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ORIGINAL RESEARCH

Early Post-TAVI Physical Activity After Eccentric Training Compared to Standard Practice – Results of a Feasibility Study

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Background: Physical activity after transcatheter aortic valve implantation (TAVI) can improve cardiovascular outcomes and health-related quality of life. The aim of the study was to evaluate the functional status before and shortly after TAVI and to test the feasibility of an eccentric training program and its effect on functional mobility compared to standard care.

Methods: In this interventional controlled feasibility trial, elective TAVI patients without severe mobility limitations were enrolled. The center of pressure (CoP) measurements in standing position, the Timed Up & Go test (TUG) to assess functional mobility and the Chair-Rising test (CRT) for functional lower extremity muscle strength were assessed before and within five days after TAVI; the SF-12 test and the EuroQol–5 Dimension test was calculated. The intervention group performed daily 10-minute guided eccentric training starting earliest on day two after TAVI; controls received standard care (no structured or supervised exercise program).

Results: Of 357 screened patients, 99 met inclusion criteria; 45% declined to participate; 54 patients participated (median age 81 [78–83], 53.7% female). Orthopedic disorders were common (51.9%), as was chronic joint disease (18.5%). Before TAVI, most patients in both groups completed CoP testing. Fewer patients in the eccentric group required handrail support for the two-leg CoP test than controls (4.2% vs 31.0%, p=0.015). After TAVI, similar proportions in both groups completed the single-leg COP test (44% vs 51.7, p=0.389), all needing assistance. After day three, the intervention could be started in 72% of patients. None of those patients were able to complete all four exercises within 10 minutes No group differences were observed for TUG and CRT results (all p>0.15). The physical SF-12 score improved more in controls (+8.9 points [25.-75. percentiles −2.7–14.9], p=0.022) compared to patients receiving eccentric training (+1.6 [−4.9–9.5], p=0.463).

Conclusion: Elderly TAVI patients showed limited functional mobility pre- and early post-procedure. Initiating eccentric training within the first few postoperative days was feasible but associated with considerable barriers and might not provide short-term functional benefit compared with standard care. Early activity after TAVI remains challenging within fast-track recovery pathways.

Keywords: physical activity, TAVI, eccentric, mobility, feasibility

Introduction

Transcatheter aortic valve implantation (TAVI) has become the dominant therapy for calcific aortic stenosis (AS) with a prevalence of 5% of the population above 70 years of age.[1] During the last few years, procedural planning, TAVI systems, and clinician experience have further improved and indications for TAVI have been expanded.[2] Several studies have shown that TAVI improves patient-related outcomes including health-related quality of life, cognitive performance and functional status.[3–5] During the last decade, median length of stay after TAVI has decreased from six days to two days in the US and from ten to six days in Europe.[6,7] This development mostly relates to a higher proportion of patients

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with low and intermediate risk, the implementation of streamlined TAVI patient pathways and may also have - at least in part - monetary reasons. To date, most TAVI patients continue to be elderly individuals with multiple comorbidities and functional limitations.

Physical mobility is crucial, as it enables participation in everyday activities, maintenance of independence and continued participation in social life. Mobility seems to be a key factor in predicting short and long-term survival in patients undergoing TAVI.[8]

Results of recent systematic reviews and meta-analyses demonstrate that exercise-based cardiac rehabilitation after TAVI improves exercise tolerance, functional independence, and quality of life, with outcomes assessed using the 6-minute walk test (6-MWT) and the Barthel Index.[9–11] Cardiac rehabilitation program usually begins a few days to weeks after the TAVI procedure and includes a tailored training program of varying intensity, including continuous or intermittent endurance training with concentric activation, supplemented by muscle strength training.[12] However, concentric training can induce cardiovascular constraints, particularly an increase in heart rate in patients already weakened by their condition.[12] Structural adaptation of the musculature through eccentric activation is mainly used in sports and in physiotherapy for orthopedic complaints.[13–16] Eccentric muscle activation is characterized by a lower cardiovascular and metabolic demand compared to concentric activation.[17]

Recent studies highlight the importance of very early mobilization after TAVI. The JUMPSTART program, a self-directed, early home-based intervention, achieved high adoption and patient satisfaction without safety concerns.[18] Early inpatient rehabilitation may be particularly important for frail patients.[19] Initiating gait training on postoperative day zero to one has been associated with faster improvements in gait speed and grip strength, reductions in frailty, and shorter hospitalization compared with delayed mobilization.[20] Beyond TAVI, early mobilization is a key component of enhanced recovery pathways in cardiac surgery, as shown in a recent Swedish multicenter study reporting a median time to first out-of-bed mobilization of 7 hours and mobilization within 24 hours for 96% of patients.[21]

Taken together, these findings reflect a shift toward early functional activity training across cardiac interventions and highlight the need to evaluate feasible, structured early-mobilization strategies within current TAVI practice. The aim of this pilot interventional controlled trial was to evaluate the functional status of elderly patients undergoing TAVI before and after the procedure and to test the feasibility of an eccentric focused activation program early after TAVI and its effect on functional mobility compared to standard practice. We hypothesized that eccentric training starting early post-intervention would improve patients' everyday mobility at the time of hospital discharge and has a positive effect on health-related quality of life.

