The postoperative rehabilitation is indispensable and often key element in the process of recovery after a surgical procedure. It is natural for a patient to go through a rehabilitation cycle after orthopedic procedures to return to motor efficiency or to be taken care by physical therapists after pulmonary operations as part of respiratory rehabilitation. The concept of preoperative rehabilitation is completely different from the conventional, postoperative rehabilitation. However, the preoperative rehabilitation does not involve restoration of functionality of a system or organ that underwent surgical treatment. This one is more holistic and is not targeted to a specific procedure type. Preoperative rehabilitation should include exercises to improve general fitness, respiratory and cardiovascular exercises to prepare a patient to overcome stress related to the surgical procedure.

Such thinking limits utility of preoperative rehabilitation to extensive procedures that markedly impair body homeostasis and thus generating high operative stress.

Concurrently patients who appear to derive greatest benefits from preoperative rehabilitation include elderly subjects and subjects with cardiovascular, respiratory disorders, motor system disorders who are able to adhere to the prescribed exercise regimen.

The aim of the preoperative rehabilitation is to reduce postoperative cardiovascular and respiratory complications, to facilitate postoperative patient mobilization, to shorten duration of the hospitalization and speed up recovery and facilitate postoperative rehabilitation in the long term. The aim of this study was to assess the current knowledge of preoperative rehabilitation among surgical patients referred for abdominal procedures and to assess its effectiveness and effects on postoperative complications.

The following electronic databases were searched: PubMed, EMBASE, and The Cochrane Library using the following term combination: preoperative, rehabilitation, preconditioning, exercise, training, physical therapy, physiotherapy, surgery, abdominal, gastric, bowel. Subsequently a preselection of papers was done based on: paper title, abstract, full contents of a research paper. Full versions of papers on the subject matter were subjected to adequate selection.

Papers were included if they met the following criteria:
– the intervention involved rehabilitation with physical activity directed to improvement of respiratory efficiency, cardiovascular fitness and muscular strength and motor skills in the preoperative period;
– the endpoints included: occurrence and type of postoperative complications, duration of hospitalization and related improvement of general fitness.

Papers were excluded if:
– analysis of endpoints between the study groups was impossible,
– full text of the paper in English or Polish was unavailable.

Initially 19734 records were found in the electronic databases (EMBASE – 14826, PubMed – 4865, The Cochrane Library – 43). Abstract based verification limited the number of papers to 545 (EMBASE – 327, PubMed – 210, The Cochrane Library – 8). Elimination of repeated records in these databases resulted in reduction of papers to 116. After verification of full texts of these research papers, the final number of papers qualified to the analysis was 5. The main reason for exclusion of most of the analyzed papers was lack of association between prerehabilitation outcomes and therapeutic outcomes, assessment only of respiratory parameters or only theoretical description of potential possibilities without drawing any solid conclusions.

RESULTS
Characteristics of prehabilitation

Preoperative rehabilitation should be based on exercises to improve general fitness and facilitate function of two key systems for the patient functioning – respiratory and cardiovascular system.

Respiratory exercises are beneficial for patients; these benefits can manifest even as improvement of spirometric parameters: increase of vital capacity (VC) and maximum inspiratory pressure (MIP), provided that the exercises are adequately demanding. In a study that suggested such outcomes, the study group underwent an intervention involving respiratory exercises conducted with a special trainer for inspiratory muscles. This report lacks information on the effect of changes of spirometric parameters on postoperative complications and mortality, thus it leaves only one potential clue as how to assess patients after the preoperative exercise program and the procedure itself (1). Despite these shortcomings, conclusions from this paper indicate that the prehabilitation program should include respiratory exercises to improve oxygen saturation and respiratory flows.

Concurrently the rehabilitation program must also include cardiovascular exercises and exercises to improve general fitness level to mobilize, along with respiratory exercises, cardiovascular and respiratory reserves manifesting as improvement of such parameters as anaerobic threshold (AT), anaerobic pulse or ventilator efficiency. Benefits resulting from improved blood flow (2), better body weight control and, in particularly in the elderly patients, better mobility and independence, are of utmost importance, too.

Who can benefit from prehabilitation?

Previously published papers did not indicate groups of patients that could sustain adverse effects of preoperative rehabilitation. The biggest improvement of respiratory parameters at peak exercise after rehabilitation versus baseline was found in subjects with the lowest baseline physical activity (3). However, it is very important for the prehabilitation program to be adjusted to the patient profile: it should not be overly demanding, but should not be too simple either.
Methods of assessment of preoperative rehabilitation

Papers assessing spiroergometric parameters of the rehabilitated patients indicated low anaerobic threshold (AT < 11 ml kg⁻¹ min⁻¹) and elevated ventilator equivalent ratio for CO₂ (VE/VCO₂ > 34) correlated with reduced short- and moderate term mortality after major surgical procedures. Along with ischemic heart disease they were the clinically significant factors of overall hospital and 90-day mortality. AT was the strongest predictor, in particular in patients with cardiac risk factors. Patients with low AT were more commonly referred to intensive medical care units (IMCU) during the postoperative period. Furthermore, median duration of hospitalization was significantly longer in patients with AT <11 ml kg⁻¹ min⁻¹ versus those in whom AT was above 11 ml kg⁻¹ min⁻¹(4).

Another paper on this issue analyzed use of simpler methods to estimate the anaerobic threshold, confirming utility of DASI (Duke’s Activity Status Index) and ISWT (Incremental Shuttle Walk Test). These can be used to easily divide patients into two groups: low risk group (with AT above 11 ml kg⁻¹ min⁻¹ plus oxygen consumption, VO₂ peak, above 15 ml O₂ kg⁻¹ min⁻¹) and high risk group (AT<11 ml kg⁻¹ min⁻¹ and VO₂ peak <15 ml O₂ kg⁻¹ min⁻¹) by using a cut-off value of 37.45 points (5, 6) instead of converting VO₂ to AT (as 60% of total VO₂peak) as demonstrated by another paper (7).

In a paper that investigated utility of DASI and ISWT to estimate AT, authors found that both these tests are better predictors in low risk patients, emphasizing that some patients that were classified as high risk patients according to DASI or ISWT, successfully completed spiroergometric tests with good results (e.g. AT>11 ml kg⁻¹ min⁻¹). However, analysis of ROC curves demonstrated that both DASI and ISWT were sensitive and specific tests to estimate anaerobic threshold (p=0.003 and p=0.001, respectively) (5).

Concurrently another paper – involving upper abdominal procedures – ruled out the use of 6-minute walk test (6 MWT) as a tool to assess the risk of pulmonary complications in patients from this group (8). With regard to assessment of patients before the surgical procedure using spiroergometric testing (CPET), one must remember that some patients are unable to perform this test due to their general health or neurological issues, amputations, etc. However, some of these patients can still be able to perform simple and nondemanding exercises that could comprise a preoperative rehabilitation plan. This is especially important in view of emerging reports documenting lack of correlation between inability to perform CPET by the patient with poorer postoperative outcomes (9).

In such situation we can – using e.g. DASI form – estimate AT level in patients who are unable to perform CPET and thus identify patients with potentially poorer prognosis, while intervention involving the prehabilitation program will provide them with the opportunity to improve e.g. respiratory parameters, resulting in beneficial effect on their prognosis. Such information emerges as the basis to prognosis of positive effect of utilized preprocedural rehabilitation on the postoperative period as well as enables verification of improvement of parameters of fitness and reliable assessment of the risk of postoperative complications.

Effect of prehabilitation of parameters of fitness

A pilot study assessing preoperative rehabilitation in patients scheduled for intestinal resection procedures was published in 2009. It enrolled 19 patients (12 in the study group, 9 in the control group), with an average age of 55 years. The intervention involved preoperative aerobic exercises regimen at the level of 40-65% heart rate reserve (%HRR). Duration of the exercise program was 3.8 ± 1.2 weeks and this program comprised 27 ± 9 training sessions. The results demonstrated a significant increase of exercise tolerance at peak exercise without proportional increase of peak oxygen consumption (VO₂ max); according to authors, this indicated increased ATP production from glycolysis with concurrent increased tolerance of elevated hydrogen ion concentration. This was a potential mechanism of improved postoperative outcomes in these patients (3). However, this clearly indicated that preoperative rehabilitation could markedly affect hospitalization and patient condition after the operation. The authors concluded that
approximately 4 weeks of rehabilitation resulted in improved functional exercise reserve, which was essential in case of a surgical procedure, corresponding to another exercise that required mobilization of body reserves (3). However, this report also does not provide information on detailed course of postoperative period, neither it provides postoperative morbidity and mortality.

In 2011 a paper was published that analyzed reports on preoperative rehabilitation and its effects on the postoperative period (10). Unfortunately, only one of analyzed sources included abdominal procedures (and these were only cases of abdominal aorta aneurysms) (11). This analysis was also based on results of cardiac [coronary artery bypass grafting (CABG)] and orthopedic (total hip or knee joint replacement) procedures. Preoperative rehabilitation was found not to exert positive effect on development of complications or duration of hospitalization in joint replacement procedures, while it reduced pulmonary postoperative complications in cardiac and abdominal procedures, and reduced duration of hospitalization after CABG procedure in patients subjected to preprocedural rehabilitation (10). Assessment of reduction of hospitalization duration in abdominal aorta aneurysms was impossible since such observation was not reported in this paper.

Patients referred for lung resection underwent preoperative rehabilitation involving a cycloergometer in five training sessions during the first week, four sessions during the second and third and three sessions during the fourth week, under the guidance of a physical therapist who adjusted the exercise intensity to fitness of each patient; such intervention resulted in statistically significantly increased VO₂ peak after 4 weeks and, which seems even more important for the patient fitness, a statistically significant increase of metabolic equivalents (METS).

While this study was not designed to compare postoperative complications between the groups, the authors emphasