, the study was conducted within a defined geographic region, and cultural or healthcare system differences may influence implementation elsewhere. Despite these limitations, the findings suggested that tele-physiotherapy represents a scalable, safe, and clinically effective strategy to mitigate functional decline in older adults with T2DM. Integration of structured tele-rehabilitation into routine diabetes care pathways may address accessibility barriers and support long-term maintenance of independence in this growing population (29).

CONCLUSION

A 24-week, video-based tele-physiotherapy program significantly improved knee extension strength and functional mobility in older adults with Type 2 diabetes, with benefits partially sustained 12 weeks post-intervention. The program was safe, feasible, and associated with high adherence. Tele-physiotherapy represents a valuable, scalable adjunct to standard diabetes care for preserving physical function and independence in this vulnerable population. Future research should investigate longer-term outcomes and cost-effectiveness.

AUTHOR CONTRIBUTIONS

Author	Contribution
Zakir Ullah*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Wagma Wajid	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing

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Author	Contribution
	Has given Final Approval of the version to be published
Irfanullah	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Asad Ullah Khan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Suraya Rehmat	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Hafsa Rahim	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Mohsin Ullah	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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