ORIGINAL PAPERS

Adv Clin Exp Med 2016, **25**, 6, 1241–1371
DOI: 10.17219/acem/62239

ISSN 1899–5276

Bartosz R. Wnuk[1, A–F], Jacek Durmała[1, C, E], Krzysztof Ziaja[2, A, E, F], Przemysław Kotyla[3, C, E], Marek Woźniewski[4, A, C, E, F], Edward Błaszczak[5, C]

A Controlled Trial of the Efficacy of a Training Walking Program in Patients Recovering from Abdominal Aortic Aneurysm Surgery

[1] Department of Rehabilitation, School of Health Sciences in Katowice, Medical University of Silesia, Poland
[2] Department of General and Vascular Surgery, Medical Faculty in Katowice, Medical University of Silesia, Poland
3 Department of Internal Medicine and Rheumatology, Medical University of Silesia, Katowice, Poland
[4] Department of Physiotherapy, University School of Physical Education, Wrocław, Poland
[5] Chair and Department of Medical Biophysics, School of Medicine, Medical University of Silesia, Katowice, Poland

A – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article

Abstract

Background. Major surgical procedures as well as general anesthesia contribute to muscle weakness and posture instability and may result in increased postoperative complications and functional disorders resulting from an elective operation.
Objectives. We aim to state the significance of backward walking as a form of interval march training with patients after abdominal aortic aneurysm surgery.
Material and Methods. Sixty-five patients were randomly divided into three subgroups and three various models of physiotherapy were applied. The participants were males, aged 65–75 years, with stable cardiologic status, absence of neurological disorders, and non-symptomatic aneurysm – non-ruptured, no pain complaints and no motor system impairments. The control group had only routine physiotherapy, since therapeutic groups I and II also had walking exercises, forward in group II and backward in group I. Both experimental groups were applied interval training. The patient data analyzed was as follows: hospitalization period-days; 6-min walking test-distance (m), training heart rate (1/min), mean speed (km/h), MET; spirometry test-FVC(L), FEV1(L), FEV1/FVC and PEF(L/s).
Results. The hospital stay period in all groups did not vary significantly. Statistical analysis showed that patients with backward walking had a statistically significantly lower reduction of walking distance in the corridor test when compared to the control group ($p < 0.05$). After the operation, a significant reduction of mean speed in the control group was noted in comparison with both the forward and backward walking groups ($p < 0.05$). No significant differences were noted between the experimental groups in average walking speed as well as in heart rate in all observed groups.
Conclusions. Physical training applied to patients after major abdominal aortic aneurysm surgery influences sustaining the level of exercise tolerance to a small extent. Both backward and forward walking seem to be alternative methods when compared to classic post-surgery physiotherapy (**Adv Clin Exp Med 2016, 25, 6, 1241–1371**).

Key words: physiotherapy, abdominal aorta surgery, physical training, backward walking.

All around the world, an increasing occurrence of abdominal aortic aneurysm has been observed, partly due to the prolongation of human life span and partly due to the development of diagnostic methods. Elective surgery is the best management of the disease [1, 2]. Age, general health status, co-morbidity and the additional risk factors related to them contribute to a high risk of operative and postoperative complications. The main objective of the physiotherapy after abdominal surgery is to prevent and treat the postoperative complications and functional disorders resulting from the elective operation.

To sustain exercise tolerance, an endurance exercise, in the form of walking treatment which is adjusted to a patient's speed with heart rate monitoring, is being introduced before and after the operation [3–5]. The basic exercise in physical training after surgical procedures is walking, followed by climbing up and down stairs at the end of the hospital stay [3]. The training program may be executed in continuous or intermittent forms. Intermittent exercise forms are recommended for people with low or average exercise tolerance, with decreased muscular strength and endurance, with intermittent claudication or coexisting reduced respiratory capacity [6, 7].

