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ORIGINAL RESEARCH

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The Effect of Suspension Training vs. Traditional Resistance Training in Older Adults: Randomized Controlled Trial

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Abstract

Objective: The objective of this study is to compare the effects of traditional resistance training (RT) vs. suspension training (ST) on functional performance, body composition, and cognitive functions in older adults.

Materials and Methods: Participants were categorized into three groups: the ST group (ST, n=8, age: 71), the traditional RT group (RT, n=8, age: 70), and the control group [(C), n=7, age: 70]. All measurements, assessments, and test evaluations were performed at the baseline, the sixth week, and the twelfth week. The training programs were conducted two days per week. The ST group was included in a program consisting of exercises with the suspension apparatus, whereas the RT focused on RT with body weight and free weights. The C was not included in the training program.

Results: The arm strength was greater in the ST group than in the C group (p=0.007). Muscle mass (p=0.029), basal metabolic rate (BMR) (p=0.034), agility and dynamic balance (p=0.012), leg strength (p=0.005), arm strength (p=0.002), and cognitive function (p=0.006) were significantly different in the ST group compared to the C group (p<0.05). The balance (p=0.005) and BMR (p=0.030) were significantly improved in the ST group compared to the RT group (p<0.05).

Conclusion: Physical therapists and trainers may use a suspension method as an alternative to traditional methods for older adults. This method may provide trainers with the opportunity to improve strength, balance, and cognitive function with a single training method.

Keywords: Agility, aging, balance, cognition, resistance, suspension

Introduction

Resistance training (RT) is suggested as a beneficial treatment for sarcopenia and its effects (1-10). It also affects fat mass, balance, physical function, and muscle mass (11-19). However, some studies indicate that it does not significantly enhance physical function (20-23). Explosive RT with heavy loads is also recognized as more effective for muscle growth and strength in older adults (4, 24-26). However, many older adults engage in RT to maintain their daily activities and physical function rather than to increase muscle mass. For this reason, different approaches are needed to avoid excessive training loads and enhance functional performance more safely in older adults.

Suspension training (ST), also known as total resistance eXercise (TRX) (total RT), is more effective for core muscle activation (27-29) and has the potential to improve functional performance (27, 29-31). ST involves two straps that hang from a fixed point, with each strap's length adjustable for various exercises. Older adults can safely participate in this training method without any additional loads. Previous studies have highlighted that ST is an effective alternative method for RT (32,33). This method can potentially contribute to improving both physical function

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and body composition components (33,34). However, it is still uncertain whether ST is more effective than RT for older adults (30,32,34).

Cognitive functions naturally decline with age (35). This decline may be due to reduced muscle strength and alterations in brain structure and function (36). Additionally, cognition is linked to balance ability and muscle mass. Alzheimer's disease and cognitive impairment are also correlated with these factors (37,38). Although some research suggests that aerobic fitness is associated with changes in brain structure and cognitive function (39), RT is also known to have the potential to enhance cognition (40-44). However, studies have shown that some resistance exercises do not improve cognitive function (45,46).

Finally, RT is effective in improving some abilities and functions. However, lifting weights and gradually increasing resistance could pose risks, particularly for this age group. Furthermore, RT is not enough to improve balance and cognitive functions. Therefore, we hypothesized that ST might also influence cognition and balance without added loads. Thus, we aimed to provide data on ST for physiotherapists, physical trainers, and researchers working with the older population. The objective of this study is to compare the effects of RT vs. ST on functional performance, body composition, and cognitive functions in older adults.

Materials and Methods

Participants

All participants were reached by announcement at the Healthy and Active Aging Studies Research Center. They were aged 65-80 years, had no physical disabilities, did not use any assistive devices, reported participation in RT, had not undergone surgery in the past year, had trained for two years and had an Mini Mental State Examination Score of 23 or higher. Additionally, they do not use medication or supplements (protein, vitamin D/calcium, and vitamin B) that might contribute to increased strength were included in this study (Table 1). Participants used medications that might enhance muscle strength, had a physical disability, used an assistive device, had not trained for the past two years, had not reported participating in RT, had surgery within the last year, or used supplements such as protein, vitamin D/calcium, and vitamin B were excluded from the study.

Participants were randomly assigned to three groups. After randomization, the control group (C) was instructed to maintain their usual daily activities during the research. At baseline, 40 participants were included. However, some participants dropped out for various reasons, such as moving to another city, unexplained reasons, boredom, short-term illnesses, caring for grandchildren, or going on vacation (Figure 1). The participants were randomized into ST (n=8, female:6, male:2), RT (n=8, female:6, male:2), and C (n=7, female:4, male:3).

Procedure

Participants were involved in all tests and measurements at baseline six weeks, and post-training. The Montreal Cognitive Assessment Scale (MoCA) Turkish version was used to evaluate cognition (47,48). The sit-to-stand test was used to assess leg functional strength (49). They were instructed to complete sit-stand cycles within 30 seconds. The arm curl test was used to evaluate functional strength. The participant was asked to

Table 1. Participants' demographic status

	n	%
Marital status		
Married	17	73.9
Others (single, divorce, death)	6	26.1
Job Retired	23	100
Education status		
< University degree	6	26.1
> University graduate	17	73.9
Income status		
<5000 TL	6	26.1
>5001 TL	17	73.9
Diseases		
None	10	43.5
Hypertension	9	39.1
Diabetes	2	8.7
Vertigo	2	8.7
Regular medicine use status		
Yes	8	34.8
None	15	65.2

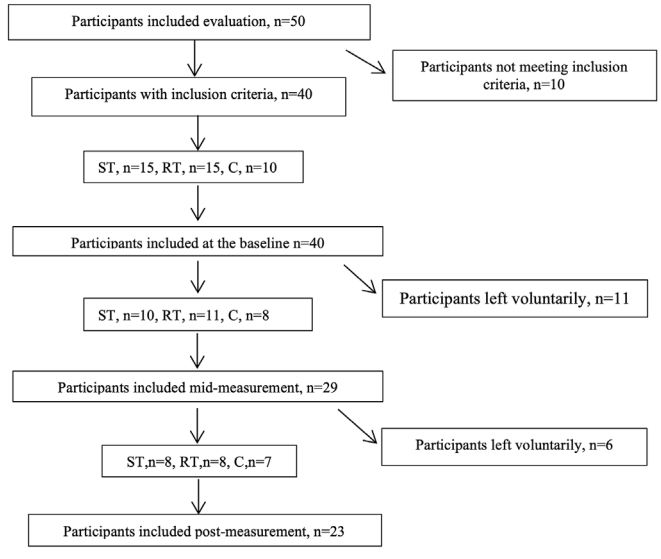

Figure 1. Participants diagram

RT: Resistance training, ST: Suspension training, C: Control group

fully bend their arm while holding dumbbells. The total arm curls were recorded in 30 seconds (dumbbell: 1 kg for women, 2 kg for men). Agility was assessed using the get-up-and-go test, and the participants were instructed to rise from the chair, walk to the end of the 2.5 m distance, and then return to sit down (49). The Turkish version of the Berg Balance Scale (BBS) was used for balance assessment (50). Body mass index (BMI), basal metabolic rate (BMR), fat mass, muscle mass, body fat percentage, and free fat mass (FFM) were evaluated using the bioelectrical impedance method (InBody 270, Co., Ltd.). Participants were instructed to avoid heavy exercise the day before and to finish their nutritional routines at least two hours before the test. All training programs and measurements were conducted at the Çanakkale Onsekiz Mart University Healthy and Active Aging Studies Research Center, Healthy and Active Aging Studies Research Center. This study was approved by Çanakkale Onsekiz Mart University Faculty of Medicine, Clinical Research Ethics Committee (decision number: 2022-03, date: 02.02.2022). Participants signed a written consent form. All participants were informed about the study and potential risks.

Interventions

Suspension Training: The ST consisted of exercises performed with TRX brand training equipment. Each strap was adjusted to each participant for different exercises. In the first week, researchers explained to the participants how to use this equipment safely. The training included squats, leg curls, rowing, chest press, butterfly, and arm curl exercises with TRX (Table 2).

Traditional Resistance Training: The RT included wall squats or single-leg squats, chair squats, elastic band knee flexion and extension, butterfly and arm curls with dumbbells, and chest presses with dumbbells (Table 2). All RT was applied in groups.

All training programs were conducted two days/week and lasted 40 minutes (including a warm-up~10 minutes and relaxing exercises 5 minutes).

The Rate of Perceived Exertion (RPE) scale was used to adjust the training load. The RPE scale was increased from the 2-3 range to the 4-5 range during the training period. In the first week, the exercises started with two sets of six repetitions, and by week 12, the sets were increased from 4 to 12 reps. The training variables (frequency, intensity, volume, and rest period) for all methods are presented in Table 2.

Statistics

The Shapiro-Wilk test was used to analyze the conformity of the data to the normal distribution. Differences between parameters that did not show normal distribution (arm curl, get-up-and-go) were analyzed using the Kruskal-Wallis test. Age, body mass, height, muscle mass, fat mass, body fat %, BMR, FFM, BMI, sit to stand, BBS Score, and MoCA Score results were analyzed using one-way ANOVA. The post-hoc Tukey test was used for differences between groups for parameters that follow a normal distribution. Differences between groups for parameters that did not follow a normal distribution were analyzed using the Mann-Whitney-U test. The paired samples t-test and Wilcoxon signed-rank test were used to determine the significance of the difference between baseline and post-period data within the group. The effect size (ES) was calculated by Cohen ES (>0.2 a small, 0.5 moderate, >0.8 large) (51). The significance level was set at <0.05. The SPSS 26.0 software was used in all analyses.

Results

There was no significantly different between ST, RT and C groups in age variable (ST =71.37±4.56, RT =70.87±3.97, C =70.00±3.21), height (ST =162.12±6.79, RT =161.62±5.52, C =164.00±6.58), and body weight (ST =72.25±8.20, RT =70.37±4.27, C =73.00±2.70) at the baseline (p>0.05). At the baseline, the age, body composition, physical and cognitive function scores were similar between the three groups (p>0.05, Table 3).

The BMI, BMR, FFM, fat mass, body fat %, muscle mass, and body mass were similar between baseline and week six in all groups (p>0.05, Table 3). Additionally, BBS, "get-up-and-go", and "sit to stand" were not different between groups (p>0.05, Table 3). However, there was a significant difference in the arm curl test, and MoCA scores from baseline to week six in all groups (p<0.05). The arm curl score was higher in both training groups compared to the C group. Furthermore, the cognitive function score was higher in the ST group than the C group (p<0.05, Table 3).

No significant differences were observed among the groups in body mass, BMI, fat mass, body fat %, and FFM (p>0.05, Table 4). However, we observed significant differences in muscle mass, BMR, MoCA, BBS, the sit to stand test, arm curl test, and get-up-and-go test scores of older individuals. We observed that the increase in muscle mass in the ST group was greater than that of the C group (ST =27.50 kg, C =23.00 kg). Additionally, the BMR in the ST group was higher than that in the RT and C groups (ST =1492.12 kcal, RT =1331.62 kcal, C =1329.71 kcal). BBS in the ST was higher than in the RT (ST =53.62, RT =51.00). Get-up-and-go test (ST =5.25 sec, C =6.28 sec), arm curl test (ST =19.50 reps, C =13.42 reps), sit to stand test (ST =17.50 reps, C =14.85 reps), and MoCA Score were higher than the C group (ST =29.87, C =28.71).

There was a significant difference in arm curl (ES =0.25), sit-to-stand (ES =0.60), BBS Score (ES =1.79), get-up-and-go (ES =0.76), and MoCA Score (ES =0.86) between groups (p<0.05). Muscle mass, BMR; get-up-and-go; sit to stand; arm curl, and MoCA Scores were significantly higher in the ST than in the C group (p<0.05, Table 4). The arm curl score was significantly better in the RT group than in the C group. The BBS score and

BMR were significantly higher in the ST than the RT group (p<0.05, Table 4).

Changes for the ST Over Time

We analyzed the data to assess differences between baseline and post-training periods. Significant improvements were observed in muscle mass (t=-4.339, p<0.05), fat mass (t=7.483, p<0.001), body fat % (t=9.000, p<0.001), FFM (t=-6.481, p<0.001), BMR (t=4.154, p<0.05), the get-up-and-go test (t=5.000, p<0.05), arm curl test (t=-3.454, p<0.05), and sit to stand test (t=-7.071, p<0.001). Additionally, there were notable improvements in the BBS Score (t=-3.476, p<0.05) and the MoCA Score (t=-4.583, p<0.05) when compared to other groups over time (Table 5).

Changes for the RT Over Time

In the RT Group, significant changes were noted in muscle mass (t=-2.497, p<0.05), body fat % (t=2.600, p<0.05), FFM (t=-3.100, p<0.05), BMR (t=-2.761, p<0.05), get-up-and-go test (t=4.583, p<0.05), arm curl test (t=-5.137, p≤0.001), and sit to stand test score (t=-5.400, p≤0.001) (Table 5).

Table 2. Suspension and resistance training programs

Weeks	Suspension training	Resistance training	RPE	Sets x rep	Rest between sets/rest between exercises (min.)
Weeks I -II	-Squat -Leg curl -Rowing -Chest press -Butterfly -Arm curl	-Chair squat -Knee curl (with band) -Leg extension (with band) -Butterfly (with dumbbell) -Arm curl (with dumbbell) -Bench press (with dumbbell)	2-3	1 x 6-8	1/3
Weeks I II-IV	-Squat -Leg curl -Rowing -Chest press -Butterfly -Arm curl	-Chair squat -Leg curl (with band) -Leg extension (with band) -Butterfly (with dumbbell) -Arm curl (with dumbbell) -Bench press (with dumbbell)	2-3	1 x 6-8	1/3
Weeks V-VI	-Squat -Leg curl -Rowing -Chest press -Butterfly -Arm curl	-Chair squat -Leg curl (with band) -Leg extension (with band) -Butterfly (with dumbbell) -Arm curl (with dumbbell) -Bench press (with dumbbell)	3-4	2 x 8-12	2/5
Tests II - all tests and evaluations					
Weeks VII-VIII	-One leg squat -Leg curl -Rowing -Chest press -Butterfly -Arm curl	-Wall squat -Leg curl (with band) -Leg extension (with band) -Butterfly (with dumbbell) -Arm curl (with dumbbell) -Bench press (with dumbbell)	4-5	2 x 8-12	2/5
Weeks IX-X	-One leg squat -Leg curl -Rowing -Chest press -Butterfly -Arm curl	-Wall squat -Leg curl (with band) -Leg extension (with band) -Butterfly (with dumbbell) -Arm curl (with dumbbell) -Bench press (with dumbbell)	4-5	3 x 8-12	2/5
Weeks XI-XII	-One leg squat -Leg curl -Rowing -Chest press -Butterfly -Arm curl	-Wall squat -One leg squat -Leg curl (with band) -Leg extension (with band) -Butterfly (with dumbbell) -Arm curl (with dumbbell) -Bench press (with dumbbell)	4-5	3 x 8-12	2/5
Test III - all tests and evaluations					

RPE: Rate of Perceived Exertion, rep: Repetitions, Min.: Minimum

Changes for the C Over Time

The fat mass (t=-2.500) showed a significant change over time (p<0.05, Table 5).

Discussion

The main finding of the present study was that both training methods improved certain body composition components, cognition score, and physical function in older adults. Another finding is that ST had a more significant impact on the BBS, MoCA cognitive function, body composition, and physical function compared to other groups. Considering the ES, ST is more effective for balance (ES =1.79), cognitive function (ES =0.86), and agility (ES =0.76) (Table 4).

A significant increase in BBS was observed for the ST group (p<0.05, Tables 3 and 4). ST engages more muscle groups and

Table 3. Differences between the baseline and after six weeks

	Baseline				Week VI			
	ST	RT	C		ST	RT	C	
	Mean ± SD	Mean ± SD	Mean ± SD	p	Mean ± SD	Mean ± SD	Mean ± SD	p
Body mass (kg)	72.25±8.20	70.37±4.27	73.00±2.70	0.505	72.25±8.31	71.00±3.74	75.14±5.17	0.512
BMI (kg/cm²)	27.62±2.32	27.87±2.99	28.14±2.67	0.933	27.12±1.55	27.75±2.76	28.14±2.67	0.708
Muscle mass (kg)	24.12±3.18	24.37±2.55	24.00±2.70	0.966	26.12±3.52	24.75±2.60	24.00±2.44	0.374
Fat mass (kg)	25.50±4.92	26.25±4.94	26.28±4.53	0.936	24.37±5.39	25.62±4.56	26.85±4.45	0.619
Body fat %	37.00±4.84	38.37±5.31	36.28±4.27	0.700	33.75±5.67	38.00±4.78	35.00±5.25	0.275
FFM (kg)	45.50±6.00	45.50±2.77	46.71±2.98	0.821	45.75±5.77	45.62±2.55	47.85±4.33	0.566
BMR (kcal)	1347.00±161.24	1263.75±76.014	1365.57±45.08	0.171	1435.62±168.33	1308.3772.21	1363.42±48.98	0.098
MoCA (Score)	29.12±0.64	28.50±0..41	28.28±1.38	0.375	29.50±0.53	29.00±0.75	28.42±0.90	0.044**
BBS (Score)	49.50±3.58	50.37±1.99	50.57±2.07	0.709	50.37±2.13	50.75±1.75	51.71±1.25	0.346
Sit to stand (rep/30 s)	12.50±1.19	13.25±1.28	13.57±1.81	0.346	15.37±1.18	15.62±1.59	14.00±2.38	0.189
Arm curl (rep/30 s)*	16.75±2.81	15.62±2.66	14.71±3.03	0.222	18.00±2.00	18.62±1.76	13.85±2.67	0.004**
Get-up-and-go (s)*	6.50±0..75	6.37±0.51	6.42±0.53	0.792	5.62±0.74	5.75±0.46	6.14±0.69	0.286

*Non-parametric Kruskal Wallis test, **p<0.05
SD: Standard deviation, ST: Suspension training, RT: Resistance training, FFM: Free Fat mass, BMI: Body mass index, BMR: Basal metabolic rate, BBS: Borg Balance Score, MoCA: Montreal Cognitive Assessment Scale, s: Second, rep: Repetitions, C: Control group

Table 4. Comparisons of all groups following 12 weeks

	ST	RT	C		
	Mean ± SD	Mean ± SD	Mean ± SD	p	ES
Body mass (kg)	72.12±8.40	70.87±3.83	75.42±5.47	0.441	-
BMI (kg/cm²)	27.37±1.30	27.75±2.43	28.57±2.76	0.582	-
Muscle mass (kg)	27.50±3.58	26.12±3.18	23.0±2.38	0.034**	0.80
Fat mass (kg)	23.50±5.15	24.87±4.48	27.00±4.50	0.376	-
Body fat %	32.50±5.18	36.75±6.58	33.287.54	0.392	-
FFM (kg)	48.50±6.09	47.75±2.86	49.71±4.23	0.714	-
BMR (kcal)	1492.12±150.10	1331.62±75.47	1329.7±08.28	0.017**	0.25
MoCA (Score)	29.87±0.35	29.37±0.74	28.71±0.75	0.008**	0.86
BBS (Score)	53.62±1.30	51.0±1.60	51.85±1.46	0.006**	1.79
Sit to stand (rep/30 s)	17.50±1.19	16.62±1.68	14.85±1.34	0.006**	0.60
Arm curl (rep/30 s)*	19.50±1.19	19.12±1.72	13.4± 2.76	0.001·	0.25
Get-up-and-go (s)*	5.25±0.46	5.62±0.51	6.28±0.75	0.022**	0.76

*Non-parametric Kruskal Wallis test, **p<0.05, ·p£0.001
SD: Standard deviation, ST: Suspension training, RT: Resistance training, C: Control, FFM: Free fat mass, BMI: Body mass index, BMR: Basal metabolic rate, BBS: Borg Balance Score, MoCA: Montreal Cognitive Assessment Scale, s: Second, rep: Repetitions, ES: Effect size

creates an unstable environment. This feature may explain why ST is more effective for neuromuscular control and balance compared to RT. Yu et al. (52) found that resistance exercises did not affect the BBS of older adults. Previous research shows RT alone does not effectively improve balance performance (23). Due to reduced balance, although force production declines in unstable conditions, RT on unstable surfaces is crucial for maintaining joint stability in the limb and trunk muscles. The relatively unstable position of ST significantly contributes to balance development and strength gains (33,53). Thus, the impact of ST on balance scores can be attributed to the unique characteristics of this training method. We hypothesized that ST could produce different results due to its nature (Table 5). We recognize that our sample size is relatively small and requires validation through future studies with larger samples. However, we emphasize that our results have the potential to introduce new methods and practical applications in geriatric sciences.

Exercise is known to increase cell proliferation in the hippocampus (54) and to support cerebral blood flow, thereby enhancing neurogenesis and learning (55). Previous research has shown that RT is effective for cognitive function (56). In this study, a relatively small improvement was observed in the cognitive function scores of older adults in both training groups ($p<0.05$, Table 3). However, the results of this study showed that the scores of older adults in the ST group were higher than those in the other groups. Unlike the basic movement components, ST is performed in a suspended position. While this feature contributes to the physical functioning of older adults, it may also affect cognitive processes by causing strain on neural and learning pathways. Exercise activates more neurons, and a stimulating environment provides greater benefits for the brain (57).

Table 5. Differences between the baseline and after 12 weeks for each group

	ST group	RT group	C group
Body mass (kg)	0.826	0.227	0.080
BMI (kg/cm^2)	0.685	0.802	0.078
Muscle mass (kg)	0.003**	0.041**	0.529
Fat mass (kg)	0.000·	0.083	0.047**
Body fat %	0.000·	0.035**	0.126
FFM (kg)	0.000·	0.017**	0.075
BMR (kcal)	0.004**	0.028**	0.310
MoCA (Score)	0.003**	0.111	0.200
BBS (Score)	0.010**	0.217	0.136
Sit to stand (rep/30 s)	0.000·	0.001··	0.093
Arm curl (rep/30 s)*	0.011**	0.001··	0.063
Get-up-and-go (s)*	0.002**	0.003**	0.736

*Non-parametric Mann Whitney U test, **p<0.05, ·p<0.001, ··p£0.001.
ST: Suspension training, RT: Resistance training, C: Control group, FFM: Free fat mass, BMI: Body mass index, BMR: Basal metabolic rate, MoCA: Montreal Cognitive Assessment Scale, BBS: Borg Balance Score, s: Second, rep: Repetitions

Cognitive function is based on learning, repetition, memory, and the coordination of these processes. When cognitive stimulation is insufficient, no further neuron formation occurs (54). It is thought that ST may have encouraged learning and increased scores due to its unusual, somewhat complex, and relatively challenging structure. Interestingly, a notable increase in cognitive function was observed in the sixth week of the study (Table 3). However, there is no clear data on the correlation between exercise duration and cognitive function (58). We believe that this early development, indirectly influences the score due to exercise-induced neural adaptation (learning). MoCA is a simple and independent cognitive screening tool that is known for its superior sensitivity (47). Although the participants have a healthy cognitive state in this study, this difference suggests it may have a more significant impact on those with cognitive decline.