Methods

Study Design and Patients

This is a prospective, single-center, interventional controlled feasibility trial including patients with severe symptomatic aortic stenosis undergoing elective TAVI at a tertiary care center. Exclusion criteria were urgent or emergency TAVI, acute infections, illnesses for which physical activity is not indicated, or if the attending physician did not recommend participation in the study. Between August 2019 and February 2020, we enrolled patients in the standard care group and from March 2020 until August 2021 continued recruitment in the eccentric training group.

Demographics, clinical characteristics, comorbidities, procedural characteristics and echocardiographic findings were obtained from the electronic medical recording system by expert staff blinded to the aim of the analysis. Adverse events (eg delirium, dizziness and pain) were monitored during training. The study was approved by the local ethics committee of Brandenburg Medical School Theodor Fontane (E-01-20190531) and conducted according to the Declaration of Helsinki. Written informed consent was obtained from all participants. The study is registered with German Clinical Trials Register (DRKS00017734).

Study Endpoints

The primary exploratory study endpoint was physical performance (measured as proportion of patients performing the center of pressure (CoP) while standing test) at day two to five after TAVI. Secondary endpoints included health related quality of life assessed as SF-12 and the EuroQol–5 Dimension (EQ5D).

Intervention

Individualized and progressive training was performed, focusing on eccentric activation. The intervention consisted of a planned ten-minutes activation of large muscle groups of the trunk and lower extremity (four exercises with 2–3 sets of 10–15 repetitions each) starting earliest on day two post TAVI until the day of hospital discharge. The exercises included i) Torso rotation using a TheraBand attached to the bed frame (rotation of the upper body in a stable sitting position; free choice of sitting position; feet on the floor or not), ii) Pull-ups using a TheraBand attached to the bed frame (raising the arms (overhead) in a sitting position; elbows slightly bent iii) Side tilt while standing next to the bed (lower the upper body to the side; keep the spine stretched; one hand touches the thigh, the other can hold on to the bed frame if necessary) and iv) Torso extension (Sit on a chair next to the bed; push the upper body forward over the sheet and slowly move it back). After the exercises, it was recorded to what extent pain occurred during training. Pain was described using a 0 to 10 numeric pain rating scale.

Control

Patients in the control group received standard care, which consisted of routine postoperative management including encouragement to sit up in bed, mobilize as tolerated, and walk according to clinical judgement as soon as possible. No structured or supervised exercise program was provided. In addition, patients received a brief structured daily interview regarding their perceived health status.

Measurement Instruments

Performance test to measure functional mobility in the intervention and control group included the Center of pressure (CoP) measurement, the Timed Up & Go (TUG) test and the Chair Rise Test (CRT). All tests were performed pre-intervention and at day two to five according to the health-status of the patient.

Feasibility criteria included the proportion of patients who were able to perform the functional mobility tests and the feasibility of the intervention (progressive training) in terms of practicability of the exercise, duration, quality and repetitions performed.

Center of Pressure Measurement

The Center of pressure (CoP) measurement in the standing position was performed. Postural control was measured using a balance board, which is a technical advancement of a Nintendo Wii® balance board.[22] The duration of stance stability in the double-leg stance (>15 seconds) and the single-leg stance (>15 seconds) as well as the use of the handrail was recorded.

Timed Up & Go Test

The Timed Up & Go (TUG) test is a composite measure of functional mobility.[23] The test allows an assessment of muscle strength, joint function and balance. Patients were familiarized with the test procedure. Patients started from a seated position without pushing off with their arms, walked three meters, performed an 180 change of direction and returned to the original sitting position as quickly as possible. At the beginning of the test, the patients sat in the middle of the chair with their feet shoulder-width apart and slightly bent backwards from the knees on the floor to maintain their balance while standing. At the "Go" signal, the patient began the test; the time was recorded until the patient returned to the original sitting position. Before and after TAVI, patients were grouped according to the grade of mobility (unrestricted everyday mobility (<10 sec)/low mobility restriction (11–19 sec)/functionally relevant mobility impairment (20–29 sec) or pronounced mobility restriction (≥30 sec).[24,25]

Chair-Rise Test

The 5 times chair-rise test (CRT) was used to assess strength and the risk of falling.[26] Patients were asked to stand up from a chair at normal sitting height five times as quickly as possible with their arms crossed in front of their chest, without using their arms, and to sit down again. Values above 15 seconds are interpreted as an increased risk of falling. If this was not possible, the number of successful attempts was recorded instead of the time.[27]

Quality of Life Questionnaires

Changes (before TAVI and at the day of discharge after TAVI) in health-related quality of life (HQoL) was assessed using two generic Patient-Reported Outcome Measures (PROMs) - the visual analogue scale of EuroQol–5 Dimension (EQ5D) and the 12-Item Short Form Health Survey (SF-12) evaluating the physical and mental health status. The visual analogue scale of the EQ5D ranges from 100 (perfect health) to 0 (worst imaginable health). Both questionnaires were calculated before TAVI and on the day of discharge.