Some authors have compared the physiological reaction of forward and backward walking exercise tests in studies on a treadmill. It has been noted that the values of maximal minute oxygen consumption (VO_{2max}), minute ventilation (V_E), heart rate (HR), respiration equivalent (RQ), and post-exertional concentration of blood lactate levels are statistically significantly higher during backward than forward walking. Authors of the studies conclude that this type of endurance exertion elicits positive cardiopulmonary reactions sufficient to achieve positive training results [8, 9, 23, 25]. On the basis of the literature review, backward walking is used in physiotherapy at orthopedics, neurology, geriatrics and sport medicine departments [8–13].

The general purpose of the present study was to evaluate physical training efficacy with the use of ventilation rate and 6-min corridor walking test results in patients after abdominal aortic aneurysm surgery with special emphasis on backward walking as a specific form of physical training for exercise tolerance.

Material and Methods

The 2-year study was conducted at the General and Vascular Surgery Department of the Medical University of Silesia at Clinical Hospital No. 7 of Silesian Medical University in Katowice – Ochojec. Prior to the study, the study protocol was approved by the Bioethics Committee of the School of Physical Education in Katowice. In the study period, 170 patients underwent abdominal aorta surgery. One hundred and seventy patients were operated on with the use of the classic surgical method under general anesthesia when an abdominal aneurysm was resected and vascular prosthesis was implanted.

The enrollment of patients with abdominal aortic aneurysm to the study was carried out on the basis of purposeful selection. Patients with abdominal aortic aneurysm were qualified to the study when fulfilling the following inclusion criteria: males, aged 65–75 years (Table 1), stable cardiological status, absence of neurological disorders, non-symptomatic aneurysm – non-ruptured, no pain complaints, no motor system impairment. We excluded patients with neurological disorders, unstable coronary heart disease, symptomatic aortic aneurysm, aortic dissection, having difficulty in locomotion, and not able to start physical training during the first or second day after surgery, patients with psychiatric diseases, lack of patient's compliance with the physiotherapist, and other medical contraindications. Finally, 65 patients fulfilled the inclusion criteria and were enrolled in the study.

Table 1. Demographic data of patients included in the study

Characteristic	Presurgery/Postsurgery		
	Exp 1 (n = 15)	Exp 2 (n = 16)	Con (n = 16)
Age (years), mean (SD)	68 (3)	70 (3)	69 (4)
Gender (m : f)	15 : 0	16 : 0	16 : 0
BMI (kg/m^2), mean (SD)	26.18 (3.46)	26.61 (2.54)	26.32 (3.49)

The randomization of the study was conducted by drawing envelopes containing a number of the appropriate group – single blind study. Patients with the number 1 were qualified for the experimental group with backward walking training (group I), with number 2 for the experimental group with forward walking training (group II) and 3 for the control group.

Seventeen people were excluded from the study during the postoperative period due to cardiac complications or disorders preventing their participation in march training and physical exercise. Patients enrolled in the study were classified as having New York Heart Association (NYHA) Functional Classification class I or II.

Co-morbidity in patients with abdominal aortic aneurysm in the three study groups was similar. In the control group, three patients had a history of myocardial infarction, while in experimental group 1 there was one patient and in experimental group 2, two patients.

The study performed on healthy people confirms the increase of heart rate, minute pulmonary ventilation and maximal minute oxygen consumption during backward walking. The intention of using backward walking training in patients with abdominal aortic aneurysm was to establish whether this specific form of physical activity is sufficient for maintaining the level of exertional tolerance after surgery.

Table 2. Six minute walking test scores in patients with forward, backward walking and controls

Outcome	Groups						p* – ANOVA rank Kruskal-Wallis Test		p – Tukey's *post hoc* test		
	presurgery			postsurgery			(con-exp 1)		postsurgery		
	exp 1 n = 15	exp 2 n = 16	con n = 16	exp 1 n = 15	exp 2 n = 16	con n = 16	presurgery	postsurgery	(con-exp 2)	(con-exp 1)	(exp 2-exp 1)
6-min walking test [m] (SD)	362.33 (41.68)	338.25 (70.75)	324.21 (63.99)	322.4 (64.65)	304.25 (72.97)	258.05 (60.36)	0.23	0.027*	0.13	0.029*	0.73
HR training heart rate [bpm] (SD) Mean speed [km/h] (SD)	74.74 (8.2) 3.64 (0.42)	76.59 (6.12) 3.47 (0.6)	78.16 (6.06) 3.41 (0.49)	81.5 (9.1) 3.42 (0.41)	81.61 (8.34) 3.15 (0.57)	78.39 (4.35) 2.7 (0.54)	0.4 0.41	0.073 0.0025*	0.94 0.047*	0.42 0.0012*	0.61 0.31
Standard metabolic equivalent [MET] (SD)	2.74 (0.19)	2.59 (0.35)	2.54 (0.3)	2.51 (0.29)	2.42 (0.35)	2.2 (0.34)	0.11	0.038*	0.14	0.031*	0.74
FVC [L] (SD)	2.2 (0.38)	2.34 (0.45)	2.1 (0.66)	1.83 (0.5)	1.97 (0.41)	1.58 (0.64)	0.35	0.092	0.098	0.39	0.75
FEV1 [L] (SD)	1.95 (0.47)	1.86 (0.82)	1.9 (0.69)	1.73 (0.51)	1.72 (0.74)	1.46 (0.61)	0.95	0.39	0.48	0.49	1
FEV1/FVC [ratio] (SD)	92.05 (8.91)	96.99 (4.05)	93.91 (8.41)	93.99 (7.28)	95.79 (7.59)	95.27 (7.77)	0.15	0.81	0.98	0.89	0.79
PEF [L/s] (SD)	4.7 (1.54)	5.33 (1.78)	4.25 (1.22)	4.41 (1.35)	4.74 (1.56)	3.9 (1.5)	0.3	0.2	0.25	0.61	0.81
Length of stay [days] (SD)				5.87 (0.83)	6.5 (0.63)	6.56 (0.73)		0.057	0.97	0.053	0.057

* NS presurgery (con-exp 2), (con-exp 1), (exp 2-exp 1) – Tukey's *post hoc* test; * statistically significant.

A basic physiotherapy program was provided to all three groups. It consisted of education, including a range of exercises performed after the surgery, respiration, circulatory (antithrombotic) and active exercises of the upper and lower extremities in a recumbent position, and education on the proper motion patterns of sitting and getting up with postoperative wound stabilization. During that period, general conditioning exercises of low intensity were applied.

After the surgery, patients in all groups performed the "skilled" exercises mentioned above, which were conducted under heart-rate and blood pressure monitoring. The exercise programs before the surgery were conducted three times daily. After surgery, the patients were supplied with an abdominal belt to stabilize the postoperative site. During the first three days after surgery, the physical exercises were performed every 2 h. During the rest of the days, the exercises were conducted less frequently. For patient safety, the program was supervised by a cardiologist.

In the two experimental groups, the basic exercise program was extended to include forward walking in group 2 and backward walking in group 1. Forward walking training in both groups was conducted on an interval training cycle. The intensity of the training was calculated based on the results of an exercise stress test, a 6-min walk test, which made it possible to individualize the training workload. A training heart rate for each patient was calculated by adding 50% of the Heart Rate Reserve (Fig. 1) [14]. In patients in the control group, walking exercises of low intensity were performed. The physiotherapy program for all the groups as well as the interval training program for the experimental groups were conducted by physiotherapists working at the surgical department for at least 10 years.

Mean walking speed calculation [km/h] [17]:

$$\text{6-min test: } \frac{\text{number of meters} \times 10}{1000}$$

Energy expenditure calculation (MET units) [17]:

$$\frac{(\text{mean walking speed in km/h}) \times 1.667 + 3.5}{3{,}5}$$

Heart rate reserve = maximum heart rate – resting heart rate

Training heart rate = resting heart rate + + 40 – 80% of heart rate reserve [14]

Fig. 1. Formula for mean walking speed, MET units, training heart rate (HR)

The applied interval endurance training was indicated in patients with abdominal aortic aneurysm with regard to the type of disease and many existing co-morbidities, which decrease exercise tolerance. The frequency and exercise duration in the pre- and postoperative period were the same in experimental group 2 with forward walking training and in experimental group 1 with backward walking training.

In both experimental groups, the training was conducted in a hospital corridor, with constant heart-rate monitoring with the use of a CASIO CHR-100 pulse oximeter, and safety measures were applied to prevent the patients from falling. During the training, patients wore abdominal belts securing the postoperative site. Every day, before starting physical exercise, the current health status of every participating patient was consulted with a cardiologist, to exclude possible current contraindications to exercise. Workload increase during the training proceeded gradually. After every minute of exercise, a 1-min break followed, and the heart rate and its regularity were checked. The heart-rate limit (training heart rate), was established at the level of 120 beats per min.

The physical training was performed once a day during the first day after surgery, followed by twice a day on the second day and three times thereafter. The duration of each training session was prolonged systematically (Table 3). In the study, the method of classical experiment with the use of parallel groups technique and method of direct observation were used. The person performing the examination did not know to which group the patient belonged.

We tested the efficacy of forward walking applied in group 2 and backward walking in group 1. In all groups, an observation of the postoperative hospitalization period was conducted. The 6-min test in the corridor was conducted twice, the first time before the surgery and the second time on the seventh day after the surgery. In the case of patients whose hospital stay was shorter than 7 days, the test was performed before the operation and on the day of discharge from the hospital. The test was repeated 2o times each time. The outcome consisted of an average of the results from all tests conducted during the preoperative and postoperative period.

The Surgery Department corridor, where the test was performed, was 30 meters long and particular sections were marked in order to measure the distance precisely. Before the test, in every patient with abdominal aortic aneurysm, blood pressure and heart rate were registered. The test was performed in the presence of a cardiologist. The heart

Table 3. The program of gait training for Exp 1 and Exp 2 groups

Pre-surgical period	Post-surgical period
Frequency: 1st day – once per day 2nd day – twice per day 3rd day – 3 times per day next day before surgery– 3 times per day time of exercise: 1st day – 4 min: 1 min of exercise/1 min of break 2nd day – 5 min: 1 min of exercise/1 min of break 3rd day – 6 min: 1 min of exercise/1 min of break next day before surgery – 6 min of gait	Frequency: 1st day – once per day 2nd day – twice per day 3rd day – 3 times per day next day after surgery – 3 times per day time of exercise: total time of gait per day 1st day – 1 min (1 min): 1 min of exercise/1 min of break 2nd day – 2 min (4 min): 1 min of exercise/1 min of break 3rd day – 3 min (9 min): 1 min of exercise/1 min of break 4th day – 4 min (12 min): 1 min of exercise/1 min of break 5th day – 5 min (15 min): 1 min of exercise/1 min of break 6th day – 6 min (18 min), 7th day – 8 min (24 min), every day thereafter – 8 min

rate was calculated on the basis of the 6-min walking test results. Metabolic cost of mean walking speed were calculated and expressed in MET units according to the formula (Fig. 1) [15–17].

Spirometry, the respiratory system test, aimed at evaluating the general health status of patients prepared for an elective operation, was performed with an Aspel A4 AsCard recorder. Spirometry in the patients with abdominal aortic aneurysm was performed twice, the first time before the surgery and the second time on the seventh day after the surgery. In the case of patients whose hospital stay was shorter than 7 days, the test was performed before the operation and on the day of discharge from the hospital. The test was repeated three times each time. The outcome consisted of an average of the results from all tests conducted during the preoperative and the postoperative period. The test was performed in all study groups with different physiotherapy models applied and every time it was repeated three times. Studied variables included: forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow (PEF), and ratio of forced expiratory volume in one second to forced vital capacity (FEV1/FVC). The results are presented as mean and standard deviation.

Statistical analysis was done with the use of STATISTICA pack v. 12.0 (Dell Software Information Management Group). Normality of distribution was checked with the use of the Kolmogorow-Smirnow test. The ANOVA rank Kruskal-Wallis and Tukey's *post-hoc* tests were used to estimate the statistical significance of differences between the groups. For changes in time, the Wilcoxon rank-sum test was applied. Statistical significance was assumed at $p < 0.05$.