These results are consistent with previous studies that observed significant improvements after three months (59), twelve months (60), and six months (61). Although a longer exercise program does not result in greater cognitive benefits (62), future studies are necessary to identify the mechanisms that affect cognitive function in the older population.

The arm strength, leg strength, muscle mass, and agility improved significantly in two training groups (Table 3). However, a more significant difference was observed in older adults when ST was compared with the C group. Additionally, arm strength was identified as a second parameter that showed improvement after the sixth week ($p<0.05$, Table 3). It is believed that the early increase in arm strength may result from older adults' limited training of their arm muscles. Similar to our research, Soligon et al. (32) found that both training methods had comparable effects on muscle mass, strength, and functional performance. The ST method can significantly enhance functional performance as it promotes greater activation of core muscles compared to RT (28). Jiménez-García et al. (31) reported that TRX training was effective in improving BMI, hand grip strength, and walking speed in older adults.

Study Limitations

This research has a few limitations. First, the sample size was relatively small. However, some studies demonstrate that ST can improve physical strength, balance, and overall quality of life among participants in a small sample size (32,63). Second, participants' dietary habits were not controlled in this study. They were only informed about supplements as part of the inclusion criteria and advised to maintain their usual dietary habits. Lastly, the effects of exercise on body

composition can vary significantly between genders. However, due to an inadequate gender distribution in the sample group, a comparison between genders could not be conducted. Therefore, future studies should consider dietary habits and gender factors in older populations.

Conclusion

ST recommended as a safe method to improve physical function for adults aged 65 to 80 who prefer to avoid traditional RT. Physical therapists and trainers may use ST as an alternative to traditional methods for older adults. This method gives trainers the opportunity to improve strength, balance, and cognitive function. However, further studies are needed to evaluate the sustainability of training effects in the older population.

Ethics

Ethics Committee Approval: This study was approved by Çanakkale Onsekiz Mart University Faculty of Medicine, Clinical Research Ethics Committee (decision number: 2022-03, date: 02.02.2022).

Informed Consent: All participants were informed about the study and potential risks.

Footnotes

Authorship Contributions

Concept: F.Ç., G.Ş., Design: F.Ç., G.Ş., Data Collection or Processing: F.Ç., Analysis or Interpretation: G.Ş., Literature Search: F.Ç., G.Ş., Writing: G.Ş.

Conflict of Interest: No conflict of interest was declared by the authors.

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ORIGINAL RESEARCH

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The Turkish Version of Hydration Risk Assessment Tool in Older Patients: Cross-Cultural Adaptation and Psychometric Evaluation

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Abstract

Objective: Dehydration is a common and serious issue among older adults, with significant implications for their health and well-being. Preventing dehydration in older adults requires a multifaceted approach that involves early identification of risk factors, accurate detection methods, targeted interventions, and ongoing monitoring to ensure adequate hydration. For this reason, the study was designed to assess the validity and reliability of the Turkish adaptation of the Northumbria Assessment of Hydration (T-NoAH) among older patients.

Materials and Methods: A methodological and descriptive approach was utilized in this investigation. After establishing linguistic validity, the study was conducted with a convenience sample of 360 older patients within 24 hours of admission to the hospital, using a descriptive information form and T-NoAH for data collection. The analyses performed included exploratory factor analysis, confirmatory factor analysis (CFA), discriminant validity assessment, internal consistency evaluation via Cronbach's alpha, item-total correlation analysis, examination of ceiling and floor effects, and Hotelling's T-squared test. Predictive accuracy was examined in the sample using a receiver operating characteristic curve, with serum osmolality as the reference test.

Results: The tool had sufficient linguistic validity. The instrument consisting of 8 items and one factor was identified. This factor explained 39.24% of the total variance. Model fit indices were ≥0.90, as per CFA. Cronbach's alpha was determined to be 0.73. There was no response bias identified, and there were no floor or ceiling effects. The optimal cut-off point (5 or more) showed sensitivity (70%) and specificity (89%) (area under the curve =0.795, 95% confidence interval, p<0.001) compared to non-dehydration group.

Conclusion: This tool is a short, easily understandable and applicable measurement for assessing older patients' hydration risk. It can be used by nurses to evaluate the risk of dehydration in older patients and to implement and evaluate effective interventions according to risk situations.

Keywords: Hydration, older adults, psychometrics, risk assessment

Introduction

Dehydration is a common health issue among older adults, leading to significant economic and social challenges (1-3). Studies provide evidence for the view that dehydration is prevalent among hospitalized older patients and is linked to higher mortality rates (4,5). A meta-analysis showed that 24% of older individuals dehydrated based on directly measured osmolality levels exceeding 300 mOsm/kg, which is regarded as the most accurate assessment method. The study by Parkinson et al. (6) revealed a high likelihood of dehydration among both long-term care residents and community-dwelling older adults. The study conducted in Türkiye found that dehydration affected 31% of 300 older patients admitted to a geriatric clinic (7). Aging-related changes, including increased body fat and decreased muscle mass, result in reduced body water percentage from its level of 60% in adulthood (8,9). The aging process is characterized by declines in physical, cognitive, and social functions, impacting various aspects of well-being, thereby affecting adequate fluid intake (10,11). Reduced thirst sensation, presence of incontinence, side effects of medications,

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and chronic conditions contribute to inadequate fluid intake among older adults, leading to disruptions in fluid balance and often resulting in dehydration (5,12,13).

Dehydration is a significant risk factor for challenging health issues in older adults, highlighting the importance of addressing proper hydration in this population to prevent adverse outcomes. Related health problems include electrolyte imbalances, urinary tract infections, kidney issues, pressure ulcers, constipation, medication toxicity, respiratory infections, cognitive decline, muscle weakness, and falls (5,13,14). The study by Lacey et al. (15) revealed that older adults with dehydration have a 40% increased risk of mortality over 8 years and a two-times higher risk of disability over 4 years compared to those with adequate hydration. Schettino et al. (16) observed that dehydration, identified through biochemical parameters, was linked to the onset of venous thromboembolism during hospitalization. Dehydration tends to worsen rather than improve after hospital admission, highlighting the critical importance of effective hydration management in hospitalized patients. This underscores the necessity of early implementation of strategies during hospitalization to mitigate adverse outcomes and complications associated with inadequate hydration. Therefore, with the aging population, prevention of this problem has become increasingly important globally (3,17). Using a screening tool to identify older adults at risk of dehydration can facilitate the restoration of adequate fluid balance, prevent potential complications or fatal outcomes, and reduce healthcare costs (5,18,19). Thus, it is critically important to be able to conduct a rapid and uncomplicated assessment of older patients' hydration status.

In clinical practice, dehydration associated with insufficient fluid intake in older adults is typically evaluated through direct measurement of serum or plasma osmolality (20). However, the test for serum osmolality, considered the gold standard, is invasive method. Such invasive approaches may not always be practical or sustainable for regular hydration assessment, particularly in older adults. Some studies suggest that, in older adults with adequate renal function, urine color and specific gravity can serve as simple, cost-effective, and efficient indicators of hydration status (21). However, factors such as medication use, dietary influences on urine color, limitations in patients' ability to accurately observe changes, and impaired renal function in conditions like chronic kidney disease may affect the reliability of these measurements. Consequently, evidence-based research emphasizes that these parameters alone are insufficient for diagnosing dehydration (17,20).

In younger adults, signs such as reduced skin turgor, sunken eyes, and dry mucous membranes are considered more clinically relevant indicators of dehydration. However, in older adults, age-related changes in skin and mucosa reduce the diagnostic value of these clinical signs (6). Therefore, relying solely on skin or mucosal changes for dehydration diagnosis is not recommended (22,23). The early identification of older adults at risk of dehydration, using an appropriate screening tool, can facilitate the restoration of optimal fluid balance, prevent complications and mortality, and contribute to cost savings in healthcare (17,19).

A review of the literature reveals that some Dehydration Screening Tool (DST) have limited diagnostic accuracy in detecting dehydrated older adults (17,24,25). To assess dehydration risk in community-dwelling and institutionalized older adults, the DST was developed. Developed by Vivanti et al. (26), this instrument includes 11 items, covering four physical indicators of dehydration (such as a decrease in systolic blood pressure, dryness of the tongue, skin turgor, and variations in body weight) along with seven items evaluating thirst perception, pain, and mobility status. The tool classifies individuals as "dehydrated" or "not dehydrated" based on these criteria (27).

Rosi et al. (19) evaluated a diagnostic approach based on the Geriatric DST-modified, which includes survey questions on drinking behavior, pain, and mobility, as well as clinical signs such as axillary dryness, body mass index, and dry mouth. The tool showed a sensitivity of 0.62 and a specificity of 0.47 when assessed against calculated serum osmolarity. Although this screening tool offers higher diagnostic accuracy compared to standalone methods, it does not represent a definitive breakthrough in hydration assessment (22).

Recent literature has explored non-invasive hydration assessment methods, such as smartphone imaging and wearable devices, in the general population, highlighting the need for further pilot studies on their applicability and long-term reliability (28).

In Türkiye, no widely accepted, validated, and reliable hydration risk screening scale is currently available for use in clinical settings for older adults at risk of dehydration. The Water Balance Questionnaire, developed by Malisova et al. (29), was adapted into Turkish and underwent a validity and reliability study, conducted by Sen and Aktac (30) in 2021. This questionnaire is recognized as a dependable and valid instrument for evaluating hydration status in the general population. In contrast, the Northumbria Hydration Assessment Tool (NoAH) was specifically designed to assess hydration risk in older adults by considering their health parameters. It is a brief, easy-to-administer screening tool suitable for clinical settings. The NoAH tool enables the identification of older individuals at risk of inadequate fluid intake, allowing for the implementation of appropriate interventions and the prevention of dehydration. NoAH protocol, introduced by Oates et al. (31), is suggested as an easy-to-use screening method to evaluate insufficient fluid intake in this age group and promote adequate hydration. This tool can facilitate the restoration of adequate fluid balance, prevent potential complications or fatal outcomes, and reduce

healthcare costs. This scale offers not only a quick and easy-to-use tool for nurses but also potential benefits in practice because nursing interventions can be determined according to the hydration risk assessment scores.

Nurses, particularly those in direct patient care, play a crucial role in recognizing and early detection of hydration status in older adults, which is essential for planning interventions and preventive measures to mitigate complications. In Türkiye, it is essential to identify a screening tool designed which nurses can use to assess hydration status in older adults for early detection of dehydration and effective intervention planning. The study aimed to evaluate the validity and reliability of the Turkish version of the NoAH (T-NoAH) for older adults. This assessment tool is crucial for identifying hydration status and implementing appropriate interventions to ensure adequate hydration levels and prevent complications.

Materials and Methods

Aim

This research aimed to translate the T-NoAH into Turkish and to evaluate the psychometric characteristics of the T-NoAH in older patients within 24 hours of their hospital admission.

Design

The psychometric characteristics of the T-NoAH were evaluated through a descriptive, methodological, and cross-sectional study design. The study followed recognized reporting standards for developing and validating scales in health, social sciences, and behavioral research (32). The NoAH was first translated into Turkish, then back-translated into English, followed by linguistic validation to ensure the translation's accuracy and consistency. Subsequently, its construct validity and reliability were evaluated.

Linguistic Validation

The tool's original creator, Dr. Lloyd Oates, gave permission to translate the NoAH and assess the psychometric properties of the T-NoAH. The tool was independently translated into Turkish by the research team from the original version in English. The translation process involved back-translation from Turkish into English to ensure accuracy and equivalence. This translation process was conducted by two bilingual professional translators who had no prior knowledge of the tool (33). The team met to examine the translations during the last phase of adaptation.

The English translation was compared with the original version, and Dr. Lloyd Oates validated the back-translation via email. No alterations were made to any items in the tool. For content validity evaluation, input was gathered from seven experts: two nursing academicians (one specialist in psychometric research and the other with expertise in both psychometrics and geriatric nursing), three clinical nurses (two with six years of experience in geriatric care and one with five years in neurology), and two geriatric specialists. Each expert rated the items on a four-point scale, ranging from 1 (inappropriate) to 4 (appropriate).

Construct Validation and Reliability Assessment

Setting and Sample

For scale development and validation studies, it is generally recommended to have a sample size of 10 participants per survey item or a sample size of between 200 and 300 observations (32). In this study, at least 160 older adults were required to perform exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), equating to approximately 20 responses per item for the 8-item scale. The research was carried out in Türkiye between April and June 2024 in medical wards specializing in neurology, cardiology, pulmonary medicine, and general internal medicine.

The participants were 360 older patients who were recruited within 24 hours of admission to hospital. The samples were chosen using convenience sampling. The criteria for inclusion in the study were as follows: volunteering to participate in the study, being 65 years of age or older, being hospitalized in medical wards, being within the first 24 hours of admission to the clinic, and being literate in Turkish. The following were the exclusion criteria: having visual or hearing disability, not knowing Turkish, and being illiterate.

Patients' sodium (Na), blood glucose, and blood urea nitrogen laboratory values at the time of their arrival at the clinic were obtained from their medical records. Various free online tools were available for calculation (34). Serum osmolality values were used to assess discriminant validity.

Data Collection

Data were collected using a descriptive information form alongside the T-NoAH.

Sociodemographic Data

The form was created to collect descriptive information about older patients, including age, sex, marital and formal education status, hospitalization clinic, and serum osmolality. In the current European Society for Clinical Nutrition and Metabolism guideline, it has been shown that serum osmolality is the gold standard for evaluating the dehydration status of older adults, and a calculated serum osmolality ≥295 mOsm/L is sufficient to detect dehydration (35). In this study, serum osmolality served as the measure for evaluating discriminant validity.

Northumbria Assessment of Hydration

The NoAH tool was created by Dr. Christopher Price and his team at Northumbria Healthcare NHS Foundation Trust. The tool was designed to assess the risk of dehydration in older

patients admitted to hospitals. It was part of an effort to create a nurse-led protocol to identify dehydration risks and implement timely interventions (31). The development involved contributions from healthcare professionals like Oates, Riddell, and Plank. The NoAH tool, revised by Oates and Price (24) in 2017, is a nurse-led assessment designed to help staff evaluate the risk of inadequate oral fluid intake in hospitalized patients aged 65 and older, ensuring that they remain well-hydrated. This tool consists of 4 screening questions (designed to exclude patients receiving palliative care, those on intravenous fluid therapy, those unable to eat orally, or those with oral fluid restrictions, respectively) and 8 risk assessment questions. If the answer to one of these four screening questions is positive, the risk assessment is abandoned. The first 6 items of the risk assessment questions are scored between 0 and 1. Items 7 and 8 are scored between 0 and 2. The overall score is calculated by adding the results of 8 risk assessment items, with possible scores ranging between 0 and 10. Risk categories are defined as low (0 or 1 point), moderate (2-4 points), and high (5 or more points). Each risk category is represented by a specific colour and geometric shape for clarity: a green circle for low risk, an amber square for moderate, and a red triangle for high. The screening tool recommends specific nursing interventions according to category. All patients were visited personally before the study, were informed about the study, and were provided signed consent. Psychometric properties of the screening tool are not included in the published protocol (31). Researchers met with each patient before the survey began to give information about the study and obtain written consent.

Ethics

The primary author of the original questionnaire granted written authorization for the psychometric assessment of the T-NoAH. The study received approval from the Dokuz Eylül University Non-invasive Research Ethics Committee (decision number: 2024/12-08, date: 27.03.2024). In addition, all patients gave their informed consent to participate after being fully briefed on the study's objectives and methodology.

Statistics

Analysis of Moment Structures 25.0 and Statistical Package for the Social Sciences 24.0 were used to conduct the analysis. We determined a confidence interval of 95% ($p<0.05$).

Seven experts confirmed the content validity. Expert feedback was assessed using the item Content Validity Index (I-CVI) and the scale-level content validity index (S-CVI) (36,37). To calculate the I-CVI, the number of experts who rated each item as "3" or "4" was divided by the total number of experts. The S-CVI was determined by summing the proportions of items that received ratings of 3 or 4 from the experts. The Kendall W analysis was used to assess the level of expert agreement. Construct validity was evaluated through EFA, CFA, and discriminant validity. The study sample was randomly split using participant entry codes. One half was analyzed with EFA to explore the measurement model, while CFA was performed on the other half to verify the model. The suitability of the data for factor analysis was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity. The suitability of the data for factor analysis was assessed using the KMO measure and Bartlett's test of sphericity. EFA with Varimax rotation was applied to identify the main components of the domains. The skewness and kurtosis indices were used to evaluate the assumption of normality in the data. Factors and items were deemed sufficiently retained when their eigenvalues were equal to or greater than one, and their factor loadings were at least 0.20. For CFA, the following variables were examined: degrees of freedom, Pearson chi-square (χ^2), Goodness-of-Fit Index (GFI), Root Mean Square Error of Approximation (RMSEA), and Comparative Fit Index (CFI) (36,38,39).

The tool's reliability was evaluated through Cronbach's alpha (19,20,21), item-total correlations, analysis of ceiling and floor effects, and Hotelling's T-squared test to detect response bias (37,40). The number of patients who could obtain the lowest score (floor, 0/10) and the highest score (ceiling, 10/10) on the tool was totaled to determine the floor and ceiling effects. These numbers were then calculated as a percentage of the total sample. The reliability analysis was performed using Cronbach's coefficient, and a result of 0.60 or higher was considered satisfactory (36).

The predictive accuracy of the T-NoAH to discriminate dehydration risk was determined through analysis of the area under the receiver operating characteristic curve. $p<0.05$ was considered statistically significant. Values for the area under the curve (AUC) ≤ 0.70 were considered low, $0.70< AUC <0.90$ as moderate, and $AUC >0.90$ as high, following recommendations by Henderson (41) in 1993. Specifically, a sensitivity of 0.70, combined with a specificity not lower than 0.50, is frequently regarded as the acceptable threshold necessary for a screening instrument to be clinically useful (42).

Results

Linguistic Validation

Following the translation and back-translation process, the items closely matched the originals, and no modifications were required (Supplementary Material 1).

The scores given for each item by seven experts for language and content validity showed no statistically significant differences (Kendall W=0.20, p=0.16). I-CVI for eight items ranged from 0.85 to 1, and S-CVI was 0.99. As a result, all items were retained.

Construct Validation and Reliability Tests

The mean age of patients (n=360) was 74.99±7.57 years (range=65-94); 50.6% (n=182) were male, 64.4% (n=232) were married, and 52.8% (n=190) were literate or had an elementary education level. The largest group of patients was in the cardiology service (28.3%, n=101) (Table 1). Patients in this survey were classified for dehydration risk as follows: low risk, n=96 (26.7%), medium risk, n=151 (41.9%), high risk, n=113 (31.4%). The mean risk score was 3.43±2.55 (range=0-10).

The KMO coefficient was found to be 0.78 and had a Bartlett's sphericity test χ^2 of 349.64 (p<0.001), indicating the suitability of the data for factor analysis. Within the EFA, one factor was identified. This factor explained 39.24% of the total variance. Factor loadings of the tool ranged from 0.21 to 0.86 (Table 2).

Model suitability was demonstrated by the CFA applied to the one-factor solution. CCFI= 0.96, GFI =0.96, χ^2/degree of freedom (df) =1.169, p<0.001, and RMSEA =0.06 were the determined model fit indices. CFA indicated satisfactory factor loadings, which ranged between 0.35 and 2.87 (Figure 1). When discriminant validity was examined, it was found between the two groups (t=-10.554, p<0.001). Dehydrated patients (serum osmolality ≥295 mOsml/L) had higher T-NoAH risk scores (5.25±2.58) than non-dehydrated patients (2.47±1.94).

The overall Cronbach's alpha was 0.73. No response bias was indicated by Hotelling's T-squared test result of 629.26, p<0.001. There were no floor or ceiling effects found (=11.1%). All item-total correlation values were acceptable, varying between 0.31 and 0.86 (Table 3).

Table 1. Descriptive characteristics of the sample (n=360)

Variables	n	%
Sex		
Female	178	49.4
Male	182	50.6
Marital status		
Married	232	64.4
Single	128	35.6
Education		
Illiterate	30	8.3
Literate/elementary school	190	52.8
High school	85	23.6
University	55	15.3
Clinics		
Pulmonary medicine	86	23.9
Neurology	76	21.1
Cardiology	102	28.3
General internal medicine	96	26.7
Hydration risk groups		
Low risk	96	26.7
Medium risk	151	41.9
High risk	113	31.4
	X	**SD**
Age (years)	74.99	7.57

X: Mean, SD: Standard deviation

Table 2. Exploratory factor analysis with Varimax rotation for T-NoAH (n=180)

Items*	Factor loadings
1. Is the patient receiving thickened fluids?	0.71
2. Does the patient have a severe visual problem?	0.57
3. Would the patient be unable to communicate their needs?	0.67
4. Is the patient prescribed furosemide or bumetanide?	0.22
5. Is the patient prescribed antibiotics?	0.21
6. Does the patient have a dry tongue and/or mouth?	0.52
7. Does the patient appear to be confused?	0.86
8. Please observe the patient and identify if they can locate a drink, pick it up, take a drink. Could she/he complete this?	0.81
Explained variance (%)	38.24

*The Turkish version of the tool was administered to the patients.
T-NoAH: Turkish adaptation of the Northumbria Assessment of Hydration

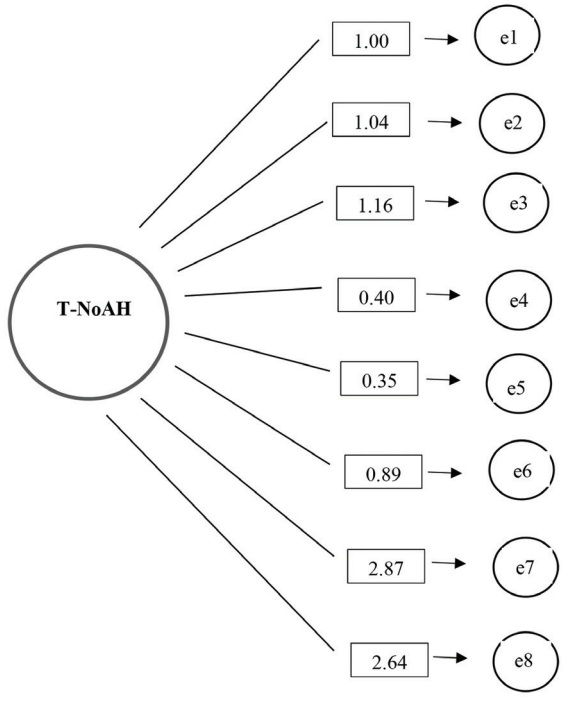

Figure 1. Confirmatory factor analysis of T-NoAH

T-NoAH: Turkish adaptation of the Northumbria Assessment of Hydration

The Predictive Accuracy

The optimal cut-off point (5 or more) showed sensitivity (70%) and specificity (89%) (AUC=0.795, 95% CI, p<0.001) compared to the non-dehydration group (Figure 2). T-NoAH has acceptable psychometric properties, to screen the dehydration risk in Turkish older adults.

Table 3. Item-total correlation scores (n=360)

Items*	Item-total correlation (r)*
1. Is the patient receiving thickened fluids?	0.58
2. Does the patient have a severe visual problem?	0.50
3. Would the patient be unable to communicate their needs?	0.65
4. Is the patient prescribed furosemide or bumetanide?	0.36
5. Is the patient prescribed antibiotics?	0.31
6. Does the patient have a dry tongue and/or mouth?	0.54
7. Does the patient appear to be confused?	0.86
8. Please observe the patient and identify if they can: Locate a drink, pick it up and take a drink? Could she/he complete this?	0.82

*p<0.001

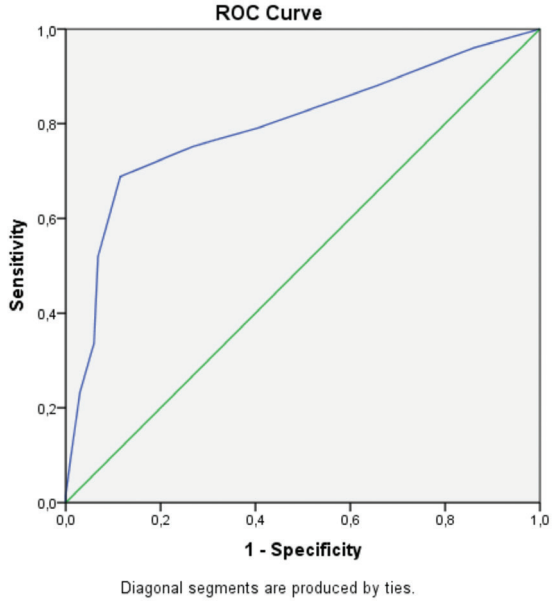

Figure 2. ROC test analysis (dehydrated and non-dehydrated). ROC test analysis showed a sensitivity of 70% and a specificity of 89%, with a cut-off of 5. The area under the ROC curve is 0.795 (95% CI: p<0.001)

ROC: Receiver operating characteristic, CI: Confidence interval

Discussion

Dehydration poses a significant concern for older adults admitted to hospitals, impacting both individual health outcomes and healthcare system costs (4,5,16). Recognizing the risk of inadequate oral fluid intake in older adults during hospitalization and implementing strategies to address this issue are vital for optimizing patient outcomes and reducing healthcare burdens.

The validity and reliable scales are needed to reveal hydration risk in older patients. The development of a nurse-led risk assessment protocol, NoAH, by Oates et al. (31) in 2017, is a significant advancement in addressing the issue. This protocol aims to provide a standardized approach to assess the risk of dehydration in hospitalized older adults, allowing for early identification and intervention to prevent adverse outcomes associated with dehydration. The original study showed that involving staff in the development of NoAH increased their awareness of hydration issues and encouraged them to improve care. The main objective of this paper was to report the reliability and validity of the T-NoAH in a sample of older adult Turkish patients.

The scale was initially developed in English, and its psychometric characteristics were not reported in the existing publication. To our knowledge, the psychometric properties of the scale have not been examined in another language. This first examination of the psychometric properties of the NoAH in a different language and cultural context presents a unique challenge due to the lack of comparative variables. According to the results, the questionnaire was well-understood and considered appropriate by the target sample, with no issues reported regarding the questions. The study on the T-NoAH scale demonstrated that all content validity scores exceeded the minimum required levels, indicating its capability to effectively measure the intended concept (39). This suggests that the T-NoAH scale is a valid tool for assessing the targeted construct.

The study on the T-NoAH scale, similar to the original (31), maintained an 8-item, single-factor structure with significant correlations observed among the items. This consistency in the factor structure and item correlations suggests that the T-NoAH scale is capable of effectively measuring the intended concept in a manner consistent with the original study. The current study concluded that the instrument's factor structure provided an appropriate fit, with all factor loadings and fit indices derived from CFA within the specified ranges. This suggests that the current scale effectively measures the intended concept, with the factor structure aligning well with the underlying construct. The lack of CFA in the initial study hindered the ability to compare variables. A crucial role in the

validation process was played by establish whether the concept being measured by the T-NoAH scale is distinct from other constructs (32). The study aimed to assess whether the T-NoAH risk scores were statistically different between dehydrated and non-dehydrated groups, and dehydrated groups indeed had higher scores. The discriminant validity results from the study on the tool suggest that it can provide valid data on hydration risk assessment for older patients. However, it is important to note that the questionnaire alone may not be sufficient to detect dehydration.

The study on the T-NoAH tool found reliable results with a Cronbach's alpha of 0.73. Results from the Hotelling T-squared test showed no significant risk of response bias, suggesting that participants answered the questions based on their personal views rather than outside influences (37,43). The floor and ceiling effect of 11.1% observed in the study is significantly lower than the commonly accepted limit of 20%, suggesting the lack of substantial bias in responses towards the lowest or highest possible scores, and indicating a more balanced distribution of responses across the scale.

The Cronbach's alpha value of 0.73, while slightly below the commonly accepted threshold of 0.80, remains within an acceptable range for newly validated clinical screening tools, particularly those designed for brief risk assessment (44,45). Several factors may have contributed to this reliability score. Despite the moderate Cronbach's alpha value, the T-NoAH demonstrates strong structural validity and discriminatory power, supporting its clinical applicability for early hydration risk assessment in older adults.

T-NOAH is a useful tool for dehydration risk screening. The optimal cut-off for screening was 5, with 89% specificity and 70% sensitivity.

Study Limitations

Participants in the survey were older adults over the age of 65 who were admitted to medical wards, including neurology, cardiology, pulmonary medicine, and general internal medicine, in Türkiye. The use of a non-random sampling approach in this study may limit the generalizability of the findings due to potential bias. Additionally, the scale was designed to be administered within the first 24 hours of hospitalization, preventing a test-retest reliability analysis and leaving the long-term stability of the scale unknown. Furthermore, as older adults were informed about the survey before participation, response bias may have been introduced. To enhance the reliability and validity of the tool, future research should consider employing a larger and more diverse sample size, as well as assessing potential variations in the tool's duration.

Moreover, the study focused on evaluating the psychometric properties of the T-NoAH scale rather than assessing hydration risk in specific patient groups; therefore, reasons for hospitalization were not initially included. Only patients' current diagnoses were recorded, which may have limited the scope of analysis. Future studies could further investigate the impact of hospitalization reasons, specific diagnoses, and comorbidities on hydration risk, allowing for a more refined adaptation of the T-NoAH scale for targeted patient populations.

Lastly, a key limitation of the study is that it evaluates hydration risk only within the first 24 hours, whereas long-term hydration monitoring is crucial for patient care. Overcoming these limitations in future studies may offer a deeper and more complete insight into assessing hydration risk among hospitalized older adults.

Conclusion

The results demonstrate that T-NoAH offers a strong single-factor structure and produces accurate and dependable conclusions about the risk of dehydration for older patients within 24 hours of hospital admission. As the number of older people with dehydration in Türkiye and around the world rises, using T-NoAH will be beneficial for nurses in evaluating older patients' risks of dehydration, and determining appropriate interventions. Given its practicality, ease of use, and rapid results, it is anticipated that this measuring tool will be used with increasing frequency by health professionals.

Ethics

Ethics Committee Approval: The study received approval from the Dokuz Eylül University Non-invasive Research Ethics Committee (decision number: 2024/12-08, date: 27.03.2024).

Informed Consent: All patients gave their informed consent to participate after being fully briefed on the study's objectives and methodology.

Footnotes

Authorship Contributions

Concept: E.A., M.A.A., B.A.S., Ö.K., Design: E.A., M.A.A., B.A.S., Ö.K., Data Collection or Processing: E.A., Analysis or Interpretation: E.A., M.A.A., Literature Search: E.A., M.A.A., B.A.S., Ö.K., Writing: E.A., M.A.A., B.A.S., Ö.K.

Conflict of Interest: No conflict of interest was declared by the authors.

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Supplementary Material 1. Link: https://d2v96fxpocvxx.cloudfront.net/cf9d60d6-523c-458a-a2e6-78728d3ffbb0/content-images/f881424b-9ec2-47b3-b2f1-25f893e0b6d7.pdf

ORIGINAL RESEARCH

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Comparison of the Effects of Vestibular-Based and Calisthenics-Based Exercises on Cognitive Function and Dual Task in Ambulatory Older Adults Living in Nursing Home: A Randomized Controlled Trial

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Abstract

Objective: This study aimed to assess the effects of vestibular-based exercises (VBEs) and calisthenics-based exercises (CBEs) on cognitive function and dual-task performance in older adults.

Materials and Methods: Thirty older adults were divided into two groups: VBE (n=15) and CBE (n=15). Standardized Mini Mental State Test (SMMST) and two dual-task tests were used to evaluate participants: (1) participants were asked to count from 1 to 20 while walking Dual Task 1 (DT 1) , and (2) participants used their foot to track a set of stimulators placed on the ground Dual Task 2 (DT 2). Participants took Part in an 8-week exercise program (3 days per week).

Results: Both groups showed significant improvements ($p<0.05$), with no differences in DT 1 scores ($p>0.05$). The VBE group had greater improvements in SMMST scores ($p<0.05$), while the CBE group showed more significant gains in DT 2 ($p<0.05$). Both VBEs and CBEs were effective in enhancing cognitive function, with VBEs outperforming CBEs in enhancing cognitive function, and CBEs excelling in dual-task performance.

Conclusion: Both types of exercises can be easily integrated into geriatric rehabilitation programs to improve cognitive function and dual-task performance of older people.

Keywords: Aging, cognitive disorders, dual task, exercise, geriatric physical therapy, healthy aging

Introduction

The aging process is a natural one in which decline is observed in sensory, motor, coordination, and cognitive functions. According to the World Health Organization (WHO), old age is defined as "the gradual decrease in the ability to adapt to environmental factors". According to the WHO, healthy ageing involves enhancing and preserving the functional abilities that support well-being in later life. The WHO outlines various stages of aging, typically categorized into specific age groups. Although there are different ways to classify elderly adults, a common classification is as follows: (1) elderly adults between the ages of 65 and 74 years as youngest-old, (2) those between ages 75 and 84 years as middle-old, (3) those aged over as oldest-old (1,2). These classifications are used in public health and demographic studies to address the needs of different age populations (3). During old age, changes begin to occur in various functions of the body. With aging, the weakening of muscle strength, a decrease in pulmonary functions, disorders in the cardiovascular system, loss of postural control, and balance can be observed. Neurological changes may also occur. In addition to slowing down in motor responses, cognitive disorders such as decreased sensory stimulation, losses in memory and learning, and disorganization of thought may also occur. The resulting

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cognitive deficiencies can sometimes cause balance disorders (4,5,6). Changes in structure, function, and blood flow in an aging brain are other factors that lead to cognitive impairments (7). With aging, decline in physical and cognitive functions is inevitable. Individually planned exercise programs, regardless of age and health status, improve physical fitness and improve cognitive functions along with neurochemical changes in the central nervous system, by increasing cerebral blood flow. In addition to weight-bearing exercises, calisthenics exercises are also recommended for elderly individuals, including walking, running, cycling, yoga, swimming, and aquatic exercises (1). Exercise improves individuals both physiologically and psychologically. It ensures the continuation of independence in the elderly. It is stated that exercise prevents the negative effects of aging on health and contributes to a person's independent living (8). Studies have shown that physical activity has an effect on cognitive functions in elderly individuals. In a study conducted by Stuck et al. (9), it was reported that cognitive dysfunctions are very important among the factors that cause a decrease in functional activity level. A study reported that the physical activity levels of elderly people with poor cognitive functions were more limited (10,11). Exercises are at the forefront in the rehabilitation of vestibular problems. Since the 1940s, exercises have been used for the treatment of complaints of decreased balance and dizziness in peripheral vestibular disorders (12). Vestibular rehabilitation is generally used to improve posture, walking stability, and balance, to ensure independence in walking and daily living activities, to improve the individual's visual ability during head movements, to reduce the patient's social isolation and increase social participation, and to increase neuromuscular control (12,13). It has been observed that aerobic exercises are more effective in improving cognitive functions in elderly female individuals with mild cognitive impairment than stretching exercises (14). Studies conducted by various researchers have reported that activities such as aerobic exercises, strength training, and balance exercises improve cognitive functions (15,16). In a meta-analysis examining the effect of aerobic exercise on cognitive functions, it was observed that aerobic exercises improved cognitive functions in elderly individuals (17). Sertel et al. (5), in their study reported that deterioration in cognitive functions and increased depression level negatively affected balance. A systematic review indicated that while physical activity is generally associated with cognitive benefits, findings from randomized controlled trials remain inconsistent (18). Up-to-date information is needed to investigate the effects of new training methods developed in recent years on cognitive function. When the literature was examined, no research was found comparing the effects of vestibular-based exercises (VBEs) and calisthenics-based exercises (CBEs). Therefore, we decided to plan a study examining this issue. The main purpose of our study was to examine the effects of VBEs and CBEs on cognitive level and dual-task activities in elderly individuals, and to compare them in terms of effectiveness. This study has two main goals. First, it aims to evaluate the impact of VBEs and CBEs on cognitive function. Second, it seeks to describe the effects of these exercises on dual-task performance in older adults.

Two main hypotheses were formulated for this study:

Hypothesis 1 (H_1): Two different exercise programs (VBE and CBE) can improve cognitive function and dual task performance in older people.

Hypothesis 2 (H_2): These two exercise programs have advantages over each other in improving cognitive function and dual-task performance in older adults.

Material and Methods

Study Design and Participants

Ethical approval was obtained from the Research Ethics Commission at Biruni University, İstanbul, Türkiye (decision number: 2022/76-14, date: 02.12.2022) and all the participants provided a written informed consent. The study began with 30 ambulatory older adults (aged 65-85) (Figure 1); all of them were enrolled participants in the Zeytinburnu Semiha Şakir Nursing Home, İstanbul, Türkiye. This study was conducted in the period of 7 months (December 2022-June 2023).

Participants eligible for this study were men and women between the ages of 65 and 85 residing in a nursing home who were capable of independently managing daily activities, including using a cane or elbow crutches. Additionally, participants had to volunteer to take part in the study. The exclusion criteria included individuals with any orthopedic, neurological, or psychiatric conditions that would prevent them from participating in the assessment or exercise program of the study. Fifteen individuals were excluded from the study due to medical conditions-most frequently untreated hypertension and balance issues-while an additional 17 declined to participate (Figure 1).

Based on the inclusion criteria and medical assessment, a total of 30 participants aged 65-85 years were randomly assigned to one of two groups: VBEs group (n=15) performing VBEs (8 weeks, 3 times per week) or CBEs group (n=15) performing CBEs (n=15) (8 weeks, 3 times per week). Participants in both groups were divided into smaller groups (each group consisted of 5 older adults) when performing the exercises.

Type of Randomization

Randomization was performed with a 1:1 distribution using the "simple random method", which aims to generate a 1:1 distribution over a given sample size using a random selection process in which each individual has an equal chance of being selected. We preferred this method because of its simplicity and

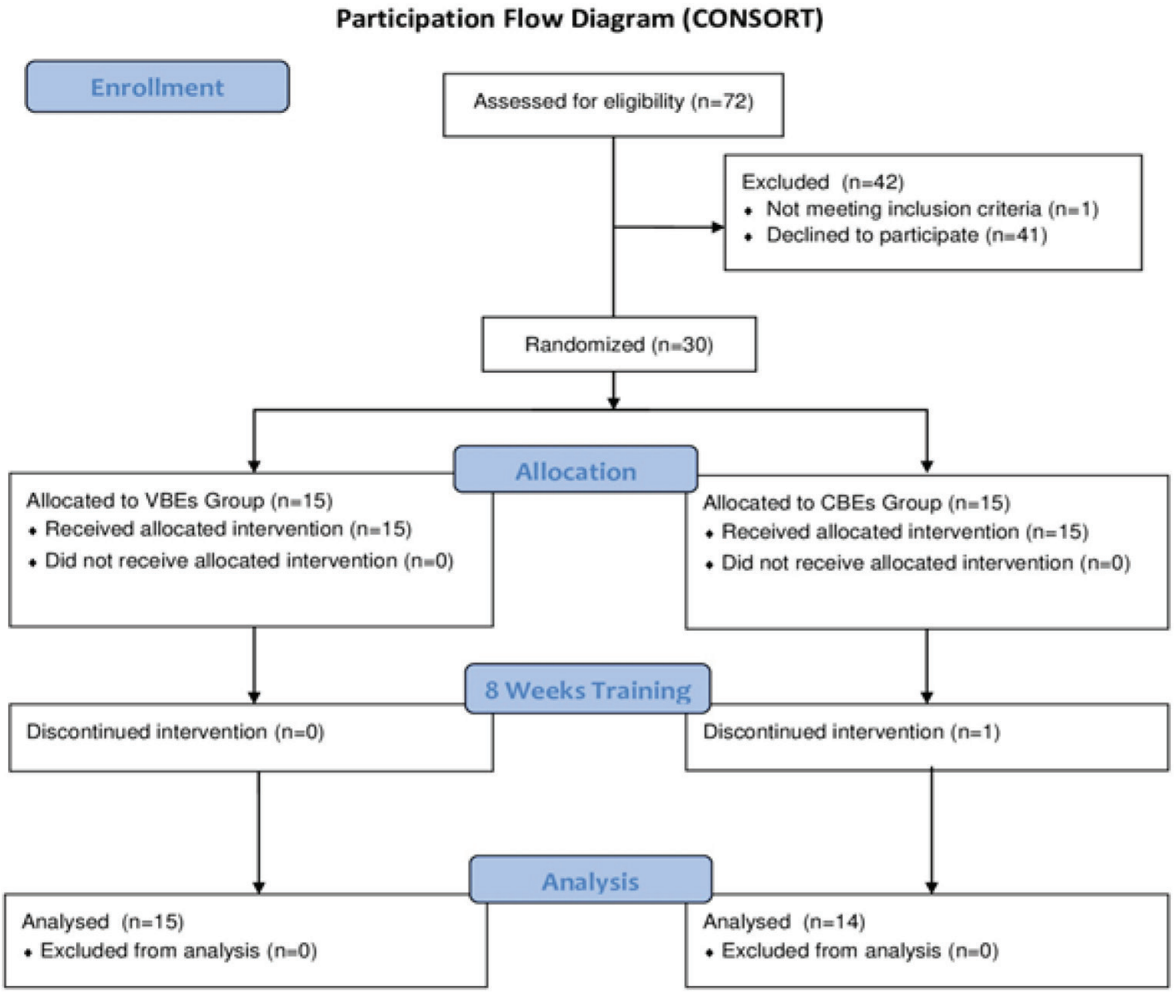

Figure 1. Flowchart of the study design

VBE: Vestibular-based exercises, CBEs: Calisthenics-based exercises

applicability. A total of 30 participants began engaging in the exercise regimens, but the full training cycle was completed by 15 participants from the VBEs group and 14 participants from the CBEs group (one participant could not complete the training program) (Figure 1).

Inclusion criteria were female and male participants between 65 and 85 years of age living in the senior home where the study was conducted, able to walk independently with or without a stick, and free of orthopedic, neurological, disease, or psychiatric.

Outcome Measures

Qualification was conducted by a physiotherapist (PT) and included a medical-history interview and analysis of medical records, after which potential participants were excluded if required on this basis. Demographic data belonging to the participants were recorded by the researcher, who is a PT working in the senior home (M.V.Ş.). The socio-demographic characteristics of all participants such as age, gender, height, body weight, body mass index (BMI) scores, education level, and length of stay in the nursing home were recorded on a structured form by the authors for this study. After that, the participants completed the The Standardized Mini-Mental Status Examinitaion (SMMSE) in a quiet and well-lit room under the supervision of the PT one by one. The other outcome measurements were performed under the same PT in the following order in the same room condition mentioned earlier: Dual Task 1 (DT 1) and Dual Task 2 (DT 2). All tests were conducted twice, before commencing the exercise program, (before the first week of the VBEs or CBEs programs) and immediately after (9^{th} week of the study). The following parameters were analyzed.

The Standardized Mini-Mental Status Examination

This test, the most commonly used by clinicians and researchers, was originally developed by Folstein et al. (19) to assess mental status. A standardized version was later developed (20).

The maximum score is 30, with scores of 24 and below indicating evaluation within the dementia framework. The Turkish adaptation was conducted (21), and the revised version was studied by Keskinoglu et al. (22). The cut-off point for the revised version is 22-23 for the educated elderly, whereas the cut-off point for the uneducated elderly is 18-19. This test assesses cognitive functions across five sections: orientation, registration, attention and calculation, recall, and language. The maximum score is 30, with scores of 24 and below indicating that evaluation should consider the possibility of dementia.

Dual Task 1 (Motor + Cognitive) Test: A 10-Meter Walking

The 10-m walk test with the added complexity of a cognitive task is often referred to as "dual-task walking" or "cognitive-motor interference" tasks. This test is commonly used to assess both physical performance (walking speed) and cognitive function (such as attention and working memory) simultaneously. The participant's walking speed in the 10-m area is assessed using a stopwatch. The participant is instructed to walk within the designated area, with timing starting when their foot touches the starting line and stopping when they cross the finish line. The measurement is taken, and the result is recorded in meters per second (m/s). The participant was asked to count from 1 to 20 while walking (23,24,25).

Dual Task 2 (Cognitive+ Motor) Test: The Trail Making Test-Part B

Originally developed by psychologists in the United States Army, the Trail Making Test - Part B is a commonly used tool in neuropsychological assessment. The test demands both visual-spatial processing and motor coordination. It is divided into two sections: Part A and Part B. Part A measures processing speed through tasks involving visual scanning, whereas Part B assesses cognitive flexibility and the ability to alternate between sequences. Due to its higher demands on visual-spatial and executive functioning, Part B is more complex and typically takes longer to complete than Part A (26,27). In addition, Part B is more difficult than Part A because it requires more motor speed, agility, and attention. That is why we chose Part B of the test for this study. Participants tracked a set of stimulators placed on the ground with their foot. Participants were first allowed a trial, then the test began.

Training

Exercise sessions (~45 minutes each) were carried out in groups of 5 participants three times a week for 8 weeks. Each exercise session was carried out three days a week in the gymnasium of the nursing home where the participants lived, accompanied by music and under the supervision of a PT. In the VBEs group, participants engaged in 12 easy-to-perform non-strenuous exercises performed in low body positions, which involved participants rotating their eyes, heads, and bodies in the sagittal, transverse, and frontal planes (Appendix A). The CBEs participants performed 12 easy-to-perform exercises (Appendix B). Training sessions were performed to music as a small group consisting of 5 persons supervised by a PT, who is working in the senior home where the study was conducted: warm-up (5 minute), exercise training (35 minute), and cool-down (5 minute). During the 8-week exercise program, we did not use any strengthening exercise protocol for progression because we did not aim to increase muscle strength. As the exercise program progressed, the number of repetitions was gradually increased (1^{st}-2^{nd} weeks: 6x; 3^{rd}-5^{th} weeks: 8x; 7^{th}-8^{th} weeks: 12x). The 8-week exercise programs consisted of three sets with a 2-minute break in each session. Sessions began with a 5-minute warm-up followed by the main part of the training program (35 minutes), in which a series of VBEs or CBEs, and 5-minute cool down exercises were performed on a stable floor in a well-lit gym. Each session consists of three sets with 2 minutes rest between sets, completed in 45 minutes.

Statistics

The distribution of the data was examined with the Shapiro-Wilk test. An Independent Samples t-test was used to compare two normally distributed independent groups. The Pearson chi-square or the Fisher's exact chi-square tests were applied to determine the homogeneity of categorical variables between two groups. The Dependent Samples t-test was applied for comparisons of two dependent groups assuming a normal distribution, and the Wilcoxon test was applied for comparisons of two dependent groups not assuming a normal distribution. The repeated measures ANOVA test was applied to evaluate the changes before and after between groups. For variables with a normal distribution, descriptive statistics were presented as mean ± standard deviation (SD), whereas non-normally distributed variables were reported using median and range (minimum-maximum). All statistical analyses were performed using IBM SPSS Statistics version 26.0, with a significance threshold set at α=0.05. This study was completed with a total of 29 participants in the two groups. Post-hoc analysis was performed. Based on the post-hoc analysis, a sample size of 29 gives 90% power to detect a difference of +1.9 between the null hypothesis mean of 22.4 and the alternative hypothesis mean of 24.3 with a known SD of 2.5 and a significance level (alpha) of 0.05 using a two-sided one-sample t-test (28,29).

Results

Of the 30 ambulatory older adults who have mostly graduated from primary school, 21 (70%) of the participants are men and 9 (30%) are women. Table 1 shows the demographic distribution of the groups. The participants in the two groups were homogeneous except for the gender distribution ($p \geq 0.05$). The

average age of the participants is about 75 years. This means that the participants in the study ranged from the youngest age group to the middle-aged group, according to the WHO.

A comparison of the descriptive statistics of the results of the Standardized Mini Mental Status Test (SMMT), DT 1, and DT 2 tests is shown in Table 2. This table shows us that both groups (VBEs and CBEs) showed significant improvement in terms of the outcome measurements [Standardized Mini Mental State test (SMMST), DT 1, DT 2] used to evaluate the participants ($p \leq 0.05$). These results supported the idea that H_1 was proven.

Table 3 shows the comparison of the test results of the groups before and after the 8-week training program. There were significant differences among the four outcome measurements ($p \leq 0.05$) except for DT 1 ($p \geq 0.05$). However, for SMMT, the change was significantly more extensive in the VBEs group than in the CBEs group. The changes in DT 2 test results were significantly higher in the CBEs group than in the VBEs group ($p \leq 0.05$). These results supported the idea that H_2, which stated that the two exercise regimes have advantages over each other, was proven.

Discussion

The results of this study, which was conducted to determine and compare the effects of two different vestibular and calisthenics-based physical exercise training (VBEs vs. CBEs) on cognitive function and dual task performance in elderly individuals, showed that improvements in cognitive function and dual task performance can be achieved with VBEs and CBEs without the use of expensive technological systems. When the results of VBEs and CBEs were compared with each other, VBEs, which included more complex figures, showed superiority over CBEs in improving mental function according to the SMMST score. On the other hand, CBEs showed enhanced performance in dual-task involving cognitive and motor tasks.

Cognitive problems have been the subject of numerous studies so far. These studies aimed to devise and implement programs to help older adults improve their cognitive function and to prevent cognitive decline. The researchers are particularly interested in the positive effects of physical exercise, well known to health providers. Similarly, PTs working with older adults with or without physical problems have tried to find optimal training methods to improve their physical functioning. However, the aging process is not only a natural process affecting the physical functioning of the elderly, but also a process in which decline is observed in cognitive functions.

As elderly people who are living in a senior home, are frequently resistant to the idea of continuing to exercise and using complicated technologic systems to be more active, a set of simple exercises aimed at improving the main components of health, including the physical and cognitive components should be designed. Based on this idea, we planned this study, which covers exercises that can be done easily by elderly people living in nursing homes and can be integrated into daily physiotherapy programs.

There are many tests or tools available to assess cognitive function in older people. The SMMSE and Trail Making test parts A and B used in this study are widely used. They have also been included in studies with a high degree of reliability, such as meta-analyses and systematic reviews. da Silva et al. (30) also used studies that included the SSME and Trail Making test Parts A and B in the assessment of cognitive function in their

Table 1. Descriptive parameters and statistical tests by groups

Variable	VBEs	CBEs	p
Gender	**n (%)**	**n (%)**	
Male/female	10 (66.7)/5 (33.3)	10 (73.3)/4 (26.7)	1[a]
Education level			
Literate	1 (6.7%)	3 (20%)	0.359[a]
Primary school	6 (40%)	9 (60%)	
Middle school	3 (20%)	2 (13.3%)	
High school	4 (26.7%)	1 (6.7%)	
University level	1 (6.7%)	-	
Variable	**Mean ± SD**	**Mean ± SD**	
Age, year	74.67±5.87	75.13±4.70	0.812[b]
Height, cm	167±7.84	169.07±8	0.481[b]
Weight, kg	77.80±9.17	80.47±11.17	0.481[b]
BMI, kg/m^2	27.90±2.99	28.19±4.02	0.827[b]
Length of staying in nursing home, year	6.73±2.39	6±3.04	0.650[b]

VBE: Vestibular-based exercises, CBE: Calisthenics-based exercises, [a]: Chi-square test, [b]: Independent Samples t-test, BMI: Body mass index, SD: Standard deviation

Table 2. Comparison the results before and after the 8-week training program belonging to the VBEs and CBEs groups

Group	Before training	After training	p
VBEs (n=15)	**Mean ± SD**	**Mean ± SD**	
SMMST	23.13±2.44	25.27±2.37	**0.001**[c]
DT 1	15.19±4.19	12.88±4.01	**0.001**[c]
DT 2	208.60±58.48	196.07±60.31	**0.001**[c]
CBEs (n=14)	**Mean ± SD**	**Mean ± SD**	
SMMST	21.47±2.10	23.21±2.25	**0.001**[c]
DT 1	18.20±4.37	15.84±4.37	**0.001**[d]
DT 2	255.33±43.72	238.93±43.97	**0.001**[d]

VBE: Vestibular-based exercises, CBE: Calisthenics-based exercises, SMMT: Standardized Mini Mental Status Test, DT 1: Dual Task 1, DT 2: Dual Task 2, [c]: Depended Samples t-test, [d]: Wilcoxon test, SMMST: Standardized Mini Mental State Test

Table 3. Comparison the results before and after the 8-week training program by the VBEs and CBEs groups

Variable	VBEs[1] Mean ± SD	CBEs[2] Mean ± SD	Mean difference (1-2)	p[e]
SMMST				
Before training	23.13±2.44	21.47±2.10	1.771	**0.044**
After training	25.27±2.37	23.21±2.25		
DT 1				
Before training	15.19±4.19	18.20±4.37	2.776	0.084
After training	12.88±4.01	15.84±4.37		
DT 2				
Before training	208.60±58.48	255.33±43.72	-43.131	**0.035**
After training	196.07±60.31	238.93±43.97		

VBE: Vestibular-based exercises, CBE: Calisthenics-based exercises, SMMT: Standardized Mini Mental Status Test, DT 1: Dual Task 1, DT 2: Dual Task 2, [e]: Repeated Measures ANOVA, SMMST: Standardized Mini Mental State Test

systematic review. In the meta-analysis conducted by Northey et al. (31), it was observed that these tests used for cognitive assessment showed improvements in cognitive function. Recently, motor-motor, motor-cognitive, or cognitive-cognitive dual-task tests have been widely used in geriatric assessment programs. Assessing the dual-task abilities of older people and training them with dual-task activities may increase the likelihood of success of functional exercise training. There are many studies in the literature on this topic. In our study, the 10-meter walk test (motor + cognitive) and Trail Making test Part B (cognitive + motor) were also used, performing a cognitive task. The authors' selection of such widely used tests is one of the strengths of this study.

The WHO Physical Activity Sedentary Behaviours Guide, published in 2020, states that regular physical activity in adults aged 65 and over has beneficial effects such as reduced all-cause mortality and improvements in many systems, including cognitive health.

In the related literature (18,32), there are also many studies, including aerobics, strength training, resistance training, yoga, clinical pilates, Tai Chi, which confirm that many exercises improve physical and cognitive function, and brain structure in older people. Siqueira et al. (33) reported that square-step exercises, which they used differently from the exercise methods we used in our study, improved both physical and cognitive function in older people. A review examining the impact of aerobic exercise, resistance training, and Tai Chi on cognitive function in older adults without diagnosed cognitive impairment found notable improvements. Specifically, resistance training led to greater gains in reasoning abilities compared to stretching or toning exercises, while Tai Chi was associated with enhanced attention and processing speed relative to inactive control groups (32). Zhang et al. (34) reported that engaging in muscle-strengthening activities was associated with cognitive health in middle-aged and older adults, independent of aerobic exercise. However, most of these studies used sophisticated techniques and expensive equipment. This study is important because it shows that these simple and cost-free exercises can also be used in the daily care of ambulatory older people living in senior homes to improve their cognitive and physical function. That is the strength of this study.

The core of vestibular rehabilitation such as the Cawthorne-Cooksey exercises (35,36,37) involves exercises and

interventions that stimulate and challenge the vestibular system to promote neural plasticity and adaptation. These exercises are carefully designed to gradually desensitize patients to movement and balance challenges, improve gaze stability, and enhance postural control. The ultimate goal is to restore optimal function and improve the patient's overall quality of life. Developed in the 1940s by Cawthorne and Cooksey (35), the exercises are widely used as an effective vestibular rehabilitation intervention. In this study, we have selected some simple exercises based on the Cawthorne-Cooksey exercises, which are commonly used to improve posture, gait stability and balance, to ensure independence in walking and activities of daily living, to improve the individual's visual ability during head movements, to reduce social isolation while increasing social participation, and to improve neuromuscular control.

There are many studies in the literature reporting the beneficial effects of vestibular stimulation exercises, such as those described in a study by Wiszomirska et al. (38). These exercises should be part of interventions to improve balance in older adults. The structured VBEs used in this study involve simple exercises that stimulate the vestibular organ. This set of exercises does not require a lot of energy or time; moreover, it stimulates cognitive function. Participants who performed VBEs showed positive changes to the SMMSE compared to participants doing CBEs. We believe this is due to the complex movements of VBEs, which include posture, gait stability and balance, independence in walking and activities of daily living, visual ability during head movements, and neuromuscular control. These findings promised new ideas to integrate VBEs into a physiotherapy program, that actuates the vestibular organs by means of movements of the head and body in different planes. To our knowledge, there are no studies reporting the effect of VBEs on cognitive function in the relevant literature. Therefore, we could not compare the results obtained from this study with the literature.

Calisthenics, a form of exercise that emphasizes bodyweight movements, has been shown to significantly improve physical functioning in ambulatory older adults. Research indicates that engaging in regular calisthenics activities enhances balance, strength, and overall mobility, which are critical for maintaining independence in this population (39). A study by Kearney et al. (40) found that older adults who participated in a structured calisthenics program exhibited improvements in functional fitness measures, including increased lower body strength and balance, leading to a reduced risk of falls. Additionally, the progressive nature of calisthenics allows older individuals to tailor their workouts according to their individual capabilities, promoting adherence and sustained physical activity (41). Overall, integrating calisthenics into the exercise regimens of ambulatory older adults can contribute positively to their physical functioning and quality of life. Different from the related literature, we aimed to show the effects of CBEs performed for 8 weeks on the cognitive function and dual task of the elderly. As predicted in our hypothesis H_1, CBEs improved the cognitive (SSMET score) and dual tasks (10-metre walk test, and Trail Making test Part B) scores of the elderly. In addition, CBEs were more effective than VBEs in improving dual task cognitive + motor scores (the Trail Making test Part B) in the elderly. Participants who did CBEs for 8 weeks improved their SSME score, but not as much as those who did VBEs. That is, participants who performed VBE showed superior improvement in terms of progression in the SSME score. However, participants who performed CBEs showed greater improvements in dual task-cognitive + motor test scores based on the Trail Making test Part B. These results support our hypothesis H_2. Although the CBEs, which are frequently integrated into exercise programs, are known to improve physical function, their effect on cognitive function has not been investigated. This is also true for the VBES. The results of this study can be considered instructive in terms of showing that both exercise programs can improve cognitive functions in the elderly.

Study Limitations

The most powerful aspect of this study is that there were no significant differences in age, height, weight, or BMI between the groups of participants who completed the two training programs. This made the comparison between the two groups stronger. In addition, the two exercise programs, simple and cost-free exercises undertaken by the participants, could show improvements in both cognitive function and dual-task performance in older adults, and the hypotheses were supported by the results obtained. However, this study has some limitations: (1) we had to conduct this study in only one nursing home with 72 older adults; so we could not ensure gender equality. Therefore, our results may not be generalizable to the whole elderly population due to the relatively small number of participants and the fact that we couldn't show the gender differences; (2) Another limitation of this study is that the exercise training program was not applied for a longer duration, and its long-term effects could not be evaluated. These limit the generalizability of the results.

Conclusion

The results of this study indicate that there is a need for much more research with more participants to explore the effects of VBES and CBE on cognitive function and dual tasking in older adults and to compare male and female older adults. Practitioners working in this field should be aware of the benefits of developing and implementing these types of exercises, which are easy for older adults to incorporate into their daily routines in order to promote a healthier lifestyle and improve health-related quality of life.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Research Ethics Commission at Biruni University, İstanbul, Türkiye (decision number: 2022/76-14, date: 02.12.2022)

Informed Consent: All the participants provided a written informed consent.

Footnotes

Authorship Contributions

Concept: M.V.Ş., U.C., Design: M.V.Ş., U.C., Data Collection or Processing: M.V.Ş., U.C., Analysis or Interpretation: M.V.Ş., U.C., Literature Search: M.V.Ş., U.C., Writing: M.V.Ş., U.C.

Conflict of Interest: No conflict of interest was declared by the authors.

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Appendix A: Vestibular-based exercises (45 minutes - three sets with 2 minutes rest between each set)
Warm up exercises (5 minutes) • Diaphragmatic breathing combined with raising and lifting both shoulders • Diaphragmatic breathing with trunk rotation while holding arms in a 90-degree position and elbows extended • Deep breathing while lifting fingertips upward • 2 minutes of free walking
The training program (35 minutes)
Tracking the finger with the eye (right and left)
Looking up with the eyes while keeping the head still
Looking down with the eyes while keeping the head still
Neck flexion and extension
Neck rotation to both sides (right and left)
Picking up an object from the ground in a sitting position
Repeating the 4th and 5th neck movements in the sitting position
Repeating the 1st, 2nd, and 3rd eye movements in the sitting position
Transferring objects from hand to hand under the knees while standing
Getting up from the sitting position and sitting again (5 repetitions with eyes open, 5 repetitions with eyes closed)
Throwing and catching a tennis ball above eye level
Standing and turning to the right and left
Cool down exercises (5 minutes) • Diaphragmatic breathing combined with raising and lifting both shoulders • Diaphragmatic breathing with trunk rotation while holding arms in a 90-degree position and elbows extended • Deep breathing while lifting fingertips upward • 2 minutes of free walking

Appendix B: Calisthenics exercises (45 minutes - three sets with 2 minutes rest between each set)
Warm up exercises (5 minutes) • Diaphragmatic breathing combined with raising and lifting both shoulder • Diaphragmatic breathing with trunk rotation while holding arms in a 90-degree position and elbows extended • Deep breathing while lifting fingertips upward • 2 minutes of free walking
The training program (35 minutes)
Outward circling with the arm (unilateral-left) in standing
Outward circling with the arm (unilateral-right) in standing
Outward circling with the arms (bilateral) in standing
Flexion and extension of both shoulders in standing
Trunk rotation to the right and left with arms at shoulder level flexed at 90 degrees with extended elbows in standing
Elbows flexion and in extension at shoulder level at 90 degree flexion in standing
Elbow flexion and extension with arms at shoulder level at 90 degrees abduction in standing
Half squat
Marching with left & right steps & side stepping with right and left leg
Standing tip-toes exercise
Unilateral hip extension (keeping the knee in extension) (right and left)
Sit to stand exercise
Cool down exercises (5 minutes) • Diaphragmatic breathing combined with raising and lifting both shoulders • Diaphragmatic breathing with trunk rotation while holding arms in a 90-degree position and elbows extended • Deep breathing while lifting fingertips upward • 2 minutes of free walking

ORIGINAL RESEARCH

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Sarcopenia and Arrhythmia Risk: An Electrocardiographic Analysis in Older Adults

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Abstract

Objective: Sarcopenia and cardiac arrhythmias are common in older adults and may have similar processes such as inflammation, fibrosis, mitochondrial dysfunction, and oxidative stress. These processes can cause myocardial remodeling and electrical instability. This study was designed to examine the link between sarcopenia and electrocardiographic (ECG) markers of arrhythmia.

Materials and Methods: In this cross-sectional, retrospective study, 283 older adults living in the community aged 60 years or older who underwent comprehensive geriatric assessment were included. Sarcopenia was defined per the European Working Group on Sarcopenia in Older People 2 criteria, using handgrip strength with population-specific thresholds (men <35 kg, women <20 kg), and skeletal muscle mass index (SMMI) [SMMI = SMM/body mass index (BMI). Standard 12-lead ECGs were analyzed for arrhythmic patterns and conduction abnormalities, including P-wave dispersion (PWD), corrected QT interval (QTc), Tp-e/QTc ratio, Tp-e interval, fragmented QRS, frontal QRST angle, first-degree atrioventricular block, bundle branch block, premature ventricular and atrial contractions, and atrial fibrillation (AF). Multivariate logistic regression identified independent associations.

Results: Sarcopenia was present in 35.7% of participants and was associated with older age, female sex, obesity, frailty, and functional impairment. ECG abnormalities were more frequent in individuals with sarcopenia, including AF (p=0.038), fragmented QRS (p=0.032), and increased PWD (p=0.010). In multivariate analysis, fragmented QRS [odds ratio (OR): 2.464, 95% confidence interval (CI): 1.068-5.683, p=0.035], obesity (OR: 2.030), frailty (OR: 1.970), and age (OR: 1.104) were independently associated with sarcopenia. When PWD replaced fragmented QRS, it also showed a significant association (OR: 1.018; 95% CI: 1.001-1.037; p=0.042).

Conclusion: Sarcopenia is independently associated with ECG abnormalities suggestive of atrial and ventricular electrical remodeling, especially fragmented QRS and PWD.

Keywords: Sarcopenia, arrythmia, electrocardiography, atrial fibrillation

Introduction

Cardiac arrhythmia prevalence rises significantly with ageing, contributing to elevated morbidity and mortality in older adults and placing a growing burden on healthcare systems (1-3). Arrhythmias can range from benign to life-threatening, with atrial fibrillation (AF) being the most commonly observed in the older population. The presence of arrhythmias is linked to increased incidence of heart failure, cerebrovascular events, and sudden cardiac mortality, all of which result in notable strain on healthcare resources (4). Before clinical symptoms of arrhythmia appear, the heart often undergoes subtle structural and electrical remodeling, which can disrupt its normal electrical conduction

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system. This subclinical electrical dysfunction may remain undetected for years before manifesting as an arrhythmia. Timely identification of patients at high-risk is critical for early intervention and improved outcomes. Several clinical risk factors predisposing for cardiac arrhythmias include hypertension (5), diabetes mellitus (6), coronary artery disease (7), valvular heart disorders (8), and chronic kidney disease (9). However, the underlying molecular mechanisms predisposing older adults to arrhythmogenesis remain incompletely understood.

Sarcopenia, a progressive and generalised skeletal muscle disorder, has been increasingly recognized as a potential contributor to adverse outcomes in older individuals, including falls, disability, and mortality (10). Multiple interconnected biological mechanisms have been implicated in sarcopenia, such as chronic systemic inflammation, mitochondrial dysfunction, oxidative damage, impaired regenerative capacity of satellite cells, increased apoptotic activity, endocrine alterations, and physical inactivity (11,12). These processes can also adversely affect cardiac structure and function. Notably, mitochondrial dysfunction and chronic inflammation are implicated in cardiac fibrosis and electrophysiological remodeling-both recognized substrates for arrhythmogenesis (13,14).

Given the shared biological mechanisms that underlie both sarcopenia and cardiac electrical remodeling, it is plausible that sarcopenia may contribute to the development of arrhythmogenic substrates. We hypothesized that this constellation of factors may be associated with specific electrocardiographic (ECG) abnormalities reflecting atrial and ventricular conduction disturbances. This study aimed to investigate whether sarcopenia serves as an independent factor associated with arrhythmias and arrhythmia-related ECG parameters.

Materials and Methods

Population and Setting

A retrospective, cross-sectional design was adopted for the study, which included community dwelling older adults aged 60 and over, who were evaluated at the geriatrics outpatient clinic at our university hospital and underwent a comprehensive geriatric assessment between January 2022-April 2024. Only those patients who demonstrated adequate cognitive function to provide accurate information and who voluntarily agreed to participate via informed consent were enrolled in the study. Demographic information and clinical data were obtained via in-person interviews. We excluded patients who had conditions that could interfere with accurate assessments using bioelectrical impedance analysis (BIA), such as the presence of edema or an implantable pacemaker, as well as conditions affecting handgrip strength (HGS) assessments, such as osteoarthritis. In addition, patients with known heart failure, ischemic ST-T changes on ECG, or significant valvular heart disease were excluded. These conditions were excluded as they could lead to ECG alterations and potentially confound the interpretation of ECG findings. Each participant gave written informed consent for the research. The study was approved by the İstanbul University, İstanbul Faculty of Medicine Ethics Committee (protocol number: 2024/2147, date: 15.11.2024) and was done in accordance with the principles outlined in the Helsinki Declaration.

Assessment of Sarcopenia

The presence of sarcopenia was diagnosed per the guidelines published by the European Working Group on Sarcopenia in Older People 2 (EWGSOP2). Confirmed sarcopenia was diagnosed with concurrent presence of low muscle mass (LMM) and low muscle strength in the absence of secondary causes (e.g., stroke, vascular diseases, or osteoarthritis) (10).

Muscle strength was assessed through HGS test using a hydraulic hand dynamometer (Jamar®), following an established protocol by a geriatric physiotherapist from the same healthcare profession had previously been certified in these assessments (15). Participants were requested to perform the HGS test 3 times for each hand by squeezing the hand dynamometer with maximum strength. The measurements were performed while the patients were seated, with the elbow flexed at 90 degrees and the wrist positioned neutrally. The highest grip strength recorded was considered the final measurement. We applied population-specific cut-off values for HGS, which were set at 35 kg for males and 20 kg for females (16).

BIA with the Tanita BC-532 model was employed to assess body composition, following an 8-hour fasting period. Fat-free mass (FFM) was derived from BIA, and skeletal muscle mass (SMM) was subsequently calculated using the formula: SMM (kg) = FFM × 0.566 (17).

Body mass index (BMI) was calculated as weight (in kg) divided by height squared (in m^2). SMM index (SMMI) was derived from the total SMM divided by BMI. Although EWGSOP2 advises employing standard cut-off values for appendicular SMM, it does not define specific limits for total SMMI. Instead, they suggest employing population-specific cut-offs when available (18). Following this guidance, the LMM thresholds were determined using mean values minus two standard deviations from a reference group of younger individuals, adhering to EWGSOP recommendations. The resulting thresholds for SMMI were found to be 0.823 kg/BMI and 1.049 kg/BMI for men and women, respectively (19).

Clinical Data

Frailty was determined with the Frail scale, comprising five items evaluating fatigue, resistance, ambulation, illness, and loss of weight (20). The total score ranges from 0 to 5, with scores 3 to 5

designating frailty, scores 1 to 2 designating pre-frailty, and a score of 0 representing a robust condition.

The six-item Katz et al. (21) activities of daily living (ADL) scale (score range: 0-6) and the eight-item Lawton Instrumental ADL (IADL) scale (score range: 0-8) (22) were used for assessment of fuctionality. For each item, 1 point was assigned for independence and 0 for dependence. Participants scoring 6 on the ADL and 8 on the IADL scales were considered fully independent; those with scores less than 6 on ADL and/or less than 8 on IADL were classified as having impaired functioning (23).

Nutritional evaluation was done with the Mini Nutritional Assessment Short-Form (MNA-SF), which categorizes scores as follows: 0-7 reflects malnutrition, 8-11 signifies a risk of malnutrition, while score greatrer than 11 denotes normal nutritional status. A score of ≤11 on the MNA-SF was used as the criterion to define undernutrition (24,25).

Electrocardiogram

A 12-lead surface ECG (Schiller Cardiovit AT-102) with a recording speed of 25 mm/s and a voltage amplitude of 10 mm/mV was obtained while the patient was lying supine. All measurements were digitally scanned and magnified 400 times using Adobe Photoshop to reduce potential errors. Two seperate cardiologists who were blinded to the patients' clinical information performed the measurements. Standard 12-lead electrocardiogram was obtained to evaluate QT, corrected QT intervals (QTc), fragmented QRS, P-Wave dispersion (PWD), Tp-Tend interval, Tp-Tend/QTC ratio, and the frontal QRS-T angle. Complete bundle branch block (BBB) patterns, first-degree atrioventricular (AV) block, premature ventricular (PVC) and atrial contractions (PAC), and AF were also evaluated and documented as part of the ECG analysis. The QT interval was measured as the distance from the start of the QRS complex to the end of the T wave from leads of V1-V6, DII, DIII, and aVF with an electronic caliper. Additionally, Bazett's formula ($QTc = QT/\sqrt{RR}$) was applied to correct the QT interval for heart rate (26).

Fragmented QRS refers to the appearance of an R' wave or the R or S wave notching in the absence of a typical BBB (27). PWD refers to the difference between the longest (P_{max}) and shortest (P_{min}) P-wave durations observed on an ECG (28). In patients with AF, P wave parameters, including PWD, were not assessed due to the absence of consistent atrial activity.The Tp-e interval is defined as the duration from the peak of the T wave to its endpoint (29). This measurement was taken from the precordial leads, with an average calculated from at least three readings for each lead and measurement. The ratio of Tp-Tend to QTc was calculated (30).

The frontal QRST angle was determined by taking the absolute difference between the QRS and T axes in the frontal plane. If this difference exceeded 180°, the QRST angle was adjusted to reflect the smallest angle, calculated as the absolute difference subtracted by 360° (31).

Interobserver variability was analyzed to determine the reliability of ECG measurements.

Statistics

For all statistical analyses, IBM SPSS Statistics (version 21.0) was used. P-values under 0.05 were accepted as statistically significant. All variable entries were cross-checked by a second researcher for accuracy. Both the Kolmogorov-Smirnov test and visual examination of histograms were done to evaluate the normality for continuous variables. Normally distributed continuous variables were reported in terms of mean and standard deviation, while skew- distributed continuous variables were documented as median (interquartile range). Categorical variables were reported in counts and percentages. Group comparisons between patients with and without sarcopenia were conducted using the independent samples t-test for normally distributed continuous variables, and the Mann-Whitney U test for non-normally distributed variables. For the analysis of categorical data, either chi-square or Fisher's exact test was used depending on the expected cell frequencies. To identify independent predictors of sarcopenia, multivariate logistic regression analyses were performed. The presence of multicollinearity among the independent variables was evaluated through correlation analyses, including Pearson, Spearman, and Kendall's tau-b. Independent variables with correlation coefficients greater than 0.7, indicating multicollinearity, were not included in the same regression analysis. Findings were expressed in terms of odds ratios (ORs) along with their 95% confidence intervals (CIs). The intraclass correlation coefficient (ICC) was used to assess interobserver reliability, based on a two-way mixed-effects model with absolute agreement. ECG measurements from a randomly selected subgroup of 30 participants were independently evaluated by two blinded cardiologists. An ICC ≥0.75 was considered to indicate good agreement.

Results

A total of 283 older adults living in the community (mean age: 73.55±6.68 years; 67.5% female) were included in the study. Sarcopenia was diagnosed in 101 participants (35.7%). Patients with sarcopenia were significantly older (75.93±6.30 vs. 72.23±6.40 years, p<0.001) and had a higher prevalence of frailty (41.4% vs. 16.2%, p<0.001) and obesity (47.5% vs. 34.6%, p=0.042). Patients with sarcopenia were more likely to be female (79.2% vs. 61.0%, p=0.002), while current smoking was

more prevalent among individuals without sarcopenia (40.1% vs. 24.2%, p=0.009). Patient diagnosed with sarcopenia showed significantly low HGS and SMMI (both p<0.001) (Table1).

In terms of ECG parameters, the sarcopenia group had a significantly higher prevalence of AF (p=0.038) and fragmented QRS complexes (p=0.032). PWD, an established marker of atrial electrical remodeling, was also significantly increased in participants with sarcopenia (p=0.010). There were no statistically significant differences between groups in terms of QTc interval, frontal QRS-T angle, Tp-e interval, Tp-Te /QT, or Tp-e/QTc ratio. Conduction abnormalities were also assessed. BBB was detected in 16 participants (4 with left BBB and 12 with right BBB), and first-degree AV block was present in 33 participants. Additionally, extrasystoles were identified in 18 individuals (8 atrial and 10 ventricular). Although conduction abnormalities-including BBB, first-degree AV block, and PVC-were more frequent in patients with sarcopenia, they were not statistically associated with sarcopenia (Table 2).

In all multivariate logistic regression models, sarcopenia served as the dependent variable, while age, gender, obesity, frailty, and impaired instrumental IADL were considered as independent variables. In the first model, fragmented QRS was also included and was independently associated with sarcopenia (OR: 2.464; 95% CI: 1.068-5.683; p=0.035), along with age (OR: 1.104; 95% CI: 1.055-1.156; p<0.001), obesity (OR: 2.030; 95% CI: 1.125-3.661; p=0.019), and frailty (OR: 2.464; 95% CI: 1.068-5.683; p=0.035) (Table 3). In the second model, fragmented QRS was replaced by PWD, and PWD was associated with sarcopenia (OR: 1.018; 95% CI: 1.001-1.037; p=0.042), while age, obesity, and frailty remained significant (Table 3). In the third model, fragmented QRS was replaced by AF, but AF was not associated with sarcopenia (OR: 3.736; 95% CI: 0.823-16.967; p=0.088) (Table 3).

Interobserver analysis demonstrated high consistency between the two independent cardiologists. The ICCs for all ECG parameters ranged from 0.86 to 0.94, reflecting good to excellent interobserver agreement.

Table 1. Demographic and clinical characteristics of the patients

Variable	All patients (n=283)	No sarcopenia (n=182)	Sarcopenia (n=101)	p-value
Sex (n, %)				**0.002**
Male	92 (32.5%)	71 (39.0%)	21 (20.8%)	
Female	191 (67.5%)	111 (61.0%)	80 (79.2%)	
Age (mean ± SD)	73.55±6.68	72.23±6.40	75.93±6.30	<0.001
Weight (mean ± SD)	72.63±13.52	72.84±14.58	72.26±11.44	0.665
BMI (mean ± SD)	29.17±5.23	28.22±5.39	30.87±4.46	<0.001
Obesity (n, %)	111 (39.2%)	63 (34.6%)	48 (47.5%)	0.042
Atrial fibrillation (n, %)	10 (3.5%)	3 (1.6%)	7 (6.9%)	0.038
Ischemic heart disease (n, %)	61 (21.6%)	41 (23.6%)	20 (21.3%)	0.670
Diabetes mellitus (n, %)	91 (32.2%)	58 (33.3%)	33 (35.1%)	0.770
Hypertension (n, %)	194 (68.6%)	126 (72.4%)	68 (72.3%)	0.990
Impaired ADL (n, %)	46 (16.3%)	23 (12.6%)	23 (22.8%)	0.027
Impaired IADL (n, %)	87 (30.7%)	43 (23.6%)	44 (43.6%)	<0.001
Frailty (n, %)				<0.001
Frail	70 (25.2%)	29 (16.2%)	41 (41.4%)	
Prefrail	130 (46.8%)	87 (48.6%)	43 (43.4%)	
Robust	78 (28.1%)	63 (35.2%)	15 (15.2%)	
Undernutrition (n, %)	94 (33.5%)	61 (33.7%)	33 (33.0%)	0.905
Smoking (n, %)	92 (32.5%)	69 (40.1%)	23 (24.2%)	0.009
Alcohol status (n, %)	20 (7.1%)	16 (9.5%)	4 (4.2%)	0.121
HGS (mean ± SD)	23.66±8.25	26.55±8.00	18.44±5.77	<0.001
Low HGS (n, %)	173 (61.1%)	72 (39.6%)	101 (100.0%)	<0.001
SMMI (BMI) (mean ± SD)	0.88±0.18	0.93±0.19	0.77±0.12	<0.001
Low SMMI (BMI) (n, %)	163	62 (34.1%)	101 (100.0%)	<0.001

5 missing variable
SD: Standard deviation, BMI: Body mass index, HGS: Hand grip strength, SMMI: Skeletal muscle mass index; ADL: Activities of daily living, IADL: Instrumental activities of daily living

Discussion

A significant correlation was observed in this research between sarcopenia and ECG-based markers reflecting arrhythmogenic potential in geriatric patients. Specifically, individuals with sarcopenia exhibited higher rates of fragmented QRS complexes, AF, and increased PWD-thereby indicating subclinical electrical remodeling in both atrial and ventricular myocardium. In addition, fragmented QRS and PWD were independently associated with sarcopenia.

The gradual deterioration of both muscle mass and muscle strength in sarcopenia is increasingly viewed as part of a broader systemic condition, rather than solely a musculoskeletal issue. Growing evidence links sarcopenia to increased cardiovascular risk, such as myocardial infarction, AF, heart failure, and peripheral artery disease (32-35). However, studies on its association with cardiac arrhythmias-particularly atrial and ventricular conduction abnormalities-are still limited. To address this gap, we evaluated several ECG parameters reflecting arrhythmogenic risk in older adults with sarcopenia, including QT/QTc intervals, fragmented QRS complexes, PWD, Tp-e interval, Tp-e/QTc ratio, and frontal QRS-T angle. Among these, fragmented QRS, PWD, and AF were associated with sarcopenia, suggesting myocardial electrical remodeling. Similarly, findings from the Bushehr Elderly Health Program support our results, reporting associations between sarcopenia and major ECG aberrations, like Q-QS waves, left ventricular hypertrophy, BBB, AF/flutter, and major ST-T changes. These findings collectively suggest that sarcopenia may contribute to electrical and structural remodeling of the aging heart, predisposing to arrhythmias (36).

Fragmented QRS indicates heterogeneous depolarization of the ventricular myocardium, which may arise from conditions such as ischemia, fibrosis, or scarring. The presence of fQRS suggests structural abnormalities in the myocardium, often associated with fibrosis, which can disrupt normal electrical conduction and

Table 2. ECG parameters according to sarcopenia

Variable	All patients	No sarcopenia	Sarcopenia	p-value
AF (n, %)	10 (3.5%)	3 (1.6%)	7 (6.9%)	0.038
1° AV block (n, %)	33 (11.7%)	18 (9.9%)	15 (14.9%)	0.213
Complete bundle branch block (n, %)	16 (5.7%)	9 (4.9%)	7 (6.9%)	0.488
PVC (n, %)	10 (3.5%)	5 (2.7%)	5 (5.0%)	0.336
PAC (n, %)	8 (2.8%)	6 (3.3%)	2 (2.0%)	0.716
P_{max} (ms) (mean ± SD)	104.88±18.81	103.35 (±19.04)	107.78 (±18.13)	0.062
P_{min} (ms) (mean ± SD)	56.26±14.79	56.98±14.14	54.97 (±15.96)	0.306
P-wave dispersion (ms) (mean ± SD)	48.72±16.63	46.51±16.52	51.92±16.11	0.010
QTc (ms) (mean ± SD)	417.02±24.63	416.54±25.04	417.91 (±23.97)	0.655
Frontal QRS–T angle [median (IQR)]	31 (14-60)	30 (13-62)	33 (14-59)	0.736
Fragmented QRS (n, %)	32 (11.3%)	15 (8.2%)	17 (17.0%)	0.032
Tp–Te interval (ms) (mean ± SD)	79.42±18.99	79.93±19.24	78.52 (±18.62)	0.558
Tp–Te/QT (mean ± SD)	0.20±0.04	0.2 (±0.05)	0.2 (±0.05)	0.673
Tp–Te/QTc (mean ± SD)	0.19±0.04	0.19 (±0.45)	0.19 (±0.44)	0.461

SD: Standart deviation, AF: Atrial fibrillation, AV: Atrioventricular, PVC: Premature venticular contractions, PAC: Premature atrial contractions, IQR: Interquartile range, ECG: Electrocardiographic, max: Maximum, min: Minimum

Table 3. Results of multivariate logistic regression analyses for sarcopenia

Variable	Model 1 OR (95% CI)	p-value	Model 2 OR (95% CI)	p-value	Model 3 OR (95% CI)	p-value
Age	1.104 (1.055-1.156)	**<0.001**	1.092 (1.042-1.144)	**<0.001**	1.097 (1.049-1.148)	**<0.001**
Sex	1.719 (0.908-3.252)	0.096	1.507 (0.767-2.961)	0.234	1.751 (0.927-3.305)	0.084
Obesity	2.030 (1.125-3.661)	**0.019**	2.347 (1.265-4.354)	**0.007**	1.978 (1.103-3.548)	**0.022**
Frailty	1.970 (1.286-3.019)	**0.002**	1.921 (1.236-2.986)	**0.004**	2.124 (1.385-3.259)	**0.001**
Impaired IADL	1.267 (0.667-2.408)	0.470	1.331 (0.678-2.612)	0.406	1.100 (0.577-2.099)	0.771
Fragmented QRS	2.464 (1.068-5.683)	**0.035**	-	-	-	-
P-wave dispersion	-	-	1.018 (1.001–1.037)	**0.042**	-	-
AF	-	-	-	-	3.736 (0.823–16.967)	0.088

Dependent variable: sarcopenia, independent variables: age, gender, obesity, frailty, impaired IADL, Fragnented QRS/P dispersion/AF
OR: Odds ratio, IADL: Instrumental activities of daily living, AF: Atrial fibrillation, CI: Confidence interval, AF: Atrial fibrillation

predispose individuals to various arrhythmogenic events (37,38). In our cohort, fQRS was significantly more prevalent among patients with sarcopenia (17.0% vs. 8.2%) and independently associated with sarcopenia (OR: 2.464), supporting the hypothesis that sarcopenia and myocardial remodeling may share common pathophysiological mechanisms. These include low-grade prolonged inflammation, oxidative stress, endocrine alterations and mitochondrial dysfunction, all well-recognized features of sarcopenia that may also contribute to myocardial fibrosis and conduction abnormalities (3,39,40).

Similarly, increased PWD observed in individuals with sarcopenia may reflect atrial conduction heterogeneity and structural remodeling, which are known precursors of AF (28). Although we observed a higher prevalence of AF in patients with sarcopenia, it was not independently associated with sarcopenia in our analysis-potentially due to the limited number of AF cases in our cohort. Nonetheless, our findings are aligned with those of Tang et al. (40), who reported that both probable and confirmed sarcopenia were associated with a significantly elevated long-term risk of AF, independent of genetic predisposition and cardiovascular risk factors.

Sarcopenia and cardiac arrhythmias, though affecting different organ systems, share several pathophysiological mechanisms that may contribute to their co-occurrence, particularly in older adults. Chronic low-grade inflammation, a hallmark of sarcopenia, has also been implicated in myocardial remodeling and fibrosis (13), which in turn can alter electrical conduction and promote arrhythmogenesis.

Evidence suggests that interleukin-6 and tumor necrosis factor-α as major inflammatory mediators, are actively involved in promoting apoptosis of cardiomyocytes and structural changes in the extracellular matrix. This inflammation-induced fibrotic process disrupts atrial conduction properties and helps maintain a substrate favorable for arrhythmia development (41).

Furthermore, mitochondrial dysfunction-an established factor in both sarcopenia and cardiac arrhythmias-also compromises myocardial energetics. Mitochondrial dysfunction is strongly linked to electrophysiological and structural abnormalities observed in cardiac arrhythmias. As the primary source of adenosine triphosphate (ATP) production, mitochondria serve a fundamental function in meeting the constant energy demands of cardiac electrical activity. In arrhythmias, the balance between myocardial energy supply and demand becomes disrupted, frequently in association with impaired mitochondrial function, resulting in diminished ATP synthesis and increased production of reactive-oxygen-species. One of the primary sources of excessive reactive oxygen species is mitochondrial oxidative stress. Elevated mitochondrial oxidative stress can interfere with the normal operation of key ion channels-such as potassium, calcium, and sodium channels-as well as ryanodine receptors, thereby increasing susceptibility to cardiac arrhythmias. In parallel, disruptions in ion homeostasis, cell membrane excitability, and myocardial architecture can arise due to pathological alterations in gap junctions and inflammatory signaling pathways. These changes collectively compromise the heart's electrical stability and contribute to arrhythmogenesis (42,43).

Endocrine alterations such as reduced anabolic hormone levels (e.g., testosterone, insulin-like growth factor) and dysregulated renin-angiotensin-aldosterone signaling may also contribute to both sarcopenia progression and the development of myocardial fibrosis, thus linking muscle degradation to increased arrhythmic vulnerability. Taken together, these overlapping mechanisms suggest that sarcopenia may not merely coexist with arrhythmias but may actively contribute to their pathophysiology.

Our previous study demonstrated an independent association between sarcopenia and left ventricular diastolic dysfunction (LVDD), suggesting that sarcopenia may contribute to myocardial structural and functional impairment beyond traditional risk factors (44). Given that LVDD is a well-known substrate for atrial remodeling and a significant risk factor for arrhythmias such as AF, it is plausible that the link between sarcopenia and arrhythmias identified in this study may be partially attributable to alterations in diastolic function. These findings collectively highlight the need to further investigate the interconnected pathways linking sarcopenia, myocardial remodeling, and arrhythmogenesis.

Although QTc interval, Tp-e interval, Frontal QRS-T angle, and Tp-e/QTc ratio are documented markers of ventricular repolarization and arrhythmia risks, we did not find significant associations with sarcopenia in our cohort. QTc prolongation and increased Tp-e durations have been linked to life-threatening arrhythmias and sudden cardiac death (45). The Tp-e/QTc ratio similarly indicates arrhythmia risk, especially in those with structural heart disease. The absence of a significant relationship in our study might be attributed to the multifactorial nature of ventricular repolarization, influenced by factors like myocardial integrity, electrolyte balance, autonomic tone, medication use, and subclinical ischemia, all of which were not fully controlled in our retrospective design. Moreover, our relatively stable, community-dwelling older population without overt structural heart disease may have limited variability in repolarization parameters. Detecting subtle changes in QTc or Tp-e may also require larger samples or high-resolution ECGs. While these markers remain clinically relevant, their association with sarcopenia warrants further prospective investigation.

This study is among the first to comprehensively evaluate

multiple ECG parameters-including both atrial and ventricular markers of arrhythmic risk-in older adults with and without sarcopenia. The use of EWGSOP2 criteria for sarcopenia diagnosis and standardized ECG measurements performed by blinded cardiologists enhances the methodological rigor. Furthermore, the inclusion of community-dwelling older adults reflects a real-world clinical population, which strengthens the generalizability of our findings. A standardized and accurate evaluation of sarcopenia is fundamental for drawing meaningful conclusions in both observational and interventional studies. In our study, SMM was adjusted by BMI rather than height², as BMI-based adjustment is considered more appropriate in populations with high adiposity. Height²-adjusted indices may underestimate sarcopenia prevalence in obese individuals by failing to account for body weight. Given the high proportion of obese participants in our cohort and the growing evidence linking BMI-based muscle indices to functional outcomes, we selected this method to better reflect clinically relevant muscle deficits (46).

Study Limitations

However, certain limitations need to be noted. First, the retrospective and cross-sectional nature of the study limits the drawing of any causal relationship between sarcopenia and ECG abnormalities. Second, our sample size, although adequate for detecting differences in major ECG parameters, may have been underpowered to detect subtle alterations in repolarization indices such as QTc or Tp-e intervals. Third, we did not assess certain potential confounders, including medication use or electrolyte levels, which could influence ECG findings. Fourth, we assessed muscle mass using BIA, which is generally considered less accurate than dual-energy X-ray absorptiometry. However, BIA is accepted as a valid and practical method of SMM estimation due to its advantages: portability, wide availability, rapidity, non-invasiveness, cost-effectiveness, and ease of use. Moreover, previous studies have demonstrated that BIA shows a good correlation with magnetic resonance imaging for assessing muscle mass. Importantly, the threshold values used to define LMM in our study were derived from population-specific reference data and were established using the same BIA device model employed in our study, thereby enhancing internal consistency and applicability to our cohort (18).

Conclusion

In conclusion, the present study demonstrates a significant association between sarcopenia and certain ECG markers of arrhythmogenic risk, including fragmented QRS complexes, increased PWD, and a higher prevalence of AF. These findings suggest that sarcopenia may contribute to subclinical myocardial electrical remodeling and highlight the need for increased arrhythmic surveillance in this vulnerable population. While no significant associations were observed with repolarization-related parameters, future research should aim to better elucidate the electrophysiological consequences of sarcopenia through prospective studies with larger and more heterogeneous populations, and to determine whether early identification of such ECG changes could guide preventive strategies for arrhythmia-related adverse outcomes. Given the observed association between sarcopenia and specific ECG abnormalities, regular ECG screening may be considered in sarcopenic older adults to enable timely identification and management of potential arrhythmias.

Ethics

Ethics Committee Approval: All study procedures were done based on the ethical principles of the İstanbul University, İstanbul Faculty of Medicine Ethics Committee (protocol number: 2024/2147, date: 15.11.2024) and was done in accordance with the principles outlined in the Helsinki Declaration.

Informed Consent: Informed consent was obtained from all participants who were prospectively enrolled in the study. For retrospectively included individuals, data were collected from medical records and handled anonymously. No procedures beyond standard clinical assessments or routine laboratory tests were performed as part of this study.

Footnotes

Authorship Contributions

Concept: O.E., T.E., M.A.K., G.B., Design: O.E., T.E., M.A.K., G.B., Data Collection or Processing: O.E., Z.F., D.E.S., D.S., Ö.K., Analysis or Interpretation: T.E., S.Ö., G.B., Literature Search: O.E., T.E., S.Ö., Writing: O.E., T.E., S.Ö., G.B.

Conflict of Interest: No conflict of interest was declared by the authors.

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ORIGINAL RESEARCH

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Sarcopenia in People Aging with HIV: A Cross-Sectional Study From Türkiye

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Abstract

Objective: This study aims to determine the prevalence and risk factors of sarcopenia in people living with human immunodeficiency virus (PLWH) aged 50 years and over.

Materials and Methods: Ninety individuals who live with human immunodeficiency virus (HIV) aged 50 years and over, who were under follow-up in our outpatient clinic between May 2021 and October 2021, were included in the study. Demographic, clinical, laboratory data, and drug information of the patients, were reviewed from medical records. Sarcopenia tests were conducted, and fracture risk assessment tool scores of the patients were calculated.

Results: In our study, the prevalence of sarcopenia in PLWH aged 50 years and over was found to be 40% (8.9% definite sarcopenia, 31.1% probable sarcopenia). No association was found between elapsed time since diagnosis of HIV infection, initial CD4 T lymphocyte count, rate of antiretroviral therapy (ART) usage, duration of ART usage, ART regimens with sarcopenia. In our study, 10-year probability of major osteoporotic fracture risk and hip fracture risk was significantly higher in the male group with sarcopenia compared to the non-sarcopenic group.

Conclusion: The prevalence of sarcopenia in PLWH aged 50 years and over, was found to be higher compared to the general population. It was observed that individuals with sarcopenia had a higher risk of fractures. Since sarcopenia is associated with falls, fractures, disability, hospitalization, and mortality, screening for sarcopenia in PLWH aged 50 years and over may be beneficial in preventing adverse outcomes.

Keywords: Antiretroviral therapy, FRAX, HIV, people over 50 years old, sarcopenia

Introduction

With the extension of life expectancy resulting from antiretroviral therapy (ART), age-related comorbidities have become more frequently observed in people living with human immunodeficiency virus (HIV). Geriatric syndromes, such as frailty, osteoporotic fractures, and physical and cognitive impairments, tend to emerge at comparatively younger ages. Consequently, HIV is thought to exhibit a phenotype of "accelerated aging" (1). Some studies indicate that this "accelerated aging" phenotype may be attributed to chronic inflammation associated with HIV and prolonged exposure to specific antiretroviral drugs (2).

Accelerated muscle mass and function loss is another indicator of the aging phenotype in individuals living with HIV (1). Data on the prevalence of sarcopenia in these patients are limited. Similar to other chronic diseases, sarcopenia in this population is more prevalent and tends to occur at a younger age compared with individuals in the general population (3,4).

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A systematic review and meta-analysis led by Oliveira et al. (5), which reviewed 13 studies, reported a sarcopenia prevalence of 24.1% among people living with HIV (PLWH).The findings indicated that PLWH had a sixfold increased risk of sarcopenia relative to HIV-negative controls. Additionally, sarcopenia occurs around 15 years earlier in PLWH compared with HIV-negative individuals. (5). Despite these findings, current sarcopenia guidelines do not yet identify HIV as a recognized risk factor. (6)

Risk factors for sarcopenia in PLWH include increasing age, female sex, and reduced body mass index (BMI), and prolonged exposure to HIV infection (2). Furthermore, long-term exposure to nucleoside reverse transcriptase inhibitors (NRTIs)—known for their mitochondrial toxicity, such as zidovudine, didanosine, and stavudine—has also been identified as a risk factor for sarcopenia (7).

As life expectancy rises among PLWH, the prevalence of sarcopenia is anticipated to increase. In HIV-negative individuals, sarcopenia results in health issues such as falls, morbidity, mortality, and disability. These problems may be more frequent among PLWH than in HIV-negative individuals. Consequently, sarcopenia is anticipated to pose a notable socioeconomic challenge among PLWH. Therefore, diagnosing, preventing, and treating sarcopenia in PLWH is crucial (5).

This study aimed to assess sarcopenia status and identify risk factors in PLWH aged 50 years and older.

Materials and Methods

Patients Included in the Study

This observational study, conducted at a single center with a cross-sectional design, evaluated 90 individuals aged 50 years and older living with HIV between May 2021 and October 2021. Participants were followed up at the İstanbul University-Cerrahpaşa, Cerrahpaşa Medical Faculty Hospital, Infectious Diseases and Clinical Microbiology outpatient clinic from 2008 to 2021. All participants provided signed informed consent prior to study participation. The study was approved by the Ethics Committee of İstanbul University-Cerrahpaşa (decision number: E-83045809-604.01.02-70371, date: 04.07.2021).

Inclusion criteria: PLWH aged 50 years and older. Exclusion criteria: individuals under the age of 50 and those receiving steroid therapy.

Method

Patient data were retrieved from outpatient records and systematically recorded in standardized information forms. This information comprised demographic data, underlying comorbidities, acquired immune deficiency syndrome (AIDS)-defining illnesses, and initial CD4 T lymphocyte, and HIV RNA levels at the time of HIV diagnosis. Additionally, it included current CD4 T lymphocyte and HIV RNA levels, complete blood counts, biochemical results, and details of ART administered to the patients.

Sarcopenia diagnoses were based on guidelines from the European Working Group on Sarcopenia in Older People (EWGSOP2). The strength, assistance with walking, rising from a chair, climbing stairs, and falls (SARC-F) questionnaire, incorporating five components–SARC-F served as a screening tool for sarcopenia. Each component was scored on a scale of 0 to 2 points. The total SARC-F score ranged from 0, indicating the best outcome, to 10, indicating the worst.

Anthropometric measurements such as bodyweight, height, BMI, and calf circumference, were recorded. Height (in centimeters) and weight (in kilograms) were measured while patients wore light clothing and no shoes. A threshold value of less than 31 centimeters was used for calf circumference (8). BMI was categorized as underweight for values less than 18.5 kg/m^2, normal weight for values between 18.5 and 24.9 kg/m^2, overweight for values of 25 kg/m^2 or greater, and obese for values of 30 kg/m^2 or more (9).

The TANITA TBF-300 bioimpedance analysis (BIA) system was employed to measure the muscle mass of patients. Measurements were conducted in the morning, following a fasting period of at least four hours. Fat-free mass (FFM) was assessed using BIA, and total skeletal muscle mass (SMM) was derived through the formula SMM = FFM×0.566. To account for body size, skeletal muscle index (SMI) was calculated as SMM divided by height squared (SMM/height^2) (10). Threshold values for SMI in diagnosing sarcopenia are typically established for elderly patients. However, as most participants in our study were under 65 years old, we adopted the threshold values specified by Yazar and Olgun-Yazar (11) for the Turkish population: 10.5 kg/m^2 for males and 8.89 kg/m^2 for females. Values below these thresholds were classified as "low muscle mass".

To assess muscle strength, we conducted grip strength tests using a Jamar brand hand dynamometer. For each arm, we performed three separate measurements and recorded the highest value. Measurements below 27 kg for males and 16 kg for females were classified as "low muscle strength" (8).

Physical performance was assessed by measuring overall walking speed. Patients participated in a 6-meter walking test, during which the time taken to complete the distance was recorded in seconds using a stopwatch. A walking speed greater than 0.8 m/s was classified as normal for both males and females. In contrast, a walking speed of 0.8 m/s or less indicated "decreased muscle function" (8).

Patients were categorized based on muscle strength, muscle mass, and physical performance. Participants demonstrating

only reduced muscle strength were considered to have probable sarcopenia, whereas those with concurrent declines in both muscle strength and muscle mass were identified as having definite sarcopenia. Those with concurrent reductions in muscle strength, muscle mass, and physical performance were defined as having severe sarcopenia (8).

To estimate fracture risk in patients, the fracture risk assessment tool (FRAX) score was calculated. The version of the FRAX tool adapted for Turkey was accessed through the website (https://www.shef.ac.uk/FRAX/tool.aspx?country=6). A 10-year risk of a major osteoporotic fracture of 20% or more, or a hip fracture risk of 3% or higher, was deemed high (12).

Statistics

Continuous variables are presented as mean ± standard deviation and median (minimum-maximum) values, while categorical variables are displayed with frequencies and percentages. To determine whether continuous variables followed a normal distribution, the Shapiro-Wilk test was employed. Comparisons between two groups were conducted using the independent two-sample t-test for normally distributed data and the Mann-Whitney U test for non-normal data. For comparisons across three or more groups, one-way ANOVA was utilized for data with a normal distribution, while the Kruskal-Wallis test was used for data that did not follow a normal distribution. Comparisons between categorical variables were conducted using the chi-square test or Fisher's exact test. Factors associated with sarcopenia were assessed using univariate logistic regression analysis. Analyses were interpreted as statistically significant when the p-value was below 0.05. Statistical analyses were performed using IBM SPSS (Version 21, Chicago, IL) and NCSS (Version 21.0.3, LLC, Kaysville, Utah, USA).

Results

The study enrolled 90 individuals who met the predefined inclusion criteria. Participants had a median age of 56 years, ranging from 53 to 62 years. Of the total participants, 84% (n=76) were male and 16% (n=14) were female. All female participants in the study were postmenopausal.

Time elapsed since HIV diagnosis had a median of 3.9 years, with a range of 2.2 to 8.1 years. The median baseline CD4 count was 283 cells/mm^3, ranging from 100 to 458 cells/mm^3. HIV RNA levels were undetectable in 90% of patients. AIDS-defining illnesses were observed in 14.8% of cases. A total of 92.2% of patients were on ART, with a median duration of 3.6 years, ranging from 2 to 7.1 years. Among these regimens, 68.9% were based on tenofovir disoproxil fumarate (TDF).

According to the EWGSOP2 criteria, definite sarcopenia was identified in one female (7.1%) and seven male patients (9.2%). Probable sarcopenia was found in five females (35.7%) and 23 males (30.3%). No sarcopenia was observed in eight females (57.2%) and 46 males (60.5%).

Participants were stratified into two main groups according to their gender: female and male. Within both groups, participants were stratified into two categories depending on the presence or absence of sarcopenia. The sarcopenia group included patients diagnosed with either probable or definite sarcopenia. Three comparison groups were established: sarcopenic females vs. non-sarcopenic females, sarcopenic males vs. non-sarcopenic males, and sarcopenic females vs. sarcopenic males.

The median BMI for sarcopenic females was 26 kg/m^2, with a range of 22.9 to 27.8 kg/m^2, whereas non-sarcopenic females had a median BMI of 31 kg/m^2, ranging from 26.4 to 39.7 kg/m^2. There was a statistically significant difference in median BMI between females with and without sarcopenia (p=0.005).

The groups did not differ significantly in terms of time since HIV diagnosis, baseline CD4 count, ART usage rate, duration of ART use, or ART regimens.

Table 1 presents the clinical, demographic, and immunological data of the patients.

All patients were categorized into two groups based on their initial CD4 count: ≤350 cells/mm^3 and >350 cells/mm^3. We then compared sarcopenia tests between these groups.

In the group with an initial CD4 count of ≤350, the median SARC-F score was 1, with a range of 0 to 9. Conversely, in the group with an initial CD4 count of >350, the median score was 0, ranging from 0 to 3. The comparison between the two groups yielded a statistically significant result (p=0.038). The mean walking speed was 1.2±0.3 m/s in patients with an initial CD4 count ≤350, compared to 1.4±0.2 m/s in those with a CD4 count >350. A statistically significant difference in mean walking speed was observed between the two groups (p=0.045). Table 2 presents a comparison of sarcopenia tests based on initial CD4 levels.

We conducted a logistic regression analysis to examine variables that might influence sarcopenia in patients. The results indicated that several factors-BMI, gender, the time since HIV diagnosis, duration of ART, baseline CD4 count, initial HIV RNA levels, presence of an AIDS-defining illness at baseline, and the duration of total use of TDF, TDF + protease inhibitor, TDF + integrase inhibitor, and TDF + non-NRTI - did not affect sarcopenia. Table 3 presents the findings from the univariate logistic regression analysis of potential risk factors associated with sarcopenia.

The study compared laboratory data among different sarcopenia groups. The analysis revealed no significant differences in laboratory parameters, including Vitamin D, urea, creatinine,

Table 1. Clinical, demographic, and immunological characteristics of patients

	Total median (min-max) or %	Female median (min-max) or %			Male median (min-max) or %		
Variables	**Total n=90**	**Non-sarcopenic n=8**	**Sarcopenic n=6**	**p**	**Non-sarcopenic n=46**	**Sarcopenic n=30**	**p**
Age (years)	56 (53-62)	60.5 (52-66)	55.5 (52-67)	0.414	55 (50-67)	58 (50-73)	0.080
BMI (kg/m^2)	26.1 (23.9-28.7)	31 (26.4-39.7)	26 (22.9-27.8)	**0.005***	25.7 (19.8-34.3)	25.4 (19.1-33.6)	0.678
BMI, n (%) 18.5-24.9 (normal) 25.0-29.9 (overweight) ≥30 (obese)	 32 (35.6) 47 (52.2) 11 (12.2)	 0 (0) 3 (37.5) 5 (62.5)	 2 (33.3) 0 (0) 4 (66.7)	 **0.030**	 18 (39.1) 24 (52.2) 4 (8.7)	 12 (40) 16 (53.3) 2 (6.7)	 0.950
Alcohol use, n (%) Social drinker ≥3 U/day	19 (21.1) 18 (94.7) 1 (5.3)	0 (0) UD UD	0 (0) UD UD	UD UD	9 (19.6) 9 (100) 0 (0)	10 (33.3) 9 (90) 1 (10)	0.175 1.000
Smoking, n (%) Cigarettes (pack/year) (average ± SD)	44 (48.9) 13.6±17.5	1 (12.5) 1.8±5.3	2 (33.3) 6.6±10.3	0.538 0.491	23 (50) 13.1±16.3	18 (60) 19.1±20.6	0.393 0.180
Chronic diseases, n (%) Malignancy Hematological disease Rheumatological disease IBD CAD DM HT Hyperlipidemia CRF	8 (8.9) 3 (3.3) 5 (5.6) 3 (3.3) 6 (6.7) 11 (12.2) 20 (22.2) 20 (22.2) 14 (15.6)	2 (25) 1 (12.5) 0 (0) 0 (0) 1 (12.5) 2 (25) 3 (37.5) 1 (12.5) 0 (0)	0(0) 0 (0) 1 (16.7) 0 (0) 0 (0.0) 1 (16.7) 2 (33.3) 1 (16.7) 1 (16.7)	0.473 1.000 0.429 UD 1.000 1.000 1.000 1.000 0.429	3 (6.5) 2 (4.3) 1 (2.2) 2 (4.3) 5 (10.9) 8 (17.4) 10 (21.7) 10 (21.7) 6 (13)	3 (10) 0 (0) 3 (10) 1 (3.3) UD 0 (0) 5 (16.7) 8 (26.7) 3 (23.3)	0.675 0.516 0.294 1.000 0.150 0.019 0.587 0.621 0.244
Time elapsed since diagnosis of HIV infection (years)	3.9 (2.2-8.1)	5.5 (1.3-17.7)	8.5 (1.6-17.6)	0.282	3.9 (0-20)	2.9 (0-16.7)	0.416
Current HIV RNA, n (%) Undetectable	 81 (90)	 8 (100)	 5 (83.3)	 0.429	 42 (91.3)	 26 (86.7)	 0.705
Initial CD4 count (cell/mm^3)	283 (100-458)	181 (0-780)	279 (15-642)	0.852	292 (0-861)	313 (5-1140)	0.886
Current CD4 count (cells/mm^3)	651 (381-872)	594 (379-1360)	834 (112-1493)	0.897	614 (153-1428)	659 (44-1206)	0.862
AIDS-defining disease, n (%)	15 (14.8)	2 (25)	0 (0)	0.473	7 (15.2)	6 (20)	0.588
ART use, n (%)	83 (92.2)	8 (100)	6 (100)	UD	42 (91.3)	27 (90)	1.000
ART use duration (years)	3.6 (2-7.1)	5.4 (1.3-15.2)	6.3 (1.5-16)	0.439	3.6 (0-11.3)	2.9 (0-16.6)	0.848
TDF use, n (%)	62 (68.9)	6 (75)	6 (100)	0.473	30 (65.2)	20 (66.7)	1.000
Total TDF use (days) TDF + PI (days) TDF + INSTI (days) TDF + NNRTI (days)	730 (0-1522) 0 (0-0) 0 (0-868) 0 (0-0)	1037 (0-1551) 0 (0-1095) 242 (0-1551) 0 (0-374)	1050 (540-3684) 0 (0-3684) 634 (0-1188) 0 (0-3351)	0.438 0.746 0.893 0.751	702 (0-3301) 0 (0-3285) 99 (0-2166) 0 (0-2541)	693 (0-3358) 0 (0-3358) 303 (0-1513) 0 (0-2733)	0.914 0.639 0.732 0.431

HIV: Human immunodeficiency virus, RNA: Ribonucleic acid, AIDS: Acquired immune deficiency syndrome, ART: Antiretroviral therapy, NNRTI: Non-nucleoside reverse transcriptase inhibitors, SD: Standard deviation, min: Minimum, max: Maximum

Table 2. Sarcopenia tests according to initial CD4 levels

Variables	Initial CD4 ≤350/mm³ n=55 average ± SD median (min-max)	Initial CD4 >350/mm³ n=29 average ± SD median (min-max)	p
SARC-F questionnaire	1.3±1.8 1 (0-9)	0.5±0.9 0 (0-3)	**0.038**
Walking speed (m/s)	1.2±0.3 1.2 (0.6-2)	1.4±0.2 1.2 (0.8-2)	**0.045**
SMI (kg/m²)	11.3±1.2 11.4 (9.7-15.7)	11.2±1 11.4 (8.6-12.9)	0.921
Muscle strength (kg)	27.6±7.4 27.9 (12.5-43.2)	27.1±6.8 25.6 (14-39.6)	0.753

SARC-F: Strength, assistance with walking, rise from a chair, climb stairs, and falls, SD: Standard deviation, min: Minimum, max: Maximum, SMI: Skeletal muscle index

Table 3. Univariate logistic regression of risk factors for sarcopenia

Variables	OR (95% CI)	p
BMI	0.907 (0.80-1.030)	0.132
Gender, male	0.870 (0.274-2.758)	0.812
Time elapsed since diagnosis of HIV infection (years)	1.015 (0.928-1.111)	0.740
Initial CD4	0.784 (0.355-1.732)	0.548
Duration of ART use	1.057 (0.948-1.177)	0.319
Initial HIV RNA	1.045 (0.647-1.689)	0.858
Presence of AIDS-defining illness	1.000 (0.323-3.101)	1.000
Total TDF use	1.300 (0.516-3.272)	0.577
Total TDF (years)	1.048 (0.897-1.223)	0.556
TDF + PI (years)	0.993 (0.813-1.214)	0.946
TDF + INI (years)	0.899 (0.684-1.180)	0.443
TDF + NNRTI (years)	1.178 (0.935-1.486)	0.165
Non-TDF (years)	1.122 (0.918-1.372)	0.261

CI: Confidence interval, BMI: Body mass index, HIV: Human immunodeficiency virus, RNA: Ribonucleic acid, AIDS: Acquired immune deficiency syndrome, TDF: Tenofovir disoproxil fumarate, NNRTI: Non-nucleoside reverse transcriptase inhibitors, ART: Antiretroviral therapy, OR: Odds ratio

albumin, calcium, magnesium, and hemoglobin, across the groups.

Sarcopenia test results were compared among the different sarcopenia groups. In sarcopenic females, the median SARC-F score was 3 (range: 0-9), while non-sarcopenic females had a median score of 1.5 (range: 0-4). For males, sarcopenic individuals had a median score of 1 (range: 0-8), whereas non-sarcopenic males had a median score of 0 (range: 0-3). No statistically significant differences were observed between the groups.

The median body fat (%) and median fat mass (kg) values differed significantly between sarcopenic and non-sarcopenic females (both p=0.010). Non-sarcopenic females had higher median body fat (%) and fat mass (kg) values at 40.2% (28.5-44.9) and 32.8 kg (21.4-43.6), respectively, compared to sarcopenic females, who exhibited median values of 33.8% (16.6-36.4) and 23.7 kg (11.2-25.7). In sarcopenic males, the median body fat (%) was 21.1 (9.5-33.2). A significant difference in median body fat (%) values was observed between sarcopenic males and females (p=0.02).

The median total body water FFM values were significantly higher in sarcopenic males compared to sarcopenic females (p=0.017 for both).

Table 4 presents the results of sarcopenia tests conducted on the study patients.

The FRAX scores were compared between sarcopenia groups. Among sarcopenic females, 50% had normal FRAX scores, while the other 50% had high scores. In contrast, 90% of sarcopenic males had normal FRAX scores, with only 10% having high scores. The incidence of high FRAX scores was significantly greater in sarcopenic females than in sarcopenic males (p=0.045).

The median 10-year risk of major osteoporotic fractures was 5.5% (range: 3.5-20) for sarcopenic males, compared to 4.4% (range: 2.8-15) for non-sarcopenic males. This difference was statistically significant (p=0.019). For hip fracture risk, the median was 0.8% (range: 0.2-16) in sarcopenic males and 0.5% (range: 0.2-3.2) in non-sarcopenic males, which was found to be statistically significant (p=0.007).

Table 5 presents the FRAX scores for both sarcopenic and non-sarcopenic patients in the female and male groups.

Discussion

The prevalence of sarcopenia has recently become a concern among PLWH (13). This study investigated the prevalence and associated risk factors of sarcopenia amongPLWH, who are experiencing longer life expectancies due to ART. According to the EWGSOP2 criteria, the prevalence of definite sarcopenia was 8.9%, while probable sarcopenia was 31.1%. No cases of severe sarcopenia were identified among the patients. Specifically, definite sarcopenia was observed in 7.1% of females and 9.2% of males, whereas probable sarcopenia was observed in 35.7% of females and 30.3% of males.

Table 4. Results of sarcopenia tests

	Female median (min-max)			Male median (min-max)		
Variables	**Non-sarcopenic n=8**	**Sarcopenic n=6**	**p**	**Non-sarcopenic n=46**	**Sarcopenic n=30**	**p**
SARC-F questionnaire	1.5 (0-4)	3 (0-9)	0.237	0 (0-3)	1 (0-8)	0.081
SARC-F, n (%) <4 ≥4	 7 (87.5) 1 (12.5)	 5 (83.7) 1 (16.3)	1.000	 46 (100) 0 (0)	 27 (90) 3 (10)	0.058
Walking speed (m/s)	1.2 (0.8-1.8)	1.2 (0.6-1.5)		1.3 (0.8-2)	1.2 (0.7-1.6)	
Walking speed, n (%) Normal Low	 8 (100) 0 (0)	 5 (83.7) 1 (16.3)		 46 (100) 0 (0)	 28 (93.3) 2 (6.7)	
Body fat (%)	40.2 (28.5-44.9)	33.8 (16.6-36.4)	**0.010**	20.3 (6.3-32.3)	21.1 (9.5-33.2)	0.731
Fat mass (kg)	32.8 (21.4-43.6)	23.7 (11.2-25.7)	**0.010**	15.6 (4.4-29.5)	17 (5.7-27.5)	0.930
TBW (kg)	34.9 (32.4-48.4)	35.4 (31.4-44)	0.897	44.8 (33.5-55.6)	42.7 (32.4-60.9)	0.244
FFM (kg)	47.6 (44.3-66.1)	48.4 (42.9-60.1)	0.897	61.2 (45.7-76)	58.3 (44.2-83.2)	0.245
SMI (kg/m²)	10.8 (9-13.7)	9.9 (8.6-11.9)		11.5 (9.7-13.1)	11.3 (9.7-15.7)	
SMI, n (%) Normal Low	 8 (100) 0 (0)	 5 (83.3) 1(16.7)		 42 (91.3) 4 (8.7)	 23 (76.7) 7 (23.3)	
Muscle strength (kg)	21.3 (16.1-25.9)	14.5 (12.5-15.8)		32.9 (27.8-43.2)	22.3 (15.7-26.9)	
Muscle strength, n (%) Normal Low	 8 (100) 0 (0)	 0 (0) 6 (100)		 46 (100) 0 (0)	 0 (0) 30 (100)	
Calf circumference (cm)	38 (33-45)	37 (35-44)	0.434	38 (32-44)	36.5 (27-44)	0.193
Calf circumference, n (%) Normal Low	8 (100) 0 (0)	6 (100) 0 (0)	UD	46 (100) 0 (0)	29 (96.7) 1 (3.3)	0.395

SARC-F: Strength, assistance with walking, rise from a chair, climb stairs, and falls, TBW: Total body water, FFM: Fat-free mass, SMI: Skeletal muscle index, FFM: Fat-free mass, min: Minimum, max: Maximum

Table 5. FRAX scores of patients

	Female median (min-max)			Male median (min-max)		
Variables	**Non-sarcopenic n=8**	**Sarcopenic n=6**	**p**	**Non-sarcopenic n=46**	**Sarcopenic n=30**	**p**
Risk of major osteoporotic fracture (%)	7.3 (4.4-10)	9.9 (4.3-22)	0.438	4.4 (2.8-15)	5.5 (3.5-20)	**0.019**
Risk of hip fracture (%)	0.9 (0.4-2.2)	2.2 (0.4-5.4)	0.219	0.5 (0.2-3.2)	0.8 (0.2-16)	**0.007**
FRAX score[1], n (%) Normal High	 8 (100) 0 (0)	 3 (50) 3 (50)	 0.055	 45 (97.8) 1 (2.2)	 27 (90) 3 (10)	 0.294

[1]: p=0.045 for the comparison between sarcopenic males and sarcopenic females.
FRAX: Fracture risk in patients, the fracture risk assessment tool, min: Minimum, max: Maximum

In the literature, sarcopenia prevalence varies by ethnicity, diagnostic tests, age, and gender (11). For instance, a study by Ontan et al. (14) on the general population in Türkiye found that the prevalence of probable sarcopenia was 21.1%, definite sarcopenia was 13.7%, and severe sarcopenia was 16.2% in individuals aged 65 and older, according to EWGSOP2. Notably, the SMI thresholds used in that study (8.87 kg/m² for males and 6.42 kg/m² for females) were lower than those in our study. Another study involving 456 participants over 65 years of age in Türkiye reported a prevalence of probable sarcopenia at 19.7% in males and 9.8% in females, per EWGSOP2 criteria (15). Although participants in that study had a higher average age

(74.6 years) compared to our study (57.8 years), the prevalence of probable sarcopenia was greater in our cohort.

Comparing our findings with other studies on definite sarcopenia is problematic due to variations in threshold values and age groups. Nevertheless, considering that other studies involved older age groups and lower threshold values, the level of sarcopenia in PLWH aged 50 and over can be deemed relatively high.

A review of the literature shows that the prevalence of sarcopenia among PLWH ranges from 5% to 24% (7). A meta-analysis of 13 studies identified that PLWH have a sixfold higher risk of developing sarcopenia compared to HIV-negative controls (5). Risk factors contributing to sarcopenia include the duration of HIV infection, the use of antiretroviral drugs (notably thymidine analog NRTIs such as stavudine and zidovudine), smoking, alcohol consumption, advanced age, low BMI, and decreased CD4 count (5).

Low BMI has been linked to sarcopenia in both the general people living with HIV (PLWH) (16). In our study, we identified an association between low BMI and sarcopenia specifically in female patients.

The association between the duration of HIV infection and sarcopenia remains controversial. Echeverría et al (2). found that long-term exposure to HIV infection is associated with sarcopenia. Conversely, de Almeida et al (16). reported no association between the duration of HIV infection and sarcopenia. Our study similarly found no association between the duration of HIV infection and sarcopenia.

Several studies in the literature examine the association between initial CD4 count and sarcopenia. Abdul Aziz et al. demonstrated a relationship between high initial CD4 counts and sarcopenia, whereas Echeverria et al. (2) found no such association (6,7). In our study, we also observed no overall relationship between initial CD4 count and sarcopenia. However, when dividing patients into groups based on their initial CD4 count (≤350 and >350 cells/mm^3), we found that the group with an initial CD4 count ≤350 cells/mm^3 exhibited significantly lower walking speeds and higher SARC-F scores compared to those with an initial CD4 count >350 cells/mm^3.

Sarcopenia is recognized as a risk factor for falls and fractures in the general population (17). Matsumoto et al. (18) identified an association between high FRAX scores and sarcopenia. Correspondingly, our study found that male patients with sarcopenia had significantly higher 10-year major osteoporotic and hip fracture risks compared to their non-sarcopenic counterparts.

Study Limitations

Our study has several limitations. First, the absence of an HIV-negative control group precluded comparisons between PLWH and HIV-negative individuals. Second, as 92.2% of our patients were using ART, we were unable to assess ART's effect on sarcopenia. Lastly, the limited sample size necessitates further research with larger populations to validate these findings.

Conclusion

In conclusion, our study identified a sarcopenia prevalence of 40% among PLWH aged 50 years and older, with 8.9% having definite sarcopenia and 31.1% classified as probable sarcopenia. The prevalence of sarcopenia in PLWH may exceed that of the general population. We found no association between sarcopenia and factors such as the time elapsed since HIV diagnosis, initial CD4 count, ART usage rate, duration, or regimen. Screening for sarcopenia in PLWH aged 50 and over may be advantageous in preventing the adverse outcomes associated with this condition.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of İstanbul University-Cerrahpaşa (decision number: E-83045809-604.01.02-70371, date: 04.07.2021).

Informed Consent: All participants provided signed informed consent prior to study participation.

Footnotes

Authorship Contributions

Surgical and Medical Practices: G.A., N.S., P.K., H.Y., B.M., Ö.F.T., Concept: B.Ç., E.D., S.Y.K., P.K., H.Y., B.M., Ö.F.T., Design: B.Ç., E.D., R.K., İ.İ.B., S.Y.K., G.A., N.S., P.K., H.Y., B.M., Ö.F.T., Data Collection or Processing: B.Ç., Analysis or Interpretation: B.Ç., E.D., R.K., İ.İ.B., P.K., H.Y., B.M., Ö.F.T., Literature Search: B.Ç., R.K., İ.İ.B., S.Y.K., P.K., H.Y., B.M., Writing: B.Ç., E.D., Ö.F.T.

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ORIGINAL RESEARCH

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Internet Use and Digital Technology Needs of Older People Living in Rural Areas-A Sample of Bartın/Türkiye

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Abstract

Objective: Supporting older people emerge as an important problem. Encouraging digital health technologies is seen as one of the effective ways to address this problem. This research aims to examine the current status of internet use by older people, the factors affecting this (including physical, psychological, and social aspects), and the demand of older people for smart services.

Materials and Methods: The type of the study was determined as a descriptive quantitative study with a sample of 85 individuals aged 65 and over living in villages affiliated with the center of Bartın, Türkiye.

Results: While 72.9% of the participants reported that they did not use the internet, 27.1% reported that they used the internet. A significant portion of the participants found the use of smart bracelets and emergency call at home necessary or very necessary. The participants did not find the "telemedicine", "online health", and "online psychosocial counseling" applications necessary. Finally, 83.5% of the participants reported that they find the "older-friendly smartphone" application necessary or very necessary.

Conclusion: It is important to take these suggestions into consideration when making technological plans in old age.

Keywords: Older people, rural area, internet use, digital technology needs

Introduction

According to the data published by Türkiye Statistical Institute (TURKSTAT) in 2021 (1), the population aged 65 and over in Türkiye, which was 6 million 651 thousand 503 in 2016, increased by 24.0% five years later and reached 8 million 245 thousand 124 older people in 2021. Again, according to the same data, the ratio of the older population to the total population was determined as 8.3% in 2016 and 9.7% in 2021. In terms of population projections, the older population ratio is expected to be 11.0% in 2025, 12.9% in 2030, 16.3% in 2040, 22.6% in 2060, and 25.6% in 2080 (1). With the rapid aging of the population, the demand for health and care services for older individuals is undoubtedly increasing. Digital technologies can be seen as a solution to enable older people to continue their lives within their families or independently. Digital technologies can provide benefits increasing the quality of daily life and access to health/care services, as well as facilitating communication and socialization for older individuals. Although older individuals are more unfamiliar with digital technologies than young people may seem like an obstacle, overcoming this obstacle can make significant contributions to their independent lives (2). Health problems that restrict or prevent basic communication, mobility, and personal care activities in older individuals increase with age (2). Despite the increase in the older population, mobile applications are generally designed for young and middle-aged people, and the older population is neglected. However, internet use has become quite widespread in recent years, and the number of users over the age of 60 in digital media has also increased. Studies have begun to focus on developing assistive information and communication technologies that will support independent living for older individuals (3). Internet use among older people is limited. For example, older individuals generally use the internet for

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entertainment (such as music, videos), information access (such as news, health-related information,) and communication with others. Compared to other age groups, it can be said that the older people individuals primarily use the internet for health-related reasons (4). While most older people learn how to use the internet through their children or other young people, some learn on their own (5). The physical and mental conditions of people tend to gradually deteriorate in old age. The socialization process is important for increasing the life satisfaction and quality of older individuals. In this process, the older individual socializes by learning through social interactions they engage in to cope with the physical and mental changes they undergo (6). Rapid changes in technology have increased the need for older individuals to learn from younger family members compared to the past. Older individuals, who are in a new socialization process, are affected by both socialization tools and structural factors when accepting technological innovations in the digital field (6). Previous studies have shown that older individuals with high levels of social support are more willing and inclined to learn about the internet. In this sense, the use of digital technology by older adults can be increased through family support and encouragement (7), and digital technologies contribute to well-being by reducing social isolation in older individuals (8). Using the internet and digital technologies is particularly important for older people who are becoming isolated in rural areas due to the migration of the young population to urban centers. However, previous studies generally include older people living in cities or nursing homes, and the situation of older people living in rural areas is often ignored (9).

This research aims to investigate the current status of internet use among rural older people, their need for digital technologies, and the factors that affect their behavior. The results are important for increasing internet use among older people and creating the necessary infrastructure to meet their health, care, and social needs, improving their quality of life, and ensuring that they benefit from internet and digital services.

Within the scope of the research; the level of internet use among rural older people and how does it diversify, types of the digital technologies that the rural older people use for health and social care areas and the kinds of support and services that the older people need in the field of internet use and digital technology tried to be understood.

Materials and Methods

The type of the research is descriptive quantitative research. The research data were collected with a questionnaire prepared by the researchers to reveal the sociodemographic and internet usage and digital technology needs. The study of Sun et al. (10) was also used in the creation of the questionnaire, which has multiple choice questions. While creating the questionnaire, expert and stakeholder opinions were also consulted, a preliminary study was conducted on a small group and it was revised to determine whether there were any unclear/incomprehensible questions. The researchers obtained consent from the older people for this questionnaire, and the study was approved by the Ethics Committee of Bartın University (protocol number: 2023-SBB-0715, date: 16.11.2023).

The field study was conducted between September and December 2024 with 85 older individuals who agreed to answer the questions. The sample of the research was determined by a single-stage random probability sampling based on the main population rates. According to the last census, there are a total of 137 villages affiliated with the central district of Bartın. Among these villages, those with suitable transportation facilities and population were selected, and the questionnaire was applied face to face on a voluntary basis in villages close to the center. The criteria determined for the older the individuals participating in the research are: being 65 years old and over, having sound mental will, strong verbal skills, and volunteering for the research. The survey was conducted face-to-face with 85 elderly people living in villages close to the center. The researchers who participated in the field research provided information about the digital technologies asked of the participants during the survey, and clarified the unclear questions. In addition, they ensured that the questions were read and answered by those with reading/writing and hearing difficulties.

Statistics

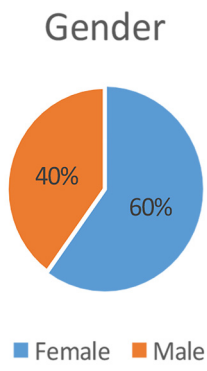
All data that entered the database were verified by the researchers. Continuous variables were given as mean ± standard deviation for normally distributed variables. Data were analyzed using only descriptive analysis. The analysis was carried out with the statistical package SPSS Version 21.0 for Windows.

Results

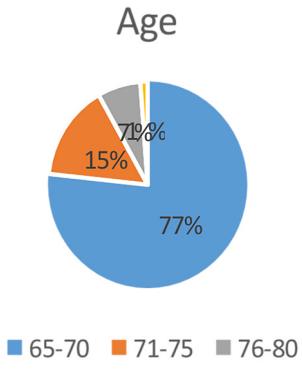
The findings are discussed in two parts: the socio-demographic characteristics of the participants and the participants' internet use and digital technology needs.

Socioeconomic and Demographic Characteristics of Participants

Fifty-one females (60%) and thirty-four males (40%) participated in the study (Graphic 1). The majority of the participants (77%) were between the ages of 65-70, 15% were between 71-75 and 7.1% were between 76-80 (Graphic 2).

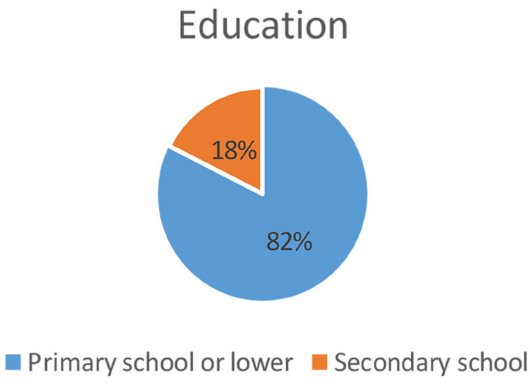


Graphic 1. Gender

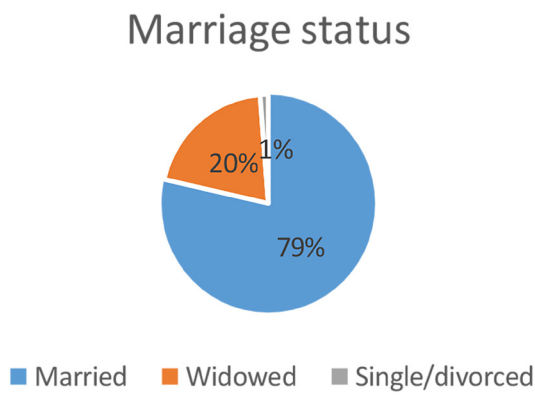


Graphic 2. Age

The majority of the participants in the study had primary school or lower education (82%). The rest had secondary school education (18%) (Graphic 3). While a large number of married participants participated in the study (79%), 20.0% of the participants were widowed. There was one and one divorced participant (1%) (Graphic 4).

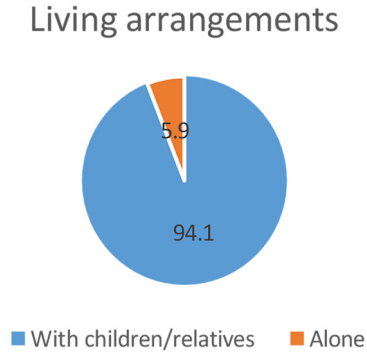


Graphic 3. Education

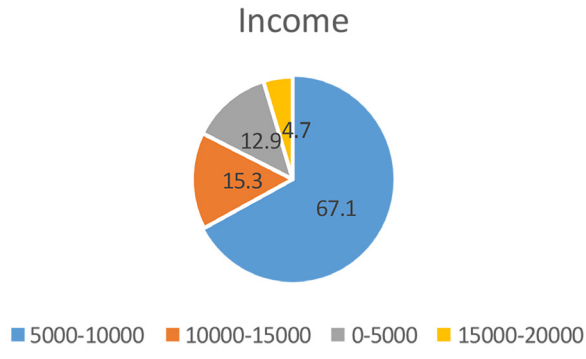


Graphic 4. Marriage status

Almost all of the participants (94.1%) live with their children or relatives. The rate of those living alone is 5.9% (Graphic 5). The income of the majority of the participants in the study (67.1%) was between 5,000 to 10,000 TL; the others were between 10,000 to 15,000 TL (15.3%); 0 to 5,000 TL (12.9%); and 15,000 TL and above 20,000 TL (4.7%), respectively (Graphic 6).

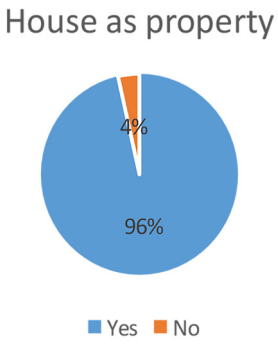


Graphic 5. Living arrangements

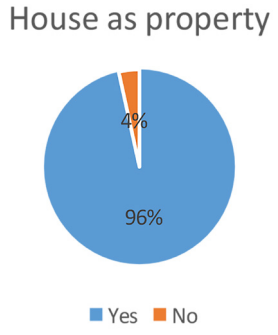


Graphic 6. Income

Almost all of the participants (96%) live in their own home (Graphic 7). While 81% of the participants stated that they did not have any chronic diseases, 19% reported that they had a chronic disease (Graphic 8). Forty percent of the participants have 3 children, 30.6% have 2 children, 14.1% have 4 children and 2.4% have 1 child. 49.4% of the participants had 1-2 friends, 32.9% had 3-5 friends, 15.3% had more than five friends, and 2.4% reported that they had no friends. Most of the participants (97.6%) answered "I never participate" in social activities, while a small portion (2.4%) answered "I sometimes participate".



Graphic 7. House as property

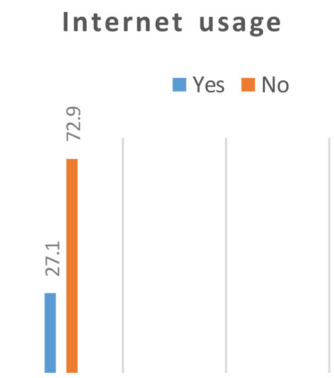


Graphic 8. Chronic diseases

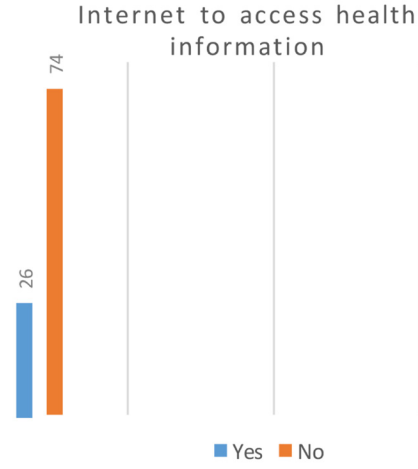
The Participants' Internet Use and Digital Technology Needs

While 72.9% of the participants reported that they did not use the internet, 27.1% reported that they used the internet (Graphic 9). Approximately half of the internet users (43.4%) use the internet less than three days a week and mostly use the internet for online chatting (78.2%) and following the news (73.9%). Some of the participants also use the internet to listen to music and watch videos (39.1%).

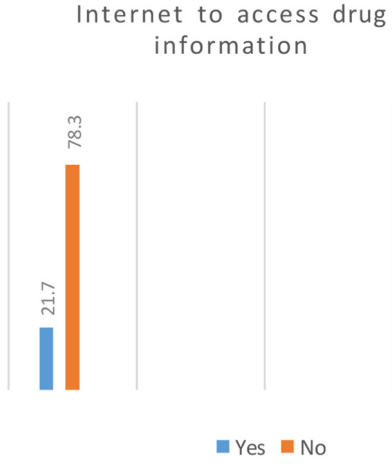
None of the participants uses the internet for gaming, online shopping or health information. Also, none of the participants used the internet for food safety, sports/fitness applications, or diet information. Only 26% of the participants who use the internet reported that they accessed health information via the internet (Graphic 10). A small portion of the participants (21.7%) use the internet to access drug information (Graphic 11).



Graphic 9. Internet usage



Graphic 10. Internet to access health information



Graphic 11. Internet to access drug information

As seen in Table 1, more than half of the participants (64.7%) find the use of "smart bracelets" necessary or very necessary. A significant portion of the participants (76.4%) find the "emergency call" at home necessary or very necessary. The participants mostly do not find the telemedicine application and online health application necessary. While 83.5% of the participants find the online appointment registration system

Table 1. Need for digital technologies (summary table)

	Very necessary n (%)		Necessary n (%)		Undecided n (%)		Not so necessary n (%)		Certainly not necessary n (%)	
Smart bracelet	14	16.5	41	48.2	6	7.1	12	14.1	12	14.1
Emergency call at home	16	18.8	49	57.6	5	5.9	7	8.2	8	9.4
Telemedicine	7	8.2	11	12.9	16	18.8	23	27.1	23	32.9
Online health application	15	3.5	8	9.4	12	14.1	25	29.4	37	43.5
Online appointment registration system	37	43.5	34	40	3	3.5	5	5.9	6	7.1
Online health payment application	5	5.9	6	7.1	3	3.5	19	22.4	52	61.2
Online psychosocial counseling application	5	5.9	10	11.8	5	5.9	23	27.1	42	49.4
Older-friendly smartphone	45	52.9	26	30.6	3	3.5	3	3.5	8	9.4

necessary, 83.6% do not find the online health payment application necessary. The participants generally do not find the online psychosocial counseling application necessary (76.5%). Finally, 83.5% of the participants reported that they find the "older-friendly smartphone" application necessary or very necessary (Table 1).

Discussion

The socio-demographic characteristics of the participants show that the majority of the older individuals included in the study are between the ages of 65-70 and married. Although the gender ratios of the participants are close to each other, the proportion of women is higher than that of men. It is a striking result that almost all of the participants are married and their spouses are alive. It is known that divorce rates are increasing in society. The single-parent family rate in Türkiye, which was 7.6% in 2014, increased to 10.1% in 2021 (1). Older people living in rural areas provide a striking change in divorce rates is observed among older people living in rural areas. Another important result is the educational background of the participants. The majority of the participants in the study had primary school or lower education (82.4%). This result is particularly important in terms of its relation to the use and need for the internet and digital technologies. The fact that almost all of the participants live with their children or relatives suggests that their social support systems are strong and that they need less technological assistance. In fact, the rate of those with chronic diseases is low among rural older people (19%).