Statistics

Statistical analyses were performed using SPSS 29.0 software (IBM). Continuous variables were reported as median (interquartile range). Given the exploratory nature of this feasibility study and the limited sample size, p-values are reported descriptively and should not be interpreted as inferential evidence. P-values close to conventional significance thresholds reflect directional trends only and do not indicate statistically meaningful effects. Accordingly, interpretation focuses on feasibility, direction and magnitude of observed changes rather than formal hypothesis testing.

No formal sample size calculation was performed. Categorical variables were expressed as absolute numbers and/or percentages and calculated using the Chi-square test or Fishers Exact test, where appropriate. Risk estimates, including 95% confidence interval were calculated by comparing patients in the eccentric group with those in the control group. Mann–Whitney *U*-test, and the chi-square test were used when appropriate to test for differences between groups. Paired samples (eg before and after TAVI) were compared using Wilcoxon-test. Original data will be made available upon reasonable request.

Results

Study Population

A total of 357 patients scheduled for TAVI were screened. 99 patients met the inclusion criteria; of those, 45% declined to participate. The most common exclusion criterion was diseases that preclude physical activity. Patient flow is shown in Figure 1. Therefore, data from 54 patients (median age 81 [78–83], 53.7% female) was analyzed. The majority of patients presented with arterial hypertension (90.7%) and congestive heart disease (53.7%). Median LVEF was 56.5% (46.3–-60.0); NT-proBNP before TAVI was 1102 pg/mL (513–2458). Overall, 51.9% of the patients had orthopedic disorders and 18.5% presented with chronic joint disease. Most patients (83.6%, 44/54) were treated in an intermediate care unit until the second day after TAVI. The median length of hospital stay was 9 days (7–9.5).

Demographics, comorbidities and procedural characteristics were comparable between patients with eccentric training (n=25) and those receiving standard practice (n=29), Table 1.

Feasibility of the Intervention

On the second day after TAVI, initiation of the intervention was not feasible in any patient. Most patients remained in intermediate care at that time, and in other cases, additional medical conditions contraindicated mobilization. One patient developed postoperative delirium, and another had to be transferred acutely to the neurology department. After day three, the intervention could be started in 18 of 25 patients (72%). The planned exercises could be realized in those patients. None of the patients were able to complete all four exercises within 10 minutes. Although all patients were able to repeat the exercises as many times as required, quality of exercise was rated as low in 30% of patients, with several exercises not performed fully according to study protocol.

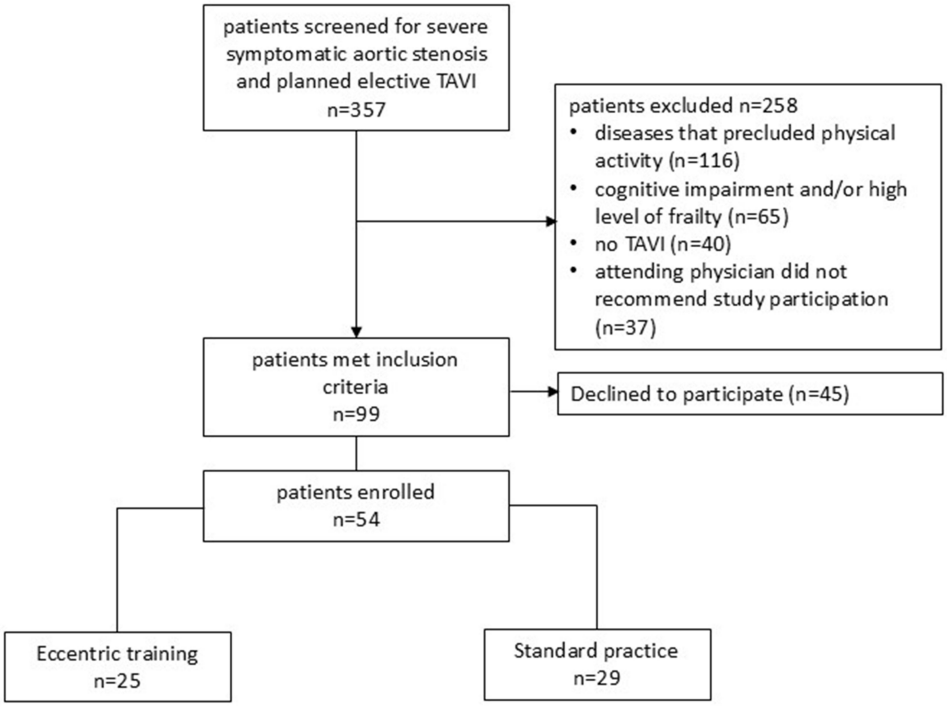

Figure 1 Patient flow through the study.