Results

The hospital stay period in all groups did not vary significantly and lasted on average 6 days. Distance in the corridor test reduced significantly when compared to the pre-surgery period in all groups. Statistical analysis showed that patients with backward walking had a statistically significantly lower reduction of walking distance in the corridor test when compared to the control group ($p < 0.05$). After the operation, a significant reduction of mean speed in the control group was noted in comparison to both the forward and backward walking groups ($p < 0.05$). No significant differences were noted between both experimental groups in average walking speed. Patients after abdominal aorta surgery were also characterized by a reduction of energy cost in the 6-min walking tests. A significant difference in energy cost was observed after the operation between the control group and the backward walking group. The reduction of energy cost was lower in the backward walking group. Heart rate calculated on the basis of the 6-min test was similar in all observed groups both before and after the operation. The analysis of the spirometry showed a similar lowering of all parameters, however with no significant differences between the groups (Table 2).

Discussion

Patients with aortic abdominal aneurysm require a special pre-surgery evaluation. This consists of a detailed cardiological evaluation, surgery assessment and dedicated physiotherapy. Exercise stress tests as well as a lung function test are important elements in the pre-surgery evaluation in

patients with AAA. A physiotherapy program that includes respiratory muscle exercises, antithrombotic modalities and general health exercises is an important factor that contributes significantly to the reduction of cardio-pulmonary complications after surgery [18, 19]. It is well known that antithrombotic modalities and lower limb exercises, performed after abdominal surgery, facilitate venous blood return and additionally are a substitute for abdominal muscle exercises. They facilitate restoration of bowel motility, which prevents bowel bloating and improves diaphragm contractility. Endurance exercises, applied in the form of walking that are repeated several times a day before and after surgery, reduce the risk of post-surgery complications and improve the process of post-surgery physiotherapy [6, 7]. Major vascular surgery procedures, especially those involving the abdominal aorta with the use of classic surgery approaches, have a significant influence upon lung function. After surgery, a reduction of lung ventilation parameters, heart rate disturbances, blood pressure and respiratory rate reduction have been observed. A comparative analysis of age, body mass index and coexisting diseases in patients with abdominal aortic aneurysm who underwent physiotherapy after surgery according to three different exercise models did not show statistically significant differences between the groups studied [1, 20–22]. The walking training, regardless its direction, had no significant influence on shortening the postoperative period, which may have been related to the invasive surgery. However, backward walking, despite the short period of physiotherapy, corresponded to a significantly lower decrease of the distance covered during the corridor test in comparison to the control group. Analyzing the mean values of walking speed and energy cost, we were not able to determine which form of training is better at maintaining the level of exercise tolerance with patients qualified to this kind of surgery. To the best of our knowledge, the present study is the first that has verified the effectiveness of backward walking training with the use of the corridor test. The papers on backward walking published so far were focused mainly on gait biomechanics and pattern of muscular activity. They were performed in walking laboratories or on treadmills [23, 24]. In the previous studies on backward walking, heart rate, oxygen consumption, 1-minute lung ventilation respiration and lactate levels were recorded [8, 25].

The main limitation of the study is the small population of patients participating in the trial, as the number of patients in each group did not exceed 30. The other limitation is the lack of long-term follow-up (longer than 28 days), since all patients were discharged from the hospital before day 28. A longer follow-up would facilitate measuring changes of the cardiopulmonary parameters more precisely and thereby to assess the functional status of the patients who used backward walking as their main physiotherapeutic procedure after aorta surgery.

Physical training applied to patients after major abdominal aortic aneurysm surgery influences maintaining the level of exercise tolerance to a small extent. Both backward and forward walking seem to be alternative methods when compared to classic post-surgery physiotherapy. The choice of the form of training should depend on the patients' clinical state as well as their preferences.

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Address for correspondence:

Bartosz Wnuk
Department of Rehabilitation
School of Health Sciences in Katowice
Medical University of Silesia
ul. Ziołowa 45/47
40-635 Katowice
Poland
Tel.: +48 501 860 486
E-mail: bwnuk@sum.edu.pl

Conflict of interest: None declared

Received: 28.07.2015
Revised: 17.11.2015
Accepted: 17.03.2016