Seventy-two point nine per cent of the participants reported that they did not use the internet. Meanwhile, 27.1% reported using the internet This result is consistent with the research results conducted by TURKSTAT (1) in Türkiye. According to the results of the 2020 Household Information Technologies Usage Survey, while the internet usage rate of the 16-74 age group in Türkiye is 77.7%, only 27.1% of this rate is made up of. Approximately half of the internet users (43.4%) use the internet less than three days a week and mostly for online chatting (78.2%) and following the news (73.9%). Recent studies also have shown that older adults can use the internet to communicate with family members and friends, and also allows individuals to enhance their face-to-face interactions with family members and friends (11-13). Therefore, the internet in some way provides communication facilities for older adults, which reduces social isolation. Some of the participants also use the internet to listen to music and watch videos (39.1%). It is significant that the limited number of older individuals using the internet use it less frequently and generally for communication purposes. This result is very similar to the former research findings (13,14). According to the recent research results, the internet has a protective effect on the mental health of older adults. Mental health can be enhanced by reducing alienation. It is necessary to provide more internet opportunities for older people, especially those in rural areas, to increase the accessibility of embodied cultural capital and bridge the digital divide between urban and rural older adults (15).

None of the participants use the internet for gaming, online shopping or health information. Also, none of the participants used the internet for food safety, sports/fitness applications, or diet information. Only 26% of the participants who used the internet reported that they accessed health information via the internet. A small portion of the participants (21.7%) used the internet to access drug information. Older individuals stated that they received help from their children or relatives for important health applications and other needed information, and that they could not use these applications on their own. These findings are consistent with the results of another study that showed that internet usage differs for older people living in rural and urban areas. According to the results of the former research, older adults living in rural areas, compared to those in urban areas, showed lower levels of all sub-types of technology use (communication, financial, health, and media technology). Additionally, non-users in rural areas exhibited more unfavorable perceptions of technology than urban residents, which means that substantial segments of older adults in rural areas are still behind in accessing and adopting digital technology (16).

More than half of the participants (64.7%) find the use of "smart bracelets" necessary or very necessary. The participants living in rural areas stated that they spend time in fields, gardens, markets, etc., and that they are sometimes alone in these areas. They are positive about the idea of smart bracelets for reaching health services quickly in case of a possible accident. A significant portion of the participants (76.4%) finds the "emergency call" at home necessary or very necessary as well. The participants mostly do not find the "telemedicine" application and "online health application" necessary. The participants do not view favorably on the concept of telemedicine or online health assistance because they think that the doctor cannot reach a full diagnosis without seeing the patient. They prefer to go to the hospital. While 83.5% of the participants find the "online appointment registration system" necessary, 83.6% do not find the online "health payment application" necessary.

The participants use the appointment system to avoid waiting in line at the hospital and their children usually make this appointment. The participants think that online payment is not necessary. Study participants stated limited trust in internet platforms, citing the high incidence of online fraud in current digital contexts as a primary concern. The participants mostly do not find the online psychosocial counseling application necessary (76.5%). Participants think that face-to-face conversations will be better for the person and that the person will express himself or herself more comfortably. For this reason, they do not look favorably on the online psychosocial counseling application. According to the findings of a survey conducted in the rural areas of China, although older adults use smart services and devices (e.g., smartphones) in their lives, they don't understand the concept of "smart aging". The main channels for information are: the village committee and friends and relatives, followed by television and radio, which shows the importance of geographic and blood relations in rural older services. Also, the lack of understanding of the concept of "smart aging" does not affect the use of products (e.g., smartphones) in real life (17).

Finally, 83.5% of the participants reported that they find the "older-friendly smartphone" application necessary or very necessary. As a result of eye problems that occur as they age, older people find it useful to make the phones they use more visible for older people to use more understandable symbols, and they see the development of such a technology as necessary.

These results show that rural older people, who live in villages close to the center in rural areas, provide their own production and mostly live with their families and relatives. They use the internet and digital technologies to a limited extent, and when necessary, they use them by getting help from their children or relatives. It would be more accurate to read this result in two ways. First of all, the strong social ties, their organic diet and active lifestyles of rural older people reduce their need for the internet or digital technologies, which is a positive and desirable situation. On the other hand, technological developments make online and digital services almost mandatory, in which case older individuals who cannot use them effectively become dependent on others.

Study Limitations

There are some limitations in our study. The participants were selected from the villages near the city center. This may give rise to selection bias. The results could not be generalized.

Conclusion

With the results of this study, it is considered important to develop internet and digital technologies as older-friendly, starting from the ones that rural older people need the most. Ensuring their distribution with the support of central and local authorities and providing appropriate guidance and training to older people are crucial. More importantly, it is essential to diversify the smartphones that almost everyone uses.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of Bartın University (protocol number: 2023-SBB-0715, date: 16.11.2023).

Informed Consent: All participants provided written informed consent.

Footnotes

Authorship Contributions

Concept: Ö.Ö., Design: Ö.Ö., Data Collection or Processing: Ö.Ö., Ş.N.T., Y.S., H.G., Analysis or Interpretation: Ö.Ö., Ş.N.T., Y.S., H.G., Literature Search: Ö.Ö., Ş.N.T., Y.S., H.G., Writing: Ö.Ö.

Conflict of Interest: No conflict of interest was declared by the authors.

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BRIEF REPORT

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Healthy Ageing in Nepal: Key Challenges and Possible Solutions

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Abstract

The ageing population worldwide, including that in Nepal, is increasing rapidly. The older population faces a range of health and non-health-related challenges. This review paper explored the concept of healthy ageing, identified the key challenges among the aged population, and proposed a revised social ecological model (SEM) that could be customized and tailored in the context of Nepal to improve the overall health and well-being of older populations. Despite existing policies like social security and elderly health care concession, implementation remains weak due to a systemic gap. Tackling these challenges will require coordinated efforts from both state and non-state sectors in Nepal focusing on social protection, healthcare accessibility, infrastructure adaptation, and shifts in societal attitudes. A multi-level SEM approach, encompassing individual, interpersonal, community, organizational and policy intervention, is recommended to foster healthy ageing in Nepal and similar low-resource settings.

Keywords: Ageing, challenges, health, Nepal, older population, socio-ecological model

Introduction

The world's population is aging rapidly, with one in six people expected to be 65 or older by 2050-up from fewer than one in ten today. Nearly 80% of these older individuals will reside in what are currently low- and middle-income countries (LMICs), including Nepal (1). In Nepal, the aged population (60 years and above) has increased from 8.1% in 2011 (2) to 10.2% in 2021 (3). As individuals age, their social and health needs increase. The concept of healthy ageing is of great importance to enjoy longevity and quality of life. Healthy ageing can be achieved by creating favorable environments and opportunities for older adults to improve their quality of life and support independent living. While we celebrate the increased longevity (4,5) we must also address the wide range of physical, mental, and social challenges associated with ageing including chronic non-communicable diseases, poor health and reduced quality of life (6-8).

Although the ageing and health agenda has gained momentum under the United Nations' Sustainable Development Goals (SDGs)-particularly SDG 3 "(ensure healthy lives and promote well-being for all at all ages")-the formulation and implementation of tailored policies in developing countries remain underexplored, despite evidence highlighting the necessity of integrating aging and health priorities into national social policies and programs (9). Therefore, this article aims to highlight the concept of healthy ageing, identify the existing challenges among the ageing population, and propose a revised social ecological model (SEM) to improve the overall health and well-being of older populations in Nepal.

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Healthy Ageing

The World Health Organization defines healthy ageing as "the process of developing and maintaining the functional ability that enables well-being in older age" (10). This functional ability of a person is determined by three factors: the person's intrinsic capacity, relevant environmental characteristics, and the interaction between them. Intrinsic capacity includes all of an individual's physical and mental capacities for independent living. The environmental characteristics consist of national to local level policies, existing systems, and services delivered related to transport, housing, social protection, parks, social facilities, institution-based care and home-based care, relationships with friends, family, and caregivers, and cultural and social perception and values (11). Thus, healthy ageing is fundamentally the creation of supportive environments and opportunities that enable people to realize their aspirations throughout the life course (12).

Challenges for Ageing Populations in Nepal

The government of Nepal has addressed many issues, including socioeconomic barriers of older people, by reflecting in several programs such as a social security fund, old age allowance, and free health care for older people. However, older people have encountered several challenges to enjoy healthy ageing in Nepal. This section examines the challenges in detail.

The readiness of the health and social system in transitional demographic and social status: Over the last decade, the social status of the people has increased because of the easier life, economic opportunities, employment, and services in urban areas (13). According to the 2011 census of Nepal, the urban population doubled from 14.2% in 2001 to 27% in 2011, with the annual growth rate three and a half times more in urban than rural areas (0.98) (14). The migration from low-income regions to higher-income regions is considered social migration, which is mostly happening in many countries (14). This trend reflects social migration, where mostly the younger populations leave their homes; often leaving older members in the rural areas As a result, many older people cannot get the filial respect, support, and care as much as they need.

Additionally, Nepal has seen a rapid shift from the joint to nuclear family. The 2011 census revealed that households with 1 to 4 members became the most common, whereas five people per households were highest size in 2001. This transition has led to the social isolation of older adults, as their traditional decision-making roles in the families and communities continue to diminish (14).

On the other hand, older people who have recently migrated with their younger families to the city are also facing many problems. Most of the cities lack adequate parks, open spaces for recreation, and age-friendly infrastructures, confining older people to their homes. Also, the unorganized traffic, unmanaged footpath, and uncontrolled air pollution in the cities have impacted people's ability to perform their outdoor physical activities, such as jogging, running, cycling, and so on. These problems collectively restrict opportunities for physical activities, social interaction, that ultimately may result in developing NCDs such as cardiovascular diseases, diabetes, and even mental health problems among the older population.

The proportion of the older population aged 60 years and above has increased in Nepal and is projected to more than double, from 8% in 2011 to 18.6% by 2050 (15). Despite this rapid ageing trend, current infrastructure, social systems, and health systems are not adequate to respond to the social and demographic challenges in Nepal (16).

Social security: The social security fund was established in Nepal on 27 November 2018, making a milestone for ageing population as more than 28% of the total 31% contribution goes to the old-age pension (17,18). However, a major challenge is enrolling all the workers, as many formal sectors have yet to register. Additionally, almost two third of Nepal's active workforce is working in the informal sector (19,20). These large proportions of casual sector workers have not been enrolled, and this cohort of older people would be deprived of obtaining security in the future. Moreover, women are disproportionately deprived of the old age pension as only a few are enrolled in the formal employment sectors (21). Therefore, the current social protection system for the older population is and will continue to be a challenge. Furthermore, the inflation and cost of care have increased dramatically over the past few decades, making the current old age allowance of approximately 29 USD per month in Nepal-is insufficient to cover the cost incurred (22).

Access and availability of health care for older people: Although the government has introduced policies to provide at least 50% concession for older people, implementation remains weak, and most of the health care services and infrastructure are not old age-friendly (23). For example, there are no assisting services for older people with impairments like hearing loss and poor vision.

Degenerative disorders and their consequences in the aged population like difficulty in walking, pain in joints, mental disorders, especially dementia and Alzheimer's diseases, fall injury, incontinence of urine and stool, osteoporosis, and osteoarthritis require specialized care from trained health professionals (24). However, Nepal faces a severe shortage of health care workforce specializing in geriatric care. Further, no dedicated hospital for older people has been established so far (25). Since most of the health care facilities are urban-centered, the old-age population residing in rural areas is less likely to use the health care services they need due to long distance and geographical barriers.

Stereotyping attitude and perception and behavior towards the older people: In Nepal, ageing is considered as natural process, leading to neglect by, family members and society. When older people become ill, they often do not receive the same levels of access to health care facilities as younger individuals. For example, during the Coronavirus Disease 2019 pandemic, people are less likely to worry if the deceased person is of older age, reflecting a societal belief that illness and disorders are inevitable in old age.

This deep-rooted attitude hinders efforts to improve the health and quality of life of the older population. Evidence shows that many older individuals in Nepal face abuse, discrimination, and violence, whether mental, psychological, or even sexual within families nursing homes, and public places. Studies conducted in different parts of Nepal revealed that over 50% of the older adults have experienced some form of abuse or mistreatment (26-28). Alarmingly, 70-95% of these incidents go neglected or unreported (29). These forms of mistreatment are strongly associated with increased morbidity and mortality among the elderly (30).

Possible Solutions to Address the Challenges

Given the increasing problem (both health and non-health related) among the older age populations in Nepal, there has been a critical need for developing a system that appropriately acknowledges their needs and challenges at the upstream (systems-level) and downstream (service-delivery level), thereby providing effective measures. Consideration of the social-ecological perspective and addressing the social determinants of health, mainly for ageing populations, would be an approach to addressing the challenges of ageing populations in Nepal. We have proposed a SEM in the context of Nepal and the details of SEM are outlined in the following section. The following are some of the key recommendations that need urgent attention in the context of healthy ageing in Nepal:

Social protection for the older population in Nepal: With rising personal and healthcare needs among Nepal's growing s ageing population comprehensive and integrated social security programs are crucial. To ensure inclusivity, the informal sectors must be enrolled into welfare schemes with timely payment mechanism to guarantee accessibility for all older citizens

The change of social and engineering infrastructure: The service outlets of new and old structures should be developed or modified to make them convenient for older people. The evidence shows that public buildings and outdoor spaces greatly impact morbidity, mortality, and quality of life (31). To achieve this, country-level policy and guidelines must be established to reengineer those structures. As urbanization rapidly increases, cities must become age-friendly to address the needs of the growing aging population. For instance, parks with green and open space should be built in every local suburb and community for recreation and physical exercises (31). In addition, for those who prefer to spend the rest of their lives in aged-care facilities among peers, the government and the private sectors should collaborate to develop well-organized aged-care homes with high-quality routine and nursing care. There is also a need to develop appropriate policies, strategies, and guidelines to regulate and guide the aged care facilities in Nepal.

Reorienting the health system: National policies, strategies, and programs must prioritize a shift from hospital-based long-term care to home-based care services. Since health can be created and maintained in the homes and communities, the critical interventions needed are: the financial compensation for family caregivers and enhanced health literacy to improve home care while developing a professional caregiving workforce. The periodic plan should emphasize multi-sectoral engagement, involving relevant ministries, to ensure effective implementation—including the allocation of a designated percentage of hospital beds and/or wards for senior citizens and the establishment of elderly community care centers, as mandated by the 16th national plan and its predecessors, to accelerate inclusive service delivery (32). The Health Sector Strategic Plan, which is developed every five years, should also outline the strategic direction for reorienting the health system to address the needs of the aged population.

Raising awareness about healthy ageing: A paradigm shift in societal attitude is imperative to overcome the prevailing ageism and reconstruct the sociocultural narrative surrounding ageing. Multilevel awareness programs targeting behavior modification towards the older populations are considered a robust strategy to achieve this transformation (33). Such interventions must be implemented across the social-ecological spectrum, from within a person to broader societal and environmental levels, and through diverse communication channels. The SEM emphasizes understanding the multifaceted and interactive effects of multiple factors including individual, familial, environmental, and systemic that collectively determine the behaviors of every individual, affecting levels from the individual to the broader societal (34-36). This model identifies key leverage points for intervention, enhancing the health and well-being of individuals, families, communities, and society on a larger scale (36-38). The structural interventions should include updating the curriculum on ageing, and these updates could extend across primary to tertiary education. Next, establish a legal accountability mechanism to ensure the right of the older population to live with dignity, with sanctions for non-compliance at familial or community levels.

Empowerment and inclusion of older people: The older people should be actively engaged in the decision-making processes that directly affect them. To combat social isolation, they must also be encouraged to participate in social and community

functions. As older people have numerous experiences throughout their lives, they must be provided the opportunities to share their opinion at meetings and committees for local development and finding solutions for various ongoing issues.

Proposed Social Ecological Model for Healthy Ageing

In the Nepalese context, we propose a revised SEM to improve the overall status of older populations (Figure 1). The SEM has been used broadly in the health sector (38-42), including in the efforts to better understand and improve the health and well-being of ageing populations (43-46). The SEM is a theory-based framework that emphasizes the understanding of multifaceted and interactive effects of factors that influence behavior. SEM supports determining behavioral and organizational leverage in efforts to enhance the health and wellbeing of the individual, family, community, and society on a larger scale (36-38). According to Urie Bronfenbrenner, the renowned American developmental psychologist, biological and genetic factors are key to human development; however, the entire ecological system where human development occurs needs to be acknowledged (47,48). The interplay between the genetic/biological factors and factors within the social-ecological systems is essential to well-being and development. Bronfenbrenner described different social-ecological factors in four systems that directly and indirectly affect development and wellbeing. These include (i) micro-system, which relates to human physical and social environments; (ii) meso-system, which explains external environments; (iii) exo-system or the external factors that affect development and wellbeing, such as social, political, and economic conditions; and (iv) macro-system, which relates to beliefs and attitudes of the general population, which then also have an influence on the factors described within the micro, meso, and exo-system, as well as to the overall development and wellbeing of individuals (48).

In general, five hierarchical levels of SEM have been recommended and used in social science, psychology, and health science. These levels include (i) Individual, (ii) interpersonal, (iii) community, (iv) organizational, and (v) policy/enabling environments (41). In particular, for protecting and promoting healthy ageing in the context of Nepal, depending on the nature of the study and programs, we propose a recommended model (Figure 1). The proposed model provides a basis for considering health at the individual, family, community, or larger societal levels, highlighting its importance. However, there is a need to develop an effective approach to the health and social well-being of the older population by a combination of all interventions at all levels. In the context of Nepal, the SEM can be considered as an integral part of the overall health and well-being of the older population, which has interdependence and

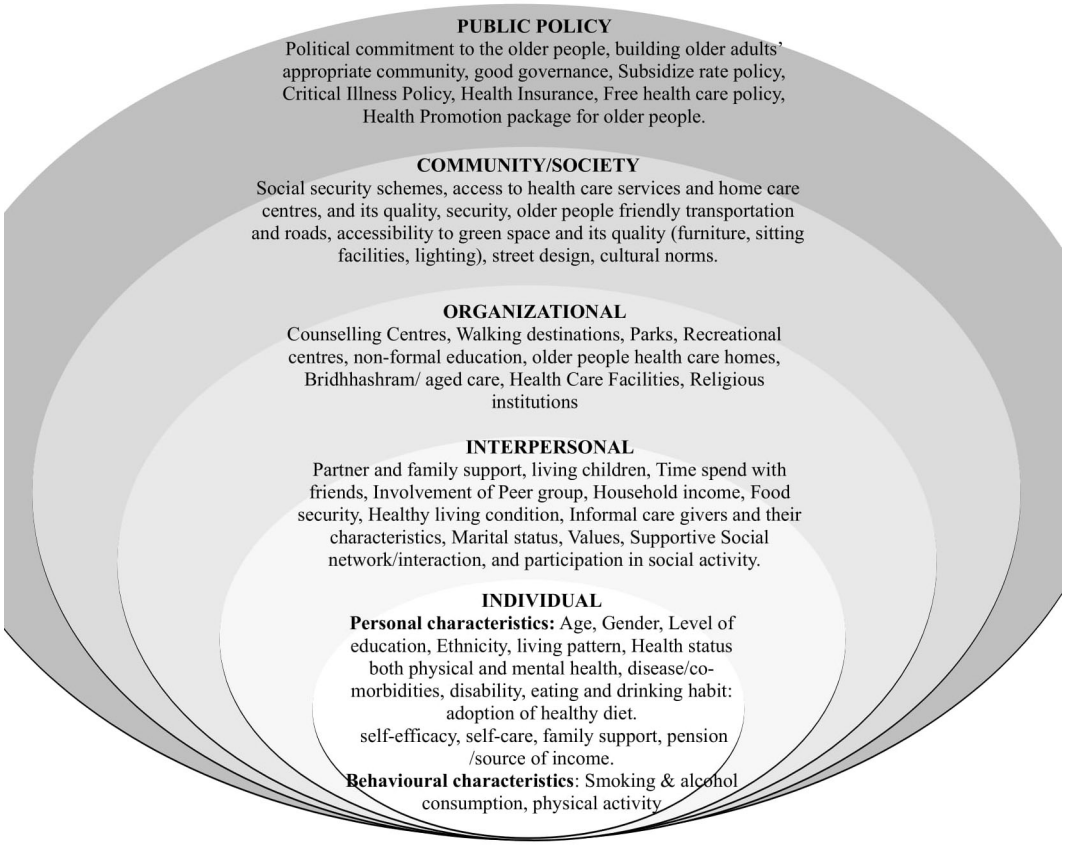

Figure 1. Proposed social ecological model of healthy ageing in low socioeconomic context

reciprocal relationship among elements of each level. The basic components of SEM and the ones proposed in the context of Nepal are best used to improve the health and well-being of ageing populations in many LMICs including Nepal. The major elements of proposed SEM that could particularly be carefully considered in the context of Nepal include:

Individual level: Provision of improving general and health literacy of older populations; adoption of healthy behaviour including diet, physical activity, and no smoking/alcohol; empower older population for self-confidence, self-care and enhance self-efficacy; provision of social security such as subsidized/free health care, subsidized transportation cost, etc.

Interpersonal level: Ensure family support and provision of physical, mental, emotional, and social supports; spending time with friends and involvement of peers; food security and healthy living conditions; provision of informal care when needed; supportive social network/interaction, and participation in the social activities.

Organizational level: Provision of parks and recreational centers for older populations; older people friendly walking paths; provision of non-formal education to older people; provision of counseling when needed; introducing and strengthening old age homes and older people health care homes; access to and availability of cultural and religious activities for older populations.

Community/society level: Provision of social security schemes; ensure access to health care services; home care centers and their quality; ensure social security; provision of older people friendly transportation and roads; accessibility to green space and its quality (furniture, sitting facilities, lighting).

Public policy level: Ensure political commitment to older people to build a community appropriate for older adults; ensure good governance and introduce a policy to subsidize care and services for older people. Policy for critical illness; Introduce a health insurance policy to ensure free health care and a health promotion package for older people.

Conclusion

Nepal's rapidly increasing population face significant challenges including limited healthcare access, inadequate social security, age-unfriendly infrastructure, and deep-rooted ageism. Addressing these issues requires urgent, multi-faceted interventions. Nepal must strengthen political commitment through policies that prioritize elderly well-being, such as expanding pensions and subsidized healthcare. Additionally, the health system should be reoriented toward long-term and home-based care, with dedicated services for older adults. Urban infrastructure must be adapted to be age-friendly, featuring safe walkways and recreational spaces, while intergenerational solidarity should be promoted to reduce social isolation. Combating ageism through awareness campaigns and education reforms is equally critical. To ensure sustainable progress, Nepal should implement the proposed SEM, which integrates interventions at individual, community, and policy levels. Collective action from government, civil society, and communities is essential to create an inclusive environment where older adults can age with dignity and good health. Moving forward, evidence-based and culturally sensitive strategies must be prioritized to meet the unique needs of Nepal's ageing population and foster a society that values and supports its elderly citizens.

Ethics

Ethics Committee Approval: Ethical approval was not applicable as this article is based on literature review and does not include human or animal studies.

Informed Consent: Informed consent was not applicable as this article is based on literature review and does not include human or animal studies.

Footnotes

Authorship Contributions

Concept: B.B.KC., G.P., L.O., K.R.P., L.B.R., Design: B.B.KC, G.P., L.O., K.R.P., L.B.R., Literature Search: B.B.KC., G.P., L.O., K.R.P., L.B.R., Writing: B.B.KC., G.P., L.O., K.R.P., L.B.R.

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