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Assess the risk of falling after cardiac surgery

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Abstract

Introduction: Balance and coordination disorders are factors provoking falls in the elderly. Their fast and precise identification is therefore of vital importance.The aim of study was to assess the risk of falls and the influence of early hospital rehabilitation on the balance and coordination parameters in patients after cardiac surgery.

Material and methods: The study was conducted on 207 patients: 44 women and 163 men (mean age 60.2 ± 14.0), who participated in cardiac rehabilitation following cardiac surgery. The risk of falls was tested twice with the use of the FallSkip device: after the initial mobilization and before the discharge.

Results: After rehabilitation, improvement was noted in the whole group in all analysed functional parameters and in the reduction of the risk of falls ($p < 0.0001$). A significantly higher risk of falls was observed in women in comparison with men, in indywiduals aged >70 in comparison with patients aged <70 ($p < 0.001$). After rehabilitation the risk of falls decreased significantly in men ($p < 0.001$) and in individuals aged <70, ($p < 0.001$), as well as in patients with the body mass index <30 ($p < 0.012$). There was a tendency for better results in men in all tested parameters.

Conclusions: It was observed that even a short, limited mobility of the patient after surgery (approx. 48 hours), increases the risk of fall. Rehabilitation after cardiac surgery significantly improved the effectiveness of gait, time of reaction in response to audio stimuli, increased muscular strength of lower limbs and significantly reduced the risk of falls. The FallSkip equipment is useful in the assessment of the risk of falls in patients after cardiac surgery.

Keywords: falls, cardiac surgery, cardiac rehabilitation, balance disorders

Introduction

Balance and coordination disorders are factors provoking falls in the elderly; therefore, it is vital to identify them quickly and with precision [1,2]. Individuals over 65 years of age are at risk of at least one serious fall per year, which, at the population level, generates social problems, such as exclusion, immobilization, the increase in the cost of treatment, as well as health problems, including the deterioration in the quality of life, prolonged injuries and hospitalizations [3–5]. Cardiology departments admit an increasing number of elderly patients who can be at higher risk of balance disturbances due to administered drugs and immobilization, both after minimally invasive surgery and after cardiac operations [6,7]. In the early stages of hospital rehabilitation after cardiac

surgery balance and coordination exercises constitute one of the key elements of return to physical fitness and self-dependence of younger and older patients alike.

Balance parameters can be assessed with the use of subjective and objective methods. In scientific research it is vital to use objective methods that allow for a thorough analysis of a functional status of the equilibrium organ – systems for the 3-D analysis of movement, such as Vicon, dynamometric platforms, or the FallSkip equipment. The equipment for such tests is very expensive, so subjective methods are frequently used to assess balance parameters (quickness, easy measurement, low cost); however, their results may depend on the experience, skills and the involvement of a physiotherapist (Romberg's test, Tinetti test, Up&Go test, Berg Balance Scale) [8,9].

FallSkip is a biomechanical application based on a modified protocol of the Timed Up and Go Test. The instrument is a small, portable, cost-effective and user-friendly console with an Inertial Measurement Unit, which collects data from sensors and provides an objective analysis of the patient's biomechanical response. The main advantage of the device is that it is portable, which enables specialists to assess the risk of falls in patients staying in hospitals, nursing and long-term care homes, without the need to transport patients to perform the tests with the use of stability platforms operated by the specialists in hospitals. Using a portable device is a definitely more cost-effective, time-saving solution, even though its precision is slightly lower than that of platforms due to the fact that the device measures fewer parametres. There have been several reports concerning the use of FallSkip within the past four years in different patient groups.The first studies involved the patients suffering from sarcopenia, Alzheimer's disease and Parkinson's disease. There has not been any information concerning the use of this equipment in the assessment of cardiac patients yet [10–12].

We assumed that patients who received early rehabilitation after the cardiac surgery procedure will have decreased risk of fall after the I stage of rehabilitation comparing to the risk of fall before the rehabilitation. We have also explored the impact of age, gender, and weight on the risk of fall after the cardiac surgery.

The purpose of this work was to assess the functional performance and risk of falls, and the influence of the early hospital rehabilitation on balance and coordination parameters in patients after cardiac surgery and the assessment of factors influencing the balance after cardiac surgery.

Material and methods

In order to evaluate the impact of early rehabilitation on the risk of fall the single-center study was designed using the analytical observational manner. The research was conducted in the National Institute of Cardiology, Warsaw, Poland with the approval of the local Bioethical Commitee (No IK.NPIA.0021.25.1904/21).

Participants were adult patients after cardiac surgery consecutively admitted to cardiac surgery ward (coronary artery bypass graft, valve surgery, other surgeries – ventricular assist devices, congenital heart diseases), who underwent early post-operative hospital rehabilitation, self-dependent in mobility. All patients were operated by sternotomy and majority of them in the extracorporeal circulation (167 pts). Exclusion criteria for the research involved: being dependent on orthopaedical support (e.g. canes, crutches etc), inability to hold an upright position without support, frequently experienced dizziness or loss of balance, diagnosed polyneuropathy, neuromuscular diseases or cognitive impairment. The participants were divided into groups according to the gender, age (aged <70 years, >70 years), as well as the body mass index (BMI) values (<30 [kg/m^2], >30 [kg/m^2]).

All patients underwent comprehensive stage I cardiac rehabilitation, which involved breathing exercises using different maneuvers, breathing exercises with resistance, antithrombotic exercises, early postoperative mobilization, dynamic exercises of smaller and bigger muscle groups, marching training, general fitness exercises, climbing the stairs and postoperative education. The rehabilitation process consisted of everyday training sessions with the help and supervision of experienced physiotherapists. The level of patient compliance was high due to preoperative education and instructions from physiotherapists.

Balance exercises at the postoperative ward were conducted with the full assistance of a physiotherapist, in a seated position (trunk tilt in all directions) and in the standing stance (shifting body weight from one limb onto another) with the control of heamodynamic parameters. On the following days, in addition to routine exercises, more complicated motor tasks were introduced. Initially, with the assistance of the grab rail, then on their own, patients performed alternately standing on one leg, step forward, to the side, reverse lunge, and they got ready for climbing stairs. Patients also trained rotations and dynamic changes of the direction of movement. In clinical practice, also diagonal patterns of neuromuscular facilitation, building tonus and balance in targeted body parts.

Every patient was tested twice with the use of the Fall Skip equipment:

- Test 1 (2–3 days after the surgery), during the first upright standing training after the surgery;
- Test 2 (7–8 days after the surgery), before the discharge from the hospital.

Three physiotherapists working at the cardiac surgery ward were assigned to perform the test. The evaluated variables consisted of the risk of falls and its components (balance, reaction, gait, and the strength of lower limbs).

The FallSkip device method enables the assessment during the training and combines the speed of performance with mathematical description of the balance parameters. The device is small in size and it does not require a special laboratory to test patients. The precision of measurement is lower in comparison with e.g. a dynamometric platform, but definitely better than in subjective methods, such as clinical assessment made by the physiotherapist. Before the test, patients' data were entered (age, gender, height, body weight, incidence of falls in the previous year) and the device was mounted with the use of a lumbar belt (a strap with a hook and loop fastener). The test consisted of several elements: start after the auditory signal, walking 3 meters at a normal pace, turning round and sitting on a chair for 3 seconds, standing up without using hands and returning to the start position. The whole test lasted for about 2 minutes.

The assessment of the functional level was expressed as a percentage of the model for a healthy population, provided by the device's manufacturer (level: >90% very high, 85–90% high, 75–85% average, 60–75% below average, 50–60% low, <50% very low). Risk index depends on age and gender. Reference values had been entered by the manufacturer as part of the settings.

During the tests, the assessed parameters included the following: balance – position of the center of gravity in a standing phase (waiting for an auditory signal), reaction – time of reaction to an auditory prompt signaling when the patient was expected to start marching, gait – position of the center of gravity during the walking phase, Sit to Stand – the strength of lower limbs during sitting down on a chair and standing up and the total time – duration of the whole task.

The risk of falls was assessed for every component in the 6-grade scale as provided by producer: very low (0.00–15.90%), low (16.00–33.50%), mild (33.60–48.68%), moderate (48.70–66.95%), high (67.00–83.50%) and very high (>83.50%).

In order to avoid possible bias the standard procedure was used as well as the strict following of inclusion/exclusion criteria. The assessment bias was minimized thanks to using the FallSkip. To establish reliable results the study size was consisted of 207 participants.

Statistical analysis

Categorical variables were reported as counts and percentages and they were calculated within group comparisons (fall risks) using the Bowker's test. Due to the normal distribution of continuous variables, absolute results were presented as mean values ± SD and changes over time as a mean value with 95% confidence interval. Paired Student's t-test was used to compare the continuous variables before and after rehabilitation observed in the whole study group. Continuous variables were compared between groups (men vs. women, aged <70 years vs. aged >70 years, BMI<30 vs. BMI>30kg/m^2) using analysis of variance adjusted for baseline level of the variable (in order to reduce the selection bias). All hypotheses were two-tailed with a 0.05 type I error. All analyses were performed using the SAS statistical software version 9.4 (SAS Institute, Inc., Cary, NC, USA).

Results

The study group included 207 patients: 44 (21.2%) women and 163 (78.8%) men aged 18 to 87 (mean 60.2 ± 14.0 years). Participants had comorbidities, such as diabetes, aortal hypertension, ischaemic stroke, obstructive pulmonary disease and asthma (Tab. 1).

Tab. 1. Characteristics of a study group

Weight, kg	83.5 ± 15.4
BMI, kg/m^2	27.9 ± 4.4
Diabetes, n (%)	47 (22.9%)
Hypertension, n (%)	102 (49.8%)
Stroke, n (%)	12 (5.8%)
COPD, n (%)	5 (2.4%)
Asthma, n (%)	3 (1.5%)
CABG	70 (33.8%)
Valve surgery	88 (42.5%)
Other surgeries	49 (23.7%)

An improvement after rehabilitation was noted for all analyzed functional parameters in the whole group. The results during the initial assessment were at a below-average level (60–75%), whereas in the follow-up test they were at an average level (75–85%). The most remarkable improvement (16%) was observed in the total time of the test performance. The results of the initial and follow-up assessment and the change between evaluations is presented in Table 2.

According to the assessment, the risk of falls was reduced in the whole group ($p < 0.001$). The percentage of patients in the very low and low categories rose after rehabilitation by 20.6%, whereas the percentage of patients in the high and very high categories decreased by 11.5% (Tab. 3).

Tab. 2. Assessment of functional activities in a tested group (% adjusted for the baseline measurement in the healthy population)

	Test 1	Test 2	p
Balance (%)	75.1 ± 19.3	78.5 ± 17.5	0.016
Gait (%)	72.9 ± 17.3	84.4 ± 15.7	<0.0001
Reaction (%)	70.8 ± 17.9	81.0 ± 13.2	<0.0001
Sit2Stand (%)	68.6 ± 14.8	74.0 ± 16.8	<0.001
Total time (sec)	17.0 ± 4.7	14.1± 3.4	<0.001
Total time (%)	59.3 ± 24.7	75.3 ± 19.2	<0.001

Tab. 3. Risk of falls in a study group assessed with the use of the FallSkip

Risk of fall	Test 1 Number of participants (%)	Test 2 Number of participants (%)
Very low, n (%)	5 (2.4%)	13 (6.2%)
Low, n (%)	25 (12.0%)	60 (28.8%)
Mild, n (%)	57 (27.4%)	70 (33.6%)
Moderate, n (%)	76 (36.5%)	44 (21.1%)
High, n (%)	35 (16.8%)	19 (9.1%)
Very high, n (%)	10 (4.8%)	2 (1.0%)

Significantly higher risk of falls at the both stages of evaluation was observed in women in comparison with men ($p < 0.001$) and in individuals aged >70 in comparison with those <70 years of age ($p < 0.001$). Significant differences in the risk of falls in patients with the BMI <30 and >30 were not observed, either before or after rehabilitation. It was established that after rehabilitation the risk of falls diminished in men ($p < 0.001$) and in patients <70 years of age, ($p < 0.001$), as well as in patients with the BMI <30 ($p < 0.001$) and >30 ($p < 0.012$) (Tab. 4).

In all tested parameters, in addition to the analysis of the shift in the center of gravity in a standing position (balance), a better result was obtained in individuals below 70 years of age. Statistical significance was observed in the parameters: gait, reaction and total time. In all tested parameters, a tendency for better results was observed in men, whereas statistical significance was observed in the results concerning the shifting of the center of gravity during the walking phase (gait), and the strength of lower limbs (Sit to Stand). A more significant improvement was observed in individuals with the BMI value >30 [kg/m^2] with reference to the position of the center of gravity in a standing posture (balance) (Tab. 5).

Tab. 4. Comparison of the risk of fall in tested groups

Risk of fall	Test 1 vs. 2 females	Test 1 vs. 2 males	Test 1 vs. 2 age < 70	Test 1 vs. 2 age > 70	Test 1 vs. 2 BMI < 30	Test 1 vs. 2 BMI > 30
Very low (%)	0 vs. 4.6	3.1 vs. 6.7	2.5 vs. 7.4	2.1 vs. 2.1	2.1 vs. 6.2	3.2 vs. 6.4
Low (%)	6.8 vs. 11.4	13.4 vs. 33.5	15.5 vs. 34.8	0 vs. 8.5	11.7 vs. 29.7	12.9 vs. 27.4
Mild (%)	18.2 vs. 29.5	29.9 vs. 34.8	31.7 vs. 35.4	12.8 vs. 27.7	27.6 vs. 28.3	25.8 vs. 45.2
Moderate (%)	29.5 vs. 29.5	38.4 vs. 18.9	33.5 vs. 18.6	46.8 vs. 29.8	37.9 vs. 24.1	33.9 vs. 14.5
High (%)	40.9 vs. 22.7	10.4 vs. 5.5	14.3 vs. 16.7	25.5 vs. 27.7	15.9 vs. 10.3	19.4 vs. 6.4
Very high (%)	4.5 vs. 2.3	4.9 vs. 0.6	2.5 vs. 0.0	12.8 vs. 4.2	4.8 vs. 1.4	4.8 vs. 0
p	$p < 0.001$		$p < 0.001$		ns	

Tab. 5. Changes in the tested parameters over time adjusted for the baseline measurement [95% CI]

	Female N = 44	Male N = 164	Male–Female	p
Balance	0.10 [–4.7; 4.9]	4.3 [1.8; 6.7]	4.2 [–1.2 ; 9.5]	0.127
Gait	6.2 [2.5; 9.9]	13.0 [11.1; 14.9]	6.8 [2.6 ; 11.0]	0.002*
Reaction	7.9 [4.5; 11.3]	10.9 [9.1; 12.6]	3.0 [–0.9; 6.8]	0.134
Sit2Stand	0.3 [–4.3; 4.8]	6.8 [4.4; 9.1]	6.5 [1.4 ; 11.6]	0.013*
Total time	15.6 [11.0 ; 20.2]	16.2 [13.8; 18.6]	0.6 [–4.6 ; 5.8]	0.821
	Age < 70 years, n = 161	Age > 70 years, n = 47	>70 years – <70 years	
Balance	3.0 [0.5; 5.6]	4.6 [-0.1;9.3]	1.5 [–3.9 ; 7.0]	0.573
Gait	13.5 [11.7; 15.4]	4.7 [1.2; 8.1]	–8.8 [–12.8; –4.9]	<0.001*
Reaction	12.1 [10.4; 13.8]	3.9 [0.7;7.0]	–8.2 [–11.9; –4.6]	<0.001*
Sit2Stand	5.5 [3.1; 7.9]	4.9 [0.5;9.4]	–0.6 [–5.6; 4.5]	0.824
Total time	19.0 [16.7; 21.2]	6.0 [1.9 ; 10.2]	–13.0 [–17.7; –8.2]	<0.001*
	BMI < 30, n = 145	BMI > 30, n = 62	BMI > 30 – BMI < 30	
Balance	1.9 [–0.7; 4.5]	6.9 [2.9; 10.9]	5.0 [0.2; 9.8]	0.042*
Gait	10.8 [8.7; 12.9]	13.0 [9.9; 16.2]	2.2 [–1.6; 6.0]	0.251
Reaction	9.5 [7.6; 11.4]	12.1 [9.2; 15.0]	2.6 [–0.9; –6.0]	0.140
Sit2Stand	6.4 [3.9; 8.9]	3.4 [–0.5; 7.3]	–3.0 [–7.7; 1.7]	0.210
Total time	15.3 [12.7; 17.8]	17.9 [14.0; 21.7]	2.6 [–2.0; 7.2]	0.270

* statistically significant

Discussion

The ageing of societies means that in the following years the problem of falls will consider an increasingly larger number of people [1]. Therefore, it is crucial to develop and improve diagnostic and training methods that help to minimize the risk of falls. In Poland, social programs to activate senior citizens are being introduced, but the awareness of their availability, and their implementation are still inadequate.

In this study we analyzed changes in the risk of falls and functional parameters in the early post-cardiac surgery period. In the initial assessment the functional performance was at the below-average level. The analyses suggest that the higher risk of falls was related to older age and female gender. We have observed significant improvement in the risk of falls after the Stage I rehabilitation in the cardiac surgery patients, with the observed decrease in the risk of falls in men and younger patients (<70 years).

According to Hartholt et al. [3], falls are not solely a health problem related to the motor system injuries, but also a social problem that is reflected in the petient's quality of life and mental health. In the group of high risk there are elderly patients hospitalised for various reasons, also cardiological ones. Cardiovascular diseases manifest themselves with dyspnea, easier fatigue and chest pains. It significantly contributes to limiting physical activity and decreasing tolerance of exertion and muscle strength, which, consequently leads to balance and coordination disturbances. Hospital treatment and concomitant immobilization significantly aggravate those symptoms [7].

Analysis of the results obtained after the initial mobilization in the study group showed profound limitations in tested parameters. It was established that the majority of patients (58.5%) were qualified as those with a higher risk of falls (from moderate to very high). It is confirmed by the tests which assessed the risk of fall incidence in patients within the first 48 hours of admission to hospital. A group of 556 patients, with the mean age 59 years, was analyzed according to the Morse Fall Scale, with reference to the muscle strength, auditory disturbances, visual problems, the reason for hospitalization, as well as gender and age. In that population, 44 individuals (8%) sustained a fall within the first 48 hours of their hospital stay [9]. In a different study, in patients after cardiac surgery a reduction of muscle mass (by about 25% after 10 days of hospitalization) was observed, which, in turn, leads to

deterioration in muscle strength, limited mobility and concomitant balance disorders [13].

Apart from immobilization, additional factors that may contribute to a higher risk of falls include a more restrictive hospital diet, pain and the fear to move. It should be noted that the consequences of the lack of movement are observed only after 24 hours of full immobilization. They include among others: decrease in VO_2max by 0.9% per day, decline in muscle mass and strength, and, in the long term, deterioration in the function of muscles that are not working. In a several week timeframe a reduction in the absorption of calcium is observed, which leads to problems with the skeletal system, manifesting themselves as a higher risk of fractures [14].

Jelinek et al. [15] proposed a 6-week training scheme, exercising three times a week, for patients after 60 years of age, who had undergone cardiac surgery, in order to maximally increase strength, resilience and balance. The program included exercises strengthening the muscles of lower limbs (tiptoe standing, knee extension, squats), as well as balance exercises, with the use of BOSU balls and sensomotoric cushions. Exercises were made increasingly difficult so that the patients had an opportunity to adapt to more demanding tasks. They started with leaning exercises and uneven distribution of weights on feet; then accessories were introduced, with a gradually increasing level of difficulty. A significant muscle contractibility, muscle strength of lower limbs and effort tolerance were achieved, which undoubtedly contributed to the reduction of the risk of falls.

The FallSkip device has been on the market for a short time yet, so its applicability in the functional evaluation and the risk of fall in patients after cardiac surgery is a novel and intensely researched method. In 2020, one of the first publications appeared with a description of FallSkip as a diagnostic tool in a functional assessment of patients. Serra-Añó et al. [16] tested 29 patients with the Parkinson's disease in the second or third phase, according to Hohen and Yahr, as well as 20 patients of a similar age without Parkinson's disease. Excluded were the individuals whose ability to move independently was rendered impossible due to neurological or orthopedic limitations. Study results revealed restrictions in the postural control (considerable shifts of the center of gravity, both in static and dynamic testing), as well as the prolonged time of performing return in those patients, proving that the FallSkip device is useful and effective in the fast and precise assessment of balance parameters and their improvement in time. Other studies also demonstrated the usefulness of the device for assessing the risk of falls in patients with sarcopenia and with Alzheimer disease [11,12].

The assessment with the use of the FallSkip device revealed significantly lower risk of falls in the whole group. Benefits of the proposed rehabilitation system were presented, as well as the usability of a new method of assessment of the patients after cardiac surgery, particularly prone to falls. It is the first work that presents the use of this method in patients after cardiac surgery.

It is necessary to present study limitations. The study was conducted in one center. It was not randomized. Subsequent eligible patients admitted to the cardiac surgery ward were included. In order to verify the results, obtained scores were corrected with reference to the baseline.

Conclusions

It was observed that even a short, limited mobility of the patient after surgery (approx. 48 hours), increases the risk of fall. The proposed comprehensive rehabilitation model after cardiac surgery appears to significantly improve the effectiveness of gait, reaction times to auditory stimuli, increase the strength of the muscles of lower limbs, and significantly reduced the risk of falls. The FallSkip device appeared to be useful for the assessment of risk of falls and the evaluation of functional parameters in patients after cardiac surgery.

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Conflict of Interest
The authors have no conflict of interest to declare.

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