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From Home to Health: The Effectiveness of Otago Exercise Program via Telerehabilitation on Fall-Related Outcomes in Older Adults

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Abstract: This study aimed to investigate the effects of the Otago Exercise Program (OEP), delivered via telerehabilitation, on pain, walking speed, lower extremity muscle strength, fear of falling, anxiety, quality of life, and balance in older adults with a history of falls. A total of 45 participants aged 65–78 were randomized into three groups: Face-to-Face Otago Exercise Group (FFOEG, n=15), Telerehabilitation-Based Otago Exercise Group (TBOEG, n=15), and Control Group (CG, n=15). The intervention consisted of 45-minute sessions, three times per week, for eight weeks. Evaluations were performed at baseline, 4th week, 8th week, and 4 weeks post-intervention using the Numeric Pain Scale, Timed Up and Go Test, 30-Second Sit-to-Stand Test, Falls Efficacy Scale, Beck Anxiety Inventory, WHOQOL-OLD, and Tinetti Balance and Gait Test. No significant difference was found in demographic variables between the groups ($p>0.05$). Intra-group analyses showed significant improvements in both intervention groups in most outcomes ($p<0.05$). Between-group comparisons revealed significant differences in favor of TOEG for fear of falling and balance ($p<0.05$). These findings support the effectiveness of OEP and suggest that telerehabilitation may be a viable alternative for delivering fall-prevention exercises to older adults in hard-to-reach areas.

Keywords: balance, elderly, falls, exercise, telerehabilitation

1. Introduction

In both developed and developing countries, the proportion of the elderly population is rapidly increasing, leading to a higher prevalence of age-related diseases. Among older adults, falls have emerged as a major concern due to their strong association with increased morbidity and mortality. To address this problem, various exercise interventions such as strengthening programs, aerobic training, tai chi, pilates, and similar approaches have been widely investigated [1]. In recent years, the Otago Exercise Program (OEP) has gained prominence as an effective strategy to reduce fall risk and improve balance in older adults, and clinical studies have further demonstrated that implementing these exercises under the supervision of a physiotherapist yields superior outcomes compared with conventional home-based programs [2]. Globally, approximately 26.5% of older adults experience at least one fall annually, according to a systematic review and meta-analysis including more than 36 million participants [3]. In Turkey, demographic trends highlight a similar concern, as the population aged 65 years and older reached 9.11 million in 2024 (10.6% of the total population), compared with 9.1% in 2019 [4]. These data underscore the urgent need for effective fall-prevention strategies worldwide and nationally.

Today, the economic burden caused by healthcare expenditures and the increased use of remote access methods due to the COVID-19 pandemic have shown that similar clinical outcomes can be achieved compared to traditional home exercise programs. Through this approach, exercises aimed at improving balance and preventing falls in older adults can be performed regularly and accurately under supervision, making follow-up and monitoring more practical for physiotherapists [5].

According to the definition of health proposed by the World Health Organization, health is not merely the absence of disease or disability, but a state of complete physical, mental, and social well-being [6].

With the global population aging rapidly, the burden of elderly individuals on healthcare systems is steadily increasing. This has often led to the provision of short-term and inadequate healthcare services for the elderly, resulting in significant disruptions in public health outcomes. Therefore, implementing long-term and carefully planned healthcare interventions for older adults is essential to improve their quality of daily life and to help them achieve a state of complete well-being as defined by the concept of health [7].

The rising proportion of older adults in the global population has led to a noticeable increase in age-related risk factors affecting both society and healthcare systems. Among the most common of these are coronary artery disease; sarcopenia, which causes loss of muscle and bone mass; obesity resulting from poor and irregular nutrition; physical inactivity; fall incidents related to cognitive decline; and neurological conditions such as dementia, which stem from the neurophysiological effects of aging [8].

Declining neurological and physical capacities in older adults contribute to increased social isolation and decreased participation in physical activities. Among those experiencing delirium a condition characterized by simultaneous neurological, physical, and psychological impairments the prevalence of frailty is notably high. Therefore, it is of great importance to encourage frail older adults to engage in activities that foster enjoyment and strengthen their connection with the community [9].

Loss of lean body mass is associated with impairments in postural balance and gait function. When strength training exercises are complemented by protein-rich dietary programs, significant improvements in muscle mass and strength levels can be observed in older adults. Among the various risk factors linked to aging, cardiovascular diseases represent another major concern. In particular, heart and vascular conditions pose serious risks for morbidity and mortality in the elderly population [10]. The increased prevalence of cardiovascular diseases associated with aging imposes a significant burden on healthcare systems, particularly in countries with a large elderly population. Reducing the incidence of such conditions is expected to not only alleviate economic strain but also enhance the quality of life in older adults. Therefore, exercise and physical activity-based rehabilitation approaches play a vital role in managing elderly individuals with cardiovascular diseases [11].

The importance and benefits of exercise in older adults are well-established and indisputable for maintaining a healthy lifestyle. However, it is essential that elderly individuals not only understand these benefits but also possess the motivation required to engage in regular physical activity. At this point, encouragement should not be limited to physiotherapists alone; in accordance with an interdisciplinary approach, all healthcare professionals should play an active role in motivating and guiding older adults toward exercise. When necessary, therapists should provide personalized education to enhance awareness and adherence. Numerous studies have indicated that the lack of exercise habits in elderly individuals is often rooted in limited knowledge and the absence of a structured exercise culture beginning from childhood and extending into later life [12].

Telerehabilitation is defined as the provision of rehabilitation services to patients remotely, without the constraints of time or location, particularly when in-person access is limited or not preferred. As a subcategory of telehealth a modern healthcare model that facilitates remote communication and, when necessary, monitoring of patients telerehabilitation has increasingly become an integral part of contemporary medical practice [13]. In the United States, the high population density in rural areas, combined with the economic disadvantages faced by many residents, often results in limited access to various aspects of healthcare. To address this gap, a range of methods that utilize remote communication tools to reach individuals lacking direct access to services is collectively referred to as "Telehealth" [14].

Within the broader framework of telehealth, clinical services delivered by healthcare professionals have been termed "telemedicine." The integration of rehabilitation services into this model has increasingly been recognized as an essential component, based on both emerging research and practical healthcare needs. According to the definition provided by the American Telemedicine Association, the term "telerehabilitation" refers to the delivery of rehabilitation services through telecommunication technologies such as computers and telephones facilitated by remote access systems [15].

Telerehabilitation enables the delivery of rehabilitation services to individuals who have limited access due to geographic constraints or who prefer remote care for time efficiency. The nature of interaction between the therapist and the patient may vary depending on the rehabilitation method and individual needs. With advancements in technology, telerehabilitation has expanded to include diverse tools such as video conferencing, sensor-based systems like pedometers, virtual reality applications, and voice calls. The common feature of these methods is the remote communication between the therapist and the patient. This interaction may occur synchronously (in real-time) or asynchronously (via recorded content), depending on the therapist's rehabilitation plan [16].

Beyond its economic benefits and time efficiency, telerehabilitation has been shown to enhance the quality of rehabilitation services delivered to individuals living in rural or hard-to-reach areas. With the advancement of technological devices, the diversity of methods and tools used in telerehabilitation has significantly expanded. When accessible, patients in need of rehabilitation experience improvements in their quality of life that align with the goals of the rehabilitation process. Furthermore, telerehabilitation enables the provision of services to a larger number of patients within shorter timeframes, while requiring fewer therapists, thereby increasing the overall efficiency of the healthcare system [17].

Within this framework, specific exercise-based interventions can be successfully adapted to remote delivery models. Among these, the Otago Exercise Program (OEP) has been established as a highly effective intervention for older adults in both clinical and home settings. The program, which consists of simple exercises designed to improve muscle strength, gait performance, and balance, can be easily supervised through telerehabilitation platforms. Developed at the University of Otago in New Zealand, OEP has been scientifically proven to significantly reduce fall risk among elderly individuals, regardless of gender [18]. Studies further demonstrate that when OEP is applied under proper supervision, even remotely, it improves balance and physical performance, thereby contributing to a reduction in fall risk [2].

In a study incorporating the Otago Exercise Program and aiming to encourage older adults to exercise through a digital platform, long-term data are being used to evaluate changes in fall risk, fall frequency, and quality of life. However, the results of this study have not yet been published [19]. Although the content of the exercise program is relatively simple, the motivation of the older adult plays a crucial role in its successful implementation. With the advancement of models such as telerehabilitation, which facilitate fast and effective communication, the Otago Exercise Program, when applied at home, has been shown to produce significant improvements not only in fall frequency and balance level, but also in grip strength, use of assistive devices, and levels of functional dependence [20].

2. Materials and Methods

2.1 Study Design and Setting

This study was conducted at the Physical Therapy and Rehabilitation Unit of Bahçeşehir University Medical Park Göztepe Hospital, with the participation of 45 voluntary individuals aged 65 and over. Prior to the initiation of the study, ethical approval was obtained from the Sinop University Human Research Ethics Committee (Approval No: 2022/115, dated 06.07.2022). All participants were thoroughly informed about the study, and written informed consent was obtained through a signed "Voluntary Consent Form."