Performance Tests for Mobility Before TAVI

Before TAVI, most patients were able to perform the CoP test for longer than 15 sec with both legs and with a single-leg. Using both legs, fewer patients in the eccentric group required a handrail for support compared to control (1/24, 4.2% vs 9/29, 31.0%, p=0.015). Most patients in both groups required assistance for the single leg COP test (eccentric: 24/24, 100% vs standard: 27/28, 96.4%, p=0.350), Table 2. More patients in the eccentric training group were classified as unrestricted everyday mobility (36.0% vs 10.4%, p=0.031) compared to patients with standard practice, Table 3. Before TAVI, 16/24 (66.7%) of patients in the eccentric group and 19/29 (65.5%) in the standard practice group required more than 15 sec for the performance of the CRT, p=0.930. The duration of TUG test and CRT was comparable between patients with early eccentric training compared to those with standard practice, (all p>0.15), Table 2.

Table 1 Baseline Data, Procedural Characteristics and Outcome

	All Patients (N=54)	**Eccentric Training (N=25)**	**Standard Practice (N=29)**	**p-value**
Demographics				
Age, years	81 (78–83)	81 (76.5–82.5)	81 (79–83)	0.448
Female Gender (%)	29 (53.7%)	14 (56.0%)	15 (51.7%)	0.790
BMI, kg/m2	27.9 (24.4–32.1)	27.8 (23.2–31.0)	28.1 (25.4–32.6)	0.555
RR systolic, mmHg	139 (129–153)	140 (131–152)	137 (128–153)	0.432
RR diastolic, mmHg	75 (67–84)	76 (68–83)	75 (66–86)	0.661
HF, bpm	70 (64–80)	70 (64–82)	70 (65–75)	0.818

(*Continued*)

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Table 1 (Continued).

	All Patients (N=54)	Eccentric Training (N=25)	Standard Practice (N=29)	p-value
Health-related quality of life before TAVI				
SF-12 (physical sum scale), points	36.3 (30.4–45.0)	37.5 (31.2–50.5)	34.4 (27.5–44.2)	0.133
SF-12 (mental sum scale), points	57.3 (51.0–62.8)	57.9 (51.7–62.4)	56.4 (50.8–63.8)	0.788
EQ-5D - score	57.5 (50.0–70.0)	55.0 (50.0–77.5)	60.0 (50.0–70.0)	0.630
Comorbidities				
NYHA II/III (%)	46 (85.2%)	19 (76%)	27 (93.1%)	0.258
NT-proBNP, pg/mL	1102 (513–2458)	974 (396–2159)	1424 (643–2606)	0.228
LVEF (%)	56.5 (46.3–60.0)	55.0 (42.0–60.0)	60.0 (50.0–75.0)	0.556
Arterial hypertension (%)	49 (90.7%)	22 (88%)	27 (93.1%)	0.519
Congestive heart disease (%)	29 (53.7%)	14 (56%)	15 (51.7%)	0.753
Orthopedic disorders (%)	28 (51.9%)	14 (56%)	14 (48.3%)	0.571
Atrial fibrillation (%)	23 (42.6%)	10 (40%)	13 (44.8%)	0.721
Diabetes (%)	20 (37.0%)	7 (28%)	13 (44.8%)	0.202
Hypercholesterolemia (%)	18 (33.3%)	11 (44%)	7 (24.1%)	0.123
Chronic kidney disease (%)	13 (24.1%)	8 (32%)	5 (17.2%)	0.344
Oncology disorder (%)	13 (24.1%)	9 (36%)	4 (13.8%)	0.057
Chronic joint disease (%)	10 (18.5%)	3 (12%)	7 (24.1%)	0.309
Osteoporosis (%)	7 (13.0%)	2 (8%)	5 (17.2%)	0.431
Myocardial infarction (%)	7 (13.0%)	4 (16%)	3 (10.3%)	0.692
TIA (%)	7 (13.0%)	3 (12%)	4 (13.8%)	>0.99
Acute joint disease (%)	6 (11.1%)	4 (16%)	2 (6.9%)	0.399
COPD (%)	5 (9.3%)	0 (0%)	5 (17.2%)	0.054
Pulmonary hypertension (%)	3 (5.6%)	0 (0%)	3 (10.4%)	0.240
Procedural characteristics and outcome				
Intubation anesthesia (%)	47 (87.0%)	21 (84%)	27 (93.1%)	0.399
Valve Type (%) - Evolut R Sapien 3 Evolut Pro	26 (48.1%) 20 (37.0%) 8 (14.8%)	11 (44%) 10 (40%) 4 (16%)	15 (51.7%) 10 (34.5%) 4 (13.8%)	0.237
Valve size, mm	29 (26–29)	29 (26–29)	26 (26–29)	0.482
Procedural duration, min	135 (123–152)	137 (117–150)	134 (125–159)	0.445
LOS hospital, days	9 (7–9.5)	8 (7–9.8)	8 (7–9.5)	0.816

Table 2 Performance Test for Mobility Before TAVI in All Patients and Separated According to Eccentric Activity and Standard Practice

	All Patients (N=54)	**Eccentric Training (N=25)**	**Standard Practice (N=29)**	**p-value**	**Risk Estimate with 95% Confidence Interval**
Patients performing the "Center of pressure" (CoP) measurements >15 sec					
Both legs (%) **With assistance (%)**	53/54 (98.2%) **10/53 (18.9%)**	24/25 (96.0%) **1/24 (4.2%)**	29/29 (100%) **9/29 (31.0%)**	0.463 **0.015**	2.21 (1.64–3.00) 5.35 (0.82–35.06)
Single leg (%) With assistance (%)	52/54 (96.3%) 51/52 (98.1%)	24/25 (96.0%) 24/24 (100%)	28/29 (96.6%) 27/28 (96.4%)	>0.99 0.350	1.08 (0.26–4.47) 1.89 (1.46–2.45)
Timed up and go Test					
Timed up and go Test, sec	13.0 (11.0–16.3)	12.0 (9.5–16.5)	14.0 (12.0–16.5)	0.177	
Chair Rise Test					
Chair Rise Test, sec	17.0 (14.0–21.0)	17.5 (13.3–19.0)	17.0 (14.0–23.0)	0.609	

Note: bold text marks significant p-values.

Table 3 Proportion of Patients with Different Levels of Mobility Before and After TAVI Using the Timed up and Go Test - Separated by Eccentric Activity and Standard Practice

	Eccentric Training (N=25)	**Standard Practice (N=29)**	**p-value**	**Risk Estimate with 95% Confidence Interval**
TUG test before TAVI				
Unrestricted everyday mobility (≤10 sec)	**9/25 (36.0%)**	**3/29 (10.4%)**	**0.031**	0.51 (0.31–0.84)
Low mobility restriction (11–19 sec)	**12/25 (48.0%)**	**23/29 (79.2%)**	**0.016**	1.99 (1.15–3.46)
Functionally relevant mobility impairment (20–29 sec)	2/25 (8.0%)	3/29 (10.4%)	>0.99	1.17 (0.39–3.58)
Pronounced mobility restriction (≥30 sec)	2/25 (8.0%)	0/29 (0%)	0.209	0.44 (0.33–0.60)
	Eccentric training (N=22)	**Standard practice (N=18)**	**p-value**	**Risk estimate with 95% Confidence interval**
TUG test after TAVI				
Unrestricted everyday mobility (<10 sec)	4/22 (18.2%)	3/18 (16.7%)	>0.99	1.06 (0.42–2.70)
Low mobility restriction (11–19 sec)	13/22 (59.1%)	10/18 (55.6%)	0.821	1.08 (0.55–2.15)
Functionally relevant mobility impairment (20–29 sec)	4/22 (18.2%)	3/18 (16.7%)	>0.99	1.06 (0.42–2.70)
Pronounced mobility restriction (≥30 sec)	1/22 (4.6%)	2/18 (11.1%)	0.579	0.65 (0.27–1.57)

Note: bold bold text marks significant p-values.

Performance Test for Mobility After TAVI

After TAVI, the proportion of patients performing the CoP test using both legs (11/25, 44.0% vs 16/29, 55.2%, p=0.413) or using single leg (11/25, 44.0% vs 15/29, 51.7%, p=0.389) was comparable between the eccentric group and the standard practice group, Table 4. All patients in both groups performing the single-leg COP required assistance. After TAVI, the proportion of patients with different levels of mobility according to the TUG test was comparable, Table 3.

Table 4 Performance Test for Mobility After TAVI and Absolute Changes in Patients with Eccentric Activity and in Patients with Standard Practice

	Eccentric Training (N=25)	Standard Practice (N=29)	p-value	Risk Estimate with 95% Confidence Interval
Patients performing the "Center of pressure" (CoP) measurements >15 sec				
Both legs, (%) With assistance, (%)	11/25 (44%) 5/11 (45.5%)	16/29 (55.2%) 3/16 (18.8%)	0.413 0.206	1.27 (0.71–2.28) 0.51 (0.22–1.19)
Single leg, (%) With assistance, (%)	11/25 (44%) 11/11 (100%)	15/29 (51.7%) 15/15 (100%)	0.571 >0.99	1.18 (0.66–2.12)
Timed up and go Test				
Timed up and go Test, sec	16.0 (11.8–23.3)	14.0 (11.0–18.5)	0.307	
N (%)	18/25 (72.0%)	22/29 (75.9%)	0.499	
Chair Rise Test				
Chair Rise Test, sec	19.0 (12.5–26.5)	18.0 (11.8–22.8)	0.890	
N (%)	17/25 (68.0%)	22/29 (75.9%)	0.164	
Absolute Changes in performance tests				
Δ *Timed up and go Test*				
Timed up and go Test, sec	2.0 (−1.0–7.0)	−0.5 (−3.3–1.0)	0.459	
Wilcoxon p-value	0.064	0.259		
Δ*Chair Rise Test*				
Chair Rise Test, sec	2.0 (−5.0–8.0)	1.5 (−1.3–3.0)	0.319	
Wilcoxon p-value	0.313	0.203		

Also, the duration of TUG test and CRT did not differ between patients with eccentric training and those with standard practice, Table 4 and Figure 2. Individual values for patients with eccentric training and patients with standard practice, grouped for TUG and CRT before and after TAVI, are shown in Supplementary Figure.

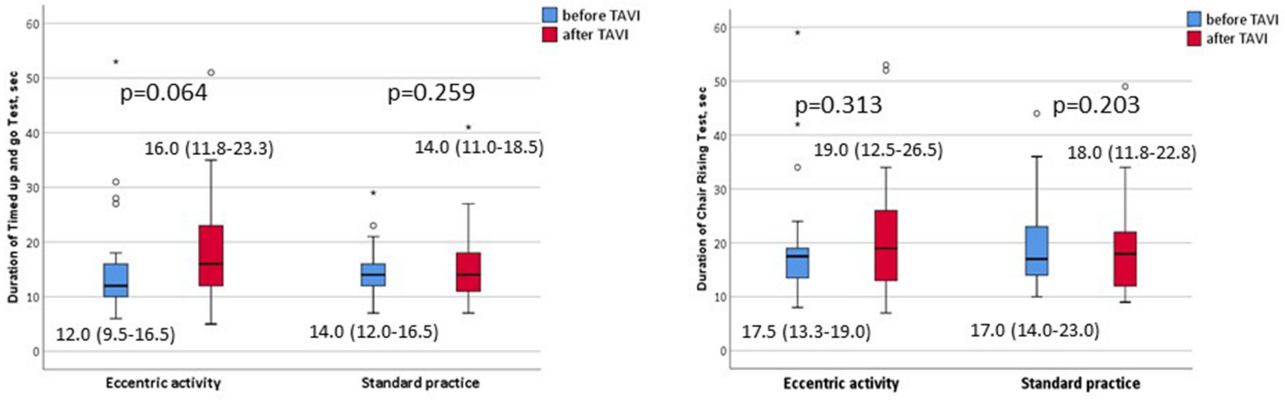

Figure 2 Duration of Timed up and Go test (left panel) and chair rise test (right panel) before (blue) and after (red) TAVI in patients with eccentric training and in those with standard practice.

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Health-Related Quality of Life Before and After TAVI

Health-related quality of life was impaired before TAVI in both groups, with lower values in the physical component of the SF-12 compared to the mental component, Table 1. Overall, patients reported improvement in physical QoL after TAVI compared to before TAVI, Table 5. This increase was mostly related to an improvement in patients receiving standard practice (+8.9 points in SF-12 physical component comparing before and after TAVI, p=0.022). Before and after TAVI, there were no group differences in health-related quality of life between patients with eccentric training compared to standard practice, Table 5.

Discussion

In this interventional controlled pilot trial, we evaluated the functional status of elderly patients and tested the feasibility of an early eccentric training program very early after TAVI and its effect on functional mobility. We studied a typical cohort of elderly, multimorbid patients undergoing TAVI, with a substantial proportion exhibiting musculoskeletal disorders or chronic joint diseases. Health-related quality of life was impaired before TAVI and tended to improve after the procedure in both groups. Most patients required support to perform the mobility tests; a proportion which remained high after TAVI. After day three after TAVI, the intervention could be initiated in two-thirds of patients, however, the quality and speed of performance was relatively low. Starting eccentric training within the same hospital stay showed no effect on all functional outcomes assessed. The duration of TUG test and CRT did not differ between patients with eccentric training and those with standard practice.

Older and frail patients with severe aortic stenosis planned for TAVI are mainly inactive as shown in our patient cohort. Only half of eligible patients participated in the present study with most of them being able to perform exercises slowly. This was largely attributable to comorbidities, including orthopedic diseases, and reflected a combination of frailty, postoperative discomfort, the perceived burden of daily exercise, and concerns about safety or unfamiliar interventions. Limited mobility or functional status can increase the risk of complications, longer hospital stays, or discharge to a care facility whereas good pre-procedure mobility suggests better cardiopulmonary reserve and recovery.[28,29] The observed low physical activity in patients before TAVI in our study is in line with other studies. In a prospective cohort study including data from 651 consecutive patients, Fawaz et al showed that poor mobility before TAVI predicted higher 1-year mortality and reduced symptomatic improvement after TAVI.[29] Data from more than 1,400 patients who underwent TAVI in the UK showed that the use of a higher level of assistance was associated with

Table 5 Health-Related Quality of Life After TAVI and Absolute Changes Overall and Separated for Patients with Eccentric Activity and Those with Standard Practice

Post TAVI	All Patients (N=54)	Eccentric Training (N=25)	Standard Practice (N=29)	p-value
SF-12 (physical sum scale), points	43.0 (30.1–51.8)	40.9 (29.3–52.6)	43.8 (31.1–51.4)	0.843
SF-12 (mental sum scale), points	57.9 (52.8–61.3)	57.9 (53.5–61.1)	58.6 (52.5–61.7)	0.895
EQ-5D - score	60.0 (50.0–75.0)	60.0 (50.0–75.0)	60.0 (50.0–75.0)	0.630
Absolute Changes in health-related quality of life				
Δ SF-12 (physical sum scale), points	2.8 (−3.1–13.4)	1.6 (−4.9–9.5)	8.9 (−2.7–14.9)	0.214
Wilcoxon p-value	0.017	0.463	0.022	
Δ SF-12 (mental sum scale), points	−0.99 (−5.8–5.9)	1.4 (−5.8–7.5)	−1.3 (−5.7–5.2)	0.895
Wilcoxon p-value	0.892	0.943	0.819	
Δ EQ-5D - score	5.0 (−12.5–20.0)	5.0 (−20.0–25.0)	5.0 (−10.0–18.8)	0.811
Wilcoxon p-value	0.379	0.736	0.320	

a threefold-increase mortality risk.[8] Approximately 30% of patients undergoing TAVI experience further deterioration in their physical functioning within 6 months of TAVI; however, a recent meta-analysis found no evidence for an association between preoperative strength and physical performance and functional deterioration after TAVI.[28]

We used individualized and progressive training, focusing mainly on eccentric activation starting earliest on day two after TAVI until the day of hospital discharge. The use of eccentric training has been limited by the occurrence of a reversible structural change and the associated muscle pain. However, a moderate and progressive training design – as used in our study - can minimize both structural damage and muscle pain and enable the use of eccentric training in rehabilitative exercise therapy.

Also, we employed various functional tests to assess different domains such as balance, muscle strength and joint function, as well as posture control. Concerning evaluation of effect size, about half of patients in both groups were able to perform the CoP test using both legs and single leg after TAVI. There was no group difference in CoP test between the eccentric group and the standard group. We used the COP test as a feasible and physiologically relevant primary measure for detecting early postural and functional responses.[22] Unlike broader functional tests, COP assessment captures small alterations in balance and stability that typically precede measurable changes in walking capacity. In contrast, commonly used clinical mobility tests such as the 6-minute walk test or gait speed are often impractical in the immediate post-TAVI period due to groin access discomfort.

There are data suggesting that the TUG test has limited predictive ability and should not be used in isolation to identify community-dwelling older people at increased risk of falls.[30] However, clinicians who assess elderly patients for risk of falling may take into account the multi-factorial nature of falls rather than relying on a single test of mobility.[30] Although most of these mobility tests have their limitations, when used in combination with each other, they provide a useful picture of the patients' functional reserves.

Our finding further suggests that, while early eccentric training is feasible, its implementation is constrained by multiple factors and may only be achievable in selected patients. Prior to TAVI, patients in the standard group more frequently required assistance to complete the COP test compared with the eccentric group. While baseline group imbalances in TUG mobility categories before TAVI did not clearly favor one study group, patients in the eccentric training group showed slightly better functional mobility in other baseline measures, raising the possibility of ceiling effects that may have limited detectable improvements.

However, the absence of measurable short-term functional benefits should also be interpreted in the context of some implementation-related constraints: Initiation of eccentric training was frequently delayed beyond postoperative day 3, the effective intervention period was short (typically 4–5 days), and full execution of all planned exercises was not achievable in all patients. Our findings therefore do not argue against the physiological efficacy of eccentric training per se, but rather highlight the challenges of delivering an adequate and timely training stimulus in the early post-TAVI inpatient setting.

The timing of post-TAVI rehabilitation remains an important consideration. While our findings suggest that eccentric exercise is feasible during the acute inpatient phase, its low cardiovascular load may also make it suitable for structured early outpatient rehabilitation, where patients are medically more stable and able to engage in higher-volume or more progressive training. Introducing eccentric exercise shortly after discharge could therefore balance safety with the opportunity for greater functional gains and should be investigated in future trials.

Suppan et al hypothesized that the decreased afterload induced by TAVI would improve physical performance by enhancing oxygen uptake in the working muscles. As intervention, a standardized exercise test on an ergometer was performed in thirty patients with severe aortic stenosis on the day before TAVI and 3 to 5 days after TAVI. Compared to before TAVI, patients achieved higher median workload after TAVI (316 Joules vs 190 Joules).[31]

Using self-reported questionnaire assessing the physical work capacity, Orvin et al evaluated 36 patients before and after TAVI and reported favorable results for functional performance and cognitive function early after TAVI.[3] An improvement in 6-MWT test 30 days after TAVI was shown in a small study including data from forty-four consecutive patients.[32] No intervention or training program was used in this study.[32]

In a randomized controlled trial including 116 patients after valve surgery, short- and mid-term effects of tailored resistance and balance training (3days/week) compared to usual cardiac rehabilitation on functional capacity,

cardiopulmonary exercise and physical performance were assessed.[33] The exercise program started forty days after the intervention. Exercise-based cardiac rehabilitation improved functional and exercise capacity, physical performance, and muscular strength.[33] Studies, including the "Moving is Improving!" study, have shown that activity prompts or structured mobilization protocols may increase patient engagement in in-hospital activities—such as transfers, walking, and use of cycle ergometers—even if global functional scores do not improve.[34] These findings highlight that early mobilization is feasible in patients undergoing surgical valve replacement, being typically younger than TAVI patients, and may positively influence day-to-day behaviors. A systematic review also suggests that initiating physical activity within 48 hours after cardiac surgery can improve function and reduce hospital stay, though differences in study protocols and the limited number of studies indicate that further research is needed.[35]

In the present study, health-related quality of life was impaired before and early after TAVI with lower values in the physical component of the SF-12 compared to the mental component.

A systematic review shows improved quality of life in studies reporting 12-months outcome after TAVI.[36]

From a clinical perspective, our findings suggest that very early eccentric training during the inpatient phase after TAVI may be feasible in a limited subset of patients, particularly those with relatively preserved baseline mobility, lower frailty, and fewer musculoskeletal limitations. In patients with pronounced frailty, orthopedic comorbidity, or post-operative complications, the feasibility and quality of structured eccentric exercise in the early postoperative period appear restricted. These observations indicate that eccentric training may not be appropriate as a uniform early intervention for all TAVI patients. Rather, eccentric exercise could be considered as part of a more individualized or staged rehabilitation approach, potentially initiated after discharge when patients are medically more stable and better able to engage in progressive training.

Strengths and Limitations

This study provides further insights into the feasibility of an early eccentric training in elderly, multimorbid patients after TAVI, using a combination of objective functional tests and patient-reported outcomes. Strengths include prospective, interventional design, standardized assessment of functional mobility, and careful reporting of adherence and safety. However, the study also has several limitations. A substantial proportion of eligible patients declined participation, and many were excluded due to conditions limiting physical activity. In addition, potential floor effects must be considered, particularly for the center of pressure (CoP) assessment, as a substantial proportion of patients were unable to perform the test early after TAVI, which may have limited the sensitivity to detect early functional changes. Simpler or more universally feasible measures—such as bedside sit-to-stand performance may better capture early postoperative mobility and should be explored in future studies.

Before randomization, baseline levels of physical activity, motivation, and mental status were not systematically assessed, which may have influenced participation and performance. These factors further reduce statistical power, limit generalizability, and introduce potential selection bias. Also, the short duration of intervention and the moderate intensity of the exercises likely constrained its potential effects. However, the patients appeared to be exhausted at the end of the training phase, so it was not possible to intensify the training. An important limitation of this study is the sequential, non-randomized design, with patients receiving standard care enrolled prior to those undergoing eccentric training. This design introduces the possibility of temporal confounding, including changes in clinical practice, care pathways, staffing, or peri-procedural management over time, which may have influenced feasibility and outcome measures independently of the intervention.

In this regard, future studies might combine clinically established mobility outcomes with sensitive balance measures to better capture early postoperative functional changes. Future studies should consider more targeted patient selection, stratify patients by baseline functional status, frailty or motivation levels and use longer or staged training programs to maximize adherence and potential benefit.

Conclusion

Early physical activity after TAVI is feasible in elderly, multimorbid patients, however practical limitations during the inpatient stay may constrain measurable functional improvements. Importantly, our findings should not be interpreted as

evidence against exercise or eccentric training in this population. Structured, longer-term, and individually tailored rehabilitation programs, potentially extending into outpatient or home-based settings, are likely necessary to achieve meaningful improvements in functional mobility and health-related quality of life. Future studies should carefully consider patient selection, baseline physical function, and motivation to optimize the benefits of post-TAVI exercise interventions.

Data Sharing Statement

Researchers with a legitimate scientific interest may contact the corresponding author to request limited access to additional deidentified data directly related to the study results. Such requests will be considered on a case-by-case basis, subject to institutional ethics approval and the completion of a data sharing agreement to ensure participant confidentiality.

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Disclosure

The authors report no conflicts of interest in this work.

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