Figure 1. Protocol of the study

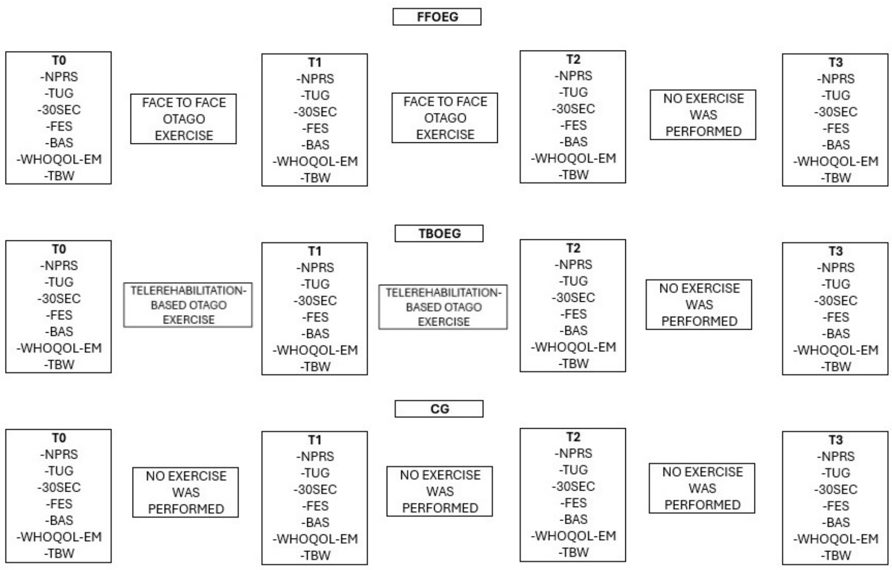
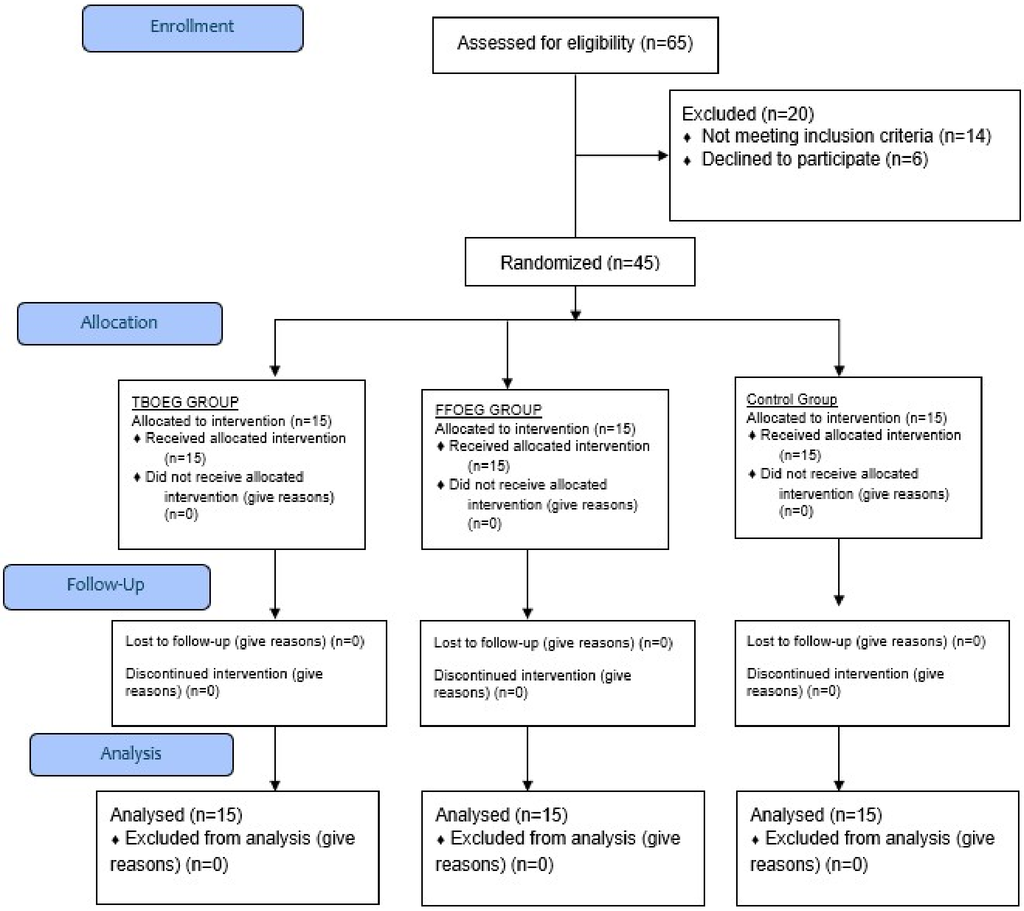


Figure 2. Consort diagram



2.2 Eligibility Criteria

2.2.1 Inclusion Criteria

- Being between 65 and 85 years of age and in good general health
- Living independently at home and able to walk without assistive devices
- Having experienced at least one fall within the past 12 months
- Willingness to participate in the study
- Signing the informed consent form
- Having access to internet and necessary equipment for remote participation

2.2.2 Exclusion Criteria

- Uncontrolled cardiovascular disease, such as recent myocardial infarction within the past 3 months, unstable angina, decompensated heart failure, or uncontrolled hypertension (>180/110 mmHg)
- Severe musculoskeletal conditions preventing safe participation in exercise (e.g., hip or lower-limb fracture within the past 6 months, recent joint replacement, or acute inflammatory flare)
- Neurological or sensory disorders interfering with balance or mobility training (e.g., severe vestibular dysfunction, profound visual impairment not correctable with lenses)

- Cognitive or psychiatric impairment that limits the ability to follow instructions (e.g., Mini-Mental State Examination [MMSE] <24)
- Any physician-determined medical contraindication to moderate physical activity (e.g., uncontrolled arrhythmia, severe aortic stenosis, acute systemic infection)
- Inability to stand unsupported for ≥1 minute
- Participation in structured balance or strength training programs within the past 3 months

2.2.3 Withdrawal Criteria

- Discontinuation of the treatment and evaluation protocol
- Injury due to trauma during the intervention process
- Emergence of contraindications that prevent continuation of the exercises
- Voluntary withdrawal from the study by the participant
- Traumatic injuries affecting the upper or lower extremities

2.3 Sample Size and Randomization

Of the 65 individuals initially assessed for eligibility, 14 were excluded due to the absence of a fall history within the past 12 months, and 6 declined to participate. As a result, the study continued with 45 participants. Each participant was assigned a number and randomly allocated using www.random.org. No participant withdrew from the study for any reason after randomization.

To determine the sample size, a power analysis was performed using the G*Power software (version 3.1.9.7). The statistical power of the study is expressed as 1–β (β = probability of Type II error). The analysis was informed by data from a randomized controlled trial conducted by Ferraro et al., which compared the effects of inspiratory muscle training and Otago exercise training on balance [21]. In that study, the mean and standard deviation scores for the Timed Up and Go (TUG) test were reported as 14.1 ± 11.0 in the Otago group and 7.9 ± 1.4 in the inspiratory muscle training group, corresponding to a moderate effect size (d = 0.49). Based on this effect size and setting the significance level at α = 0.05 with 80% power, the required sample size was calculated as 45 participants for this three-group study. Thus, our study design was refined to align with the effect sizes reported by Ferraro et al. [21].

2.4 Group Allocation

All participants were thoroughly informed about the study procedures prior to participation. Following the information session, individuals who signed the informed consent form were administered the Mini-Mental State Examination (MMSE). Participants who met the inclusion criteria were evaluated for demographic characteristics, including gender, age, weight, height, number of falls within the past year, and body mass index (BMI), all of which were calculated and recorded. Eligible participants were then randomly assigned into three groups:

- Telerehabilitation-Based Otago Exercise Group (TBOEG) (n=15; 8 males, 7 females)
- Face-to-Face Otago Exercise Group (FFOEG) (n=15; 8 males, 7 females)
- Control Group (CG) (n=15; 8 males, 7 females)

2.5 Intervention Protocol

An 8-week intervention protocol was implemented. The Otago Exercise Program (OEP) was administered three times per week for eight weeks, with each session lasting 45 minutes, including rest periods. The sessions were conducted individually with a physiotherapist, either remotely (telerehabilitation) or face-to-face, depending on the assigned group. Telerehabilitation sessions were delivered via Zoom (Zoom Video Communications, San Jose, CA, USA) in real time under the direct supervision of a licensed physiotherapist. Each session lasted 45 minutes and was conducted three times per week for eight weeks, matching the schedule of the face-to-face group. At the beginning of each session, the physiotherapist ensured appropriate camera positioning and lighting to provide full visibility of participants' posture and movements, thereby enabling real-time feedback and progression adjustments. The structure and content of the OEP were based on the official training manual published by the University of North Carolina Center for Geriatric Workforce Enhancement Program [22].

Adherence was defined as the proportion of completed sessions out of the 24 planned sessions (three sessions per week over eight weeks). All participants in both the telerehabilitation and face-to-face groups attended 100% of the prescribed sessions. Therefore, overall adherence and compliance rates were recorded as 100%, with no missed sessions or dropouts. Outcome assessors were blinded to group allocation throughout data collection and analysis. Participants were advised to wear appropriate clothing and supportive footwear, ensure chair stability, and keep water accessible. Exercises were to be discontinued in the event of pain, dizziness, or shortness of breath. Post-exercise stretching was recommended to reduce the risk of muscle soreness or spasms. Each movement was performed for a minimum of 10 repetitions. No intervention was applied to the control group other than the assessments. Upon completion of the study, participants in the control group were offered appropriate rehabilitation services free of charge at the participating institution.

2.6 Assessment Timeline

Measurements were conducted at four different time points for each group:

- T0: baseline (immediately before the intervention)
- T1: end of the 4th week
- T2: end of the 8th week
- T3: end of the 12th week

The timing of assessments was consistent across all groups.

2.7 Outcome Measures

Demographic data including age, gender, body weight, height, BMI, and number of falls in the past year were recorded. Height was measured using a standard tape measure, and weight using a digital scale (Aprilla Abs 1029). BMI was calculated as weight (kg) divided by height (m^2).

Pain levels were assessed using the Numeric Pain Rating Scale (NPRS) [23]. Functional mobility was assessed with the Timed Up and Go (TUG) Test, where a time longer than 12 seconds indicated a high risk of falling [24]. Lower extremity strength and balance were measured with the 30-Second Chair Stand Test [25]. Fear of falling was evaluated using the Falls Efficacy Scale (FES), with scores above 70 indicating high concern [26]. Anxiety was measured with the Beck Anxiety Inventory (BAI); total scores below 21 indicated low anxiety, 22–35 moderate, and 36 or above severe anxiety [27]. Quality of life was assessed with the World Health Organization Quality of Life – Older Adults Module (WHOQOL-OLD) [28]. Balance and gait performance were measured using the Tinetti Balance and Gait Test (TINETTI), where total scores below 18 indicated high fall risk, 19–24 moderate risk, and scores above 24 low fall risk [29].

2.8 Statistical Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software, version 23.0 (SPSS Inc., Chicago, IL, USA). A significance level of $p < 0.05$ was considered statistically significant. Descriptive statistics were expressed as mean ± standard deviation (SD) for continuous variables and as number (n) and percentage (%) for categorical variables. The normality of data distribution within groups was assessed using the Kolmogorov–Smirnov test. For between-group comparisons, one-way analysis of variance (ANOVA) was used for normally distributed variables, while the Kruskal–Wallis test was used for non-normally distributed variables. For pairwise group comparisons, the Independent Samples T-test was applied to normally distributed data, and the Mann–Whitney U test was used for non-normally distributed data. For within-group comparisons across different time points, the Paired Samples T-test was used for normally distributed data, and the Wilcoxon signed-rank test was applied for non-normally distributed data. Since no statistically significant differences were found between male and female participants, gender-based analyses were not reported.

3. Results

Table 1. Demograhpic data of groups

Parameters	Mean±SD (Min-Max)			p
	TBOEG	FFOEG	CG	
Age	70,73 ±3,58 (66-78)	69,60 ±3,02 (66-76)	70,60 ±3,74 (65-78)	$0,621^{W}$
Weight (Kg)	82,20 ±8,55 (64-95)	84,69 ±4,55 (77-96)	84,60 ±8,15 (68-97)	$0,575^{W}$
Height (cm)	169,47 ±7,14 (158-182)	170,80 ±4,35 (162-179)	169,07 ±9,95 (155-182)	$0,804^{W}$
BMI (Kg/m^2)	28,53 ±1,81 (24,7-31,8)	28,99 ±1,31 (26,8-30,8)	29,79 ±3,83 (24,1-36,2)	$0,641^{E}$
Gender *Female* *Male*	8 (53,3) 7 (46,7)	8 (53,3) 7 (46,7)	8 (53,3) 7 (46,7)	$0,796^{Q}$
Falling in the last 1 year	2,27 ±1,44 (1-5)	2,33 ±1,54 (1-6)	2,53 (±1,64) (1-6)	$0,891^{E}$

Abbreviations: Min: Minimum, **Max:** Maximum, **SD**: Standard Deviation**, TOEG:** Telerehabilitation Otago Exercise Group¸ **FFOEG:** Face-to-Face Otago Exercise Gropu, **CG:** Control Group**, BMI:** Body Mass Index, **W**: ANOVA Testi, **E**: Kruskal-Wallis Testi, **Q**: Chi-Square Test. *p < 0.05.

Table 2. Comparison of intra- and inter-group parameters

Parameters	**Mean±SD**			**p** **I & II & III**
	TBOEG	**FFOEG**	**CG**	
NPRS T0	3,47 ±1,73^{a}	4,40 ±1,50^{a}	3,27 ±1,79	0,155
NPRS T1	3,07 ±1,44^{a}	2,47 ±1,19^{b}	2,87 ±1,51	0,349
NPRS T2	1,33 ±0,90^{b}	1,67 ±0,9^{c}	4,07 ±1,28	0,000^{E}
NPRS T3	1,47 ±0,99^{b}	1,80 ±1,21^{c}	3,40 ±1,77	0,001^{W}
p	<0,001	<0,001	0,389	
TUG T0	14,40 ±1,55^{a}	14,53 ±0,83^{a}	13,47 ±4,69	0,237
TUG T1	12,93 ±1,22^{b}	12,67 ±1,05^{b}	13,27 ±3,67	0,749
TUG T2	12,07 ±0,96^{b}	11,67 ±1,05^{b}	12,93 ±2,60	0,130
TUG T3	12,40 ±1,12^{b}	12,20 ±1,21^{b}	13,00 ±3,32	0,571
p	<0,001	<0,001	0,573	
30SEC T0	6,60 ±1,40^{a}	6,07 ±1,22^{a}	6,00 ±1,46	0,427
30SEC T1	7,27 ±1,71^{ab}	7,27 ±1,22^{ab}	6,13 ±1,30	0,053
30SEC T2	8,40 ±1,45^{b}	8,67 ±1,54^{b}	6,13 ±1,64	0,000^{W}
30SEC T3	8,20 ±1,70^{b}	8,20 ±1,47^{b}	5,67 ±1,84	0,000^{W}
p	<0,001	<0,001	0,351	
FES T0	40,87 ±5,73^{a}	47,47 ±8,18^{a}	42,13 ±15,53	0,210
FES T1	29,47 ±6,56^{b}	33,87 ±9,63^{b}	48,33 ±12,66	0,000^{E}
FES T2	19,60 ±4,03^{b}	24,40 ±6,58^{c}	45,80 ±14,16	0,000^{E}
FES T3	23,00 ±4,91^{b}	22,93 ±5,71^{c}	43,40 ±15,61	0,000^{E}
p	<0,001	<0,001	0,913	
BAS T0	39,20 ±4,09^{a}	37,33 ±5,01^{a}	36,33 ±4,03	0,206
BAS T1	27,73 ±4,76^{b}	29,20 ±5,23^{b}	36,73 ±4,01	0,000^{W}
BAS T2	23,27 ±6,54^{b}	23,27 ±5,92^{c}	37,60 ±4,76	0,000^{W}
BAS T3	25,60 ±7,79^{b}	22,93 ±5,93^{c}	36,73 ±5,15	0,000^{W}
p	<0,001	<0,001	0,673	
WHOQOL-EM T0	68,60 ±4,56^{a}	66,93 ±7,19^{a}	67,73 ±8,00	0,796
WHOQOL-EM T1	76,73 ±4,56^{b}	75,00 ±3,96^{b}	69,40 ±7,41	0,002^{W}
WHOQOL-EM T2	79,13 ±4,73^{b}	76,93 ±4,82^{b}	66,00 ±5,90	0,000^{W}
WHOQOL-EM T3	76,87 ±4,81^{b}	75,80 ±3,67^{b}	68,53 ±6,45	0,000^{W}
p	<0,001	<0,001	0,872	
TBW T0	22,33 ±4,72^{a}	17,47 ±6,42^{a}	21,93 ±4,67	0,053
TBW T1	25,73 ±2,82^{a}	21,80 ±5,51^{a}	21,00 ±5,48	0,019^{E}
TBW T2	30,87 ±2,03^{b}	28,00 ±3,49^{b}	23,13 ±3,25	0,000^{W}
TBW T3	29,40 ±2,23^{b}	28,53 ±2,90^{b}	23,53 ±3,34	0,000^{W}
p	<0,001	<0,001	0,077	

Note: The letters *a,b,c,ab represent the result of Posthoc analysis. There is a statistically significant difference between different letters. There is no difference between the same letters.

Abbreviations: W: ANOVA Testi, **E**: Kruskal-Wallis Testi, **D**: Mann-Whitney U Testi **SD**: Standard Deviation**, NPRS: N**umerical Pain Rating Scale, **TUG:** Timed get up and go test, **30SEC:** 30 Second Stand-Up and Sit Test, **FES:** Falls Efficacy Scale, **BAS:** Beck Anxiety Scale, **WHOQOL-EM:** World Health Organization Quality of Life Scale - Elderly Module, **TBW**: Tinetti Balance and Walking Test.

Table 3. Comparing the difference between groups

Parameters	Mean±SD			p
	TBOEG	FFOEG	CG	
NPRS	2,00 ±1,46[a]	2,60 ±1,84[a]	-0,13 ±2,47[b]	0,006
TUG	2,00 ±1,41	2,33 ±0,98	0,47 ±3,68	0,139
30SEC	14,80 ±2,83[a]	14,27 ±2,37[a]	11,67 ±3,06[b]	0,005
FES	63,87 ±8,41[a]	70,40 ±10,97[ab]	85,53 ±27,93[c]	0,008
BAS	13,60 ±6,97[a]	14,40 ±6,70[a]	-0,40 ±5,93[b]	<0,001
WHOQOL-EM	-8,27 ±5,08[a]	-8,87 ±6,82[a]	-0,80 ±8,80[b]	0,012
TBW	-7,07 ±4,74[a]	-11,07 ±5,28[b]	-1,60 ±5,04[c]	<0,001

$p<0{,}05$.

The letters *a,b,c,ab represent the result of Posthoc analysis. There is a statistically significant difference between different letters. There is no difference between the same letters.

Abbreviations: TBOEG: Telerehabilitation-Based Otago Exercise Group ¸ **FFOEG:** Face-to-Face Otago Exercise Gropu, **CG:** Control Group**, W**: ANOVA Testi, **E**: Kruskal-Wallis Testi, **D**: Mann-Whitney U Testi, **Q**: Chi-Square Test, **SD**: Standard Deviation**, NPRS: N**umerical Pain Rating Scale, **TUG:** Timed get up and go test, **30SEC:** 30 Second Stand-Up and Sit Test, **FES:** Falls Efficacy Scale, **BAS:** Beck Anxiety Scale, **WHOQOL-EM:** World Health Organization Quality of Life Scale - Elderly Module, **TBW**: Tinetti Balance and Walking Test.

Figure 1. Mean NPRS values across assessment points within each group

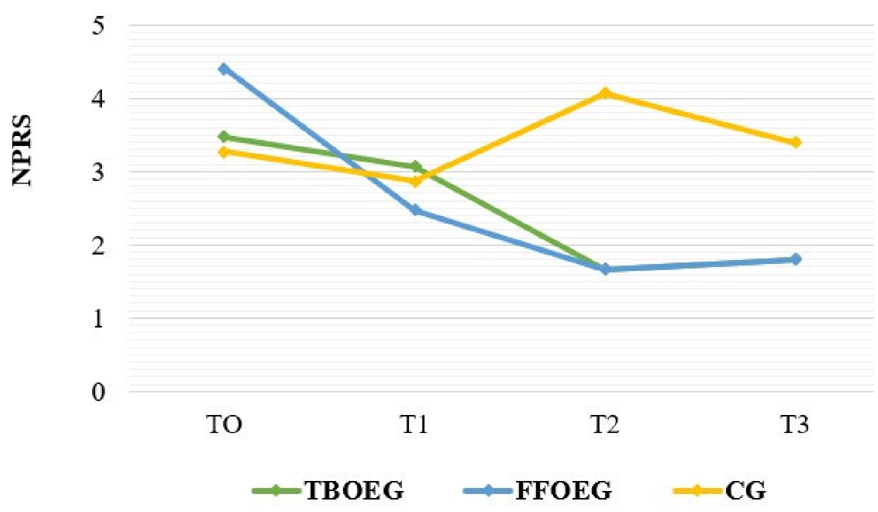


Figure 2. Mean TUG values across assessment points within each group

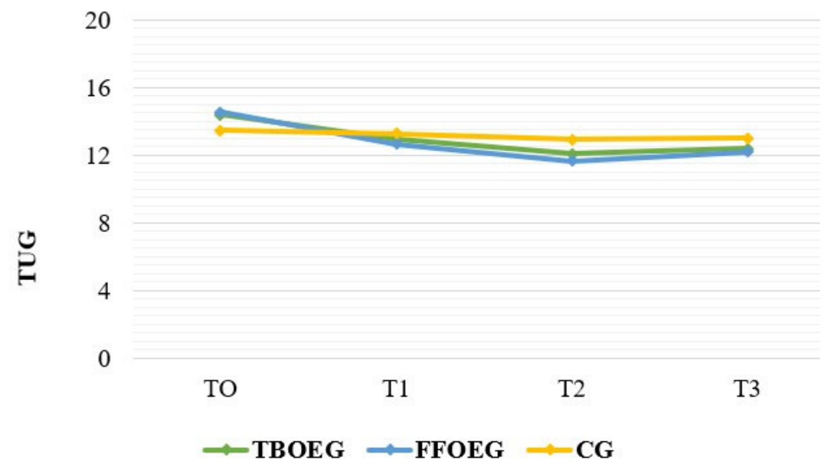


Figure 3. Mean 30SEC values across assessment points within each group

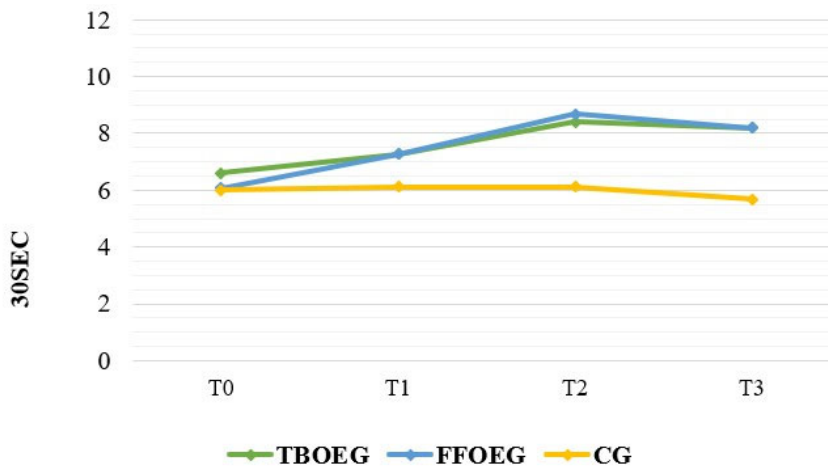


Figure 4. Mean FES values across assessment points within each group

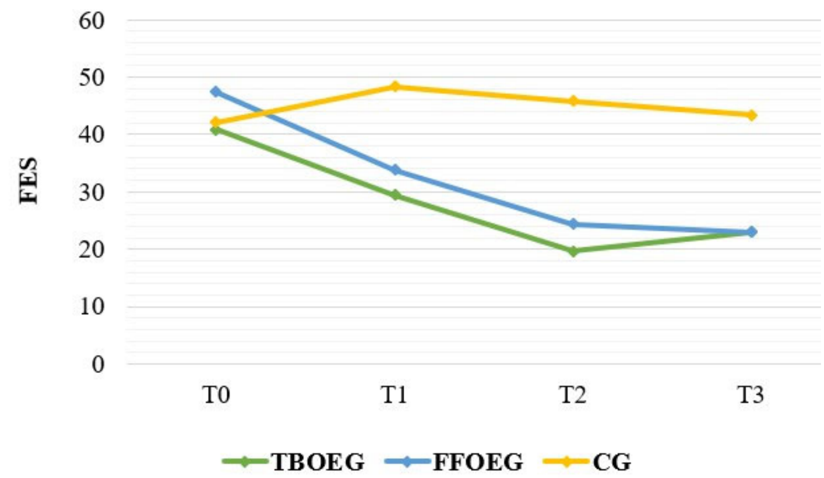


Figure 5. Mean BAS values across assessment points within each group

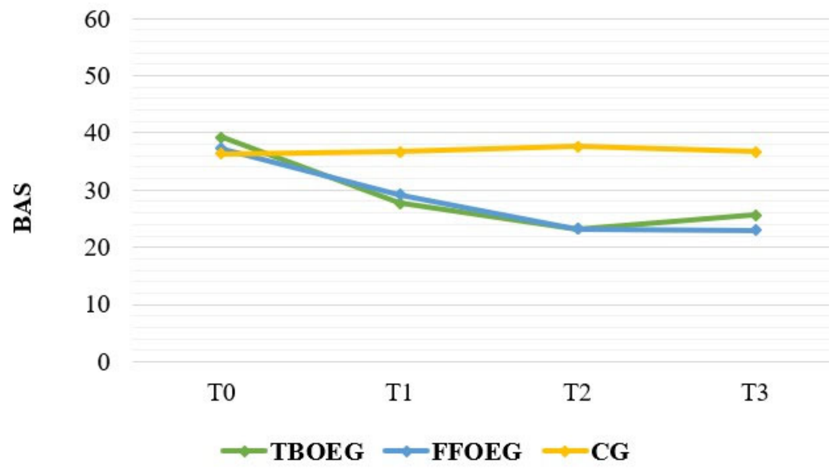


Figure 6. Mean WHOQOL-EM values across assessment points within each group

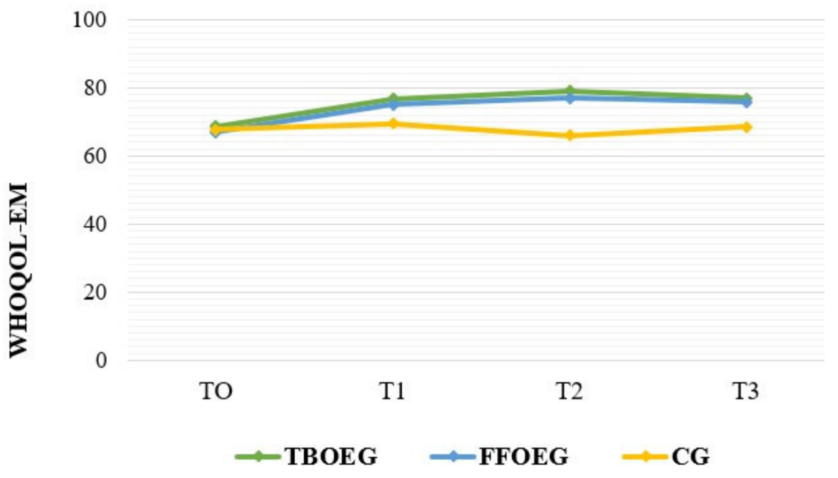
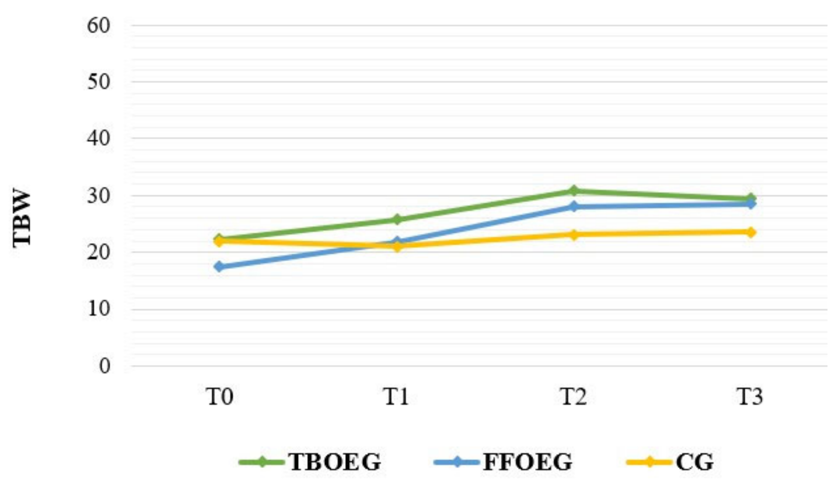


Figure 7. Mean TBW values across assessment points within each group



4. Discussion

The present study demonstrated that both telerehabilitation-based and face-to-face Otago Exercise Programs (OEP) were effective in reducing pain, improving gait speed, enhancing lower extremity strength, decreasing anxiety, and improving quality of life in older adults with a history of falls. Importantly, the telerehabilitation group showed greater improvements in balance and fear of falling compared with both the face-to-face and control groups, confirming the growing role of digital health interventions in fall prevention.

One possible explanation for the superior outcomes in fear of falling and balance in the telerehabilitation group is the home-based environment, which may reduce anxiety and promote confidence in functional tasks. Performing exercises in familiar surroundings likely enhanced psychological comfort and adherence, while real-time feedback provided by physiotherapists supported safe and correct performance of balance-related tasks. These results align with prior findings that home-based programs can reduce fall-related concerns and enhance self-efficacy [21,38].

Our findings are consistent with previous trials evaluating OEP and other technology-supported exercise interventions. Ferraro et al. [23] reported significant improvements in balance after OEP and inspiratory muscle training, and the effect size of our telerehabilitation group was comparable to their reported outcomes. Zhang et al. [30] demonstrated that technology-assisted exercise protocols improved pain and functional mobility in older adults with knee osteoarthritis, while Silva et al. [31] confirmed similar benefits in patients with chronic low back pain. Campo-Prieto et al. [32] reported improvements in physical function through immersive virtual reality exercise, further supporting the role of digital tools in rehabilitation.

The benefits of digital interventions extend to psychological domains as well. Oh and Choi [33] demonstrated improvements in balance and gait using motor imagery training, highlighting the potential for innovative methods to enhance functional mobility. Vlietstra et al. [34] emphasized the link between sarcopenia, arthritis, and fatigue, underscoring the importance of strength training in older adults. Similarly, Christensen et al. [35] reported that anxiety and cognitive concerns influence functional independence in Alzheimer's disease, reinforcing the importance of exercise-based interventions to improve psychological well-being.

Additional evidence supports the impact of exercise on quality of life in older populations. Häfele et al. [36] observed significant improvements in quality of life among older women after aquatic training, consistent with our findings using WHOQOL-OLD. Irandoust et al. [37] demonstrated improvements in postural stability with aquatic exercise in older adults, echoing our results on balance. Ángeles et al. [38] reported that OEP effectively reduced fear of falling in community-dwelling adults, while Menengi et al. [39] showed that dual-task telerehabilitation improved motor and cognitive outcomes in patients with Alzheimer's disease. Together, these studies reinforce that OEP, whether delivered face-to-face or via telerehabilitation, provides consistent and meaningful benefits across diverse populations.

During the COVID-19 pandemic, telerehabilitation emerged as an effective alternative to traditional in-person rehabilitation. A recent randomized controlled trial in older adults with post-COVID-19 syndrome demonstrated that a 12-week telerehabilitation program significantly improved VO_2peak, lower-limb muscle strength, and body composition compared with controls [40]. Likewise, a recent systematic review and meta-analysis confirmed that telerehabilitation enhanced physical function and quality of life in post-COVID-19 populations, underscoring its feasibility and scalability under pandemic-related constraints [41]. These findings support the broader applicability of telerehabilitation beyond fall prevention and reinforce its role in maintaining functional independence among older adults.

Recent contributions from Balneo and PRM Research Journal further emphasize the feasibility of remote rehabilitation approaches. Ciucă-Pană et al. (2023) demonstrated that remote cardiac rehabilitation is a viable alternative to on-site programs in Romania, yielding comparable functional outcomes [42]. Likewise, a 2024 review by Nicoara et al. highlighted the role of rehabilitation strategies such as telerehabilitation, Tai Chi, and yoga in enhancing quality of life among elderly patients with heart failure, reinforcing the applicability of these interventions to older populations [43].

This study also has limitations. First, the follow-up period was limited to 12 weeks, which restricts conclusions about long-term sustainability. Second, although all 45 participants completed the program, the small sample size limits generalizability. Third, technical issues such as unstable internet connections and variability in device quality may have affected the efficiency of the Zoom platform. Future studies should adopt free and widely accessible applications, which may enhance feasibility and minimize barriers, particularly in rural and low-income regions where specialized platforms may not be practical.

From a health economics perspective, telerehabilitation offers a cost-effective alternative to home physiotherapist visits by reducing travel and supervision costs. In resource-limited settings, the integration of OEP into public health initiatives through accessible digital platforms may improve scalability and equity of rehabilitation services. Such integration could reduce the burden of falls among older adults and contribute to healthier aging at the population level.

5. Conclusions

In conclusion, both telerehabilitation and face-to-face OEP interventions were effective in improving fall-related outcomes. However, telerehabilitation demonstrated superior benefits in reducing fear of falling and improving balance. These findings indicate that telerehabilitation is not only clinically effective but also feasible, cost-efficient, and scalable for older adults, particularly in underserved or rural communities. Future studies with larger samples, extended follow-up, and accessible platforms are needed to validate the long-term benefits and support integration into public health systems.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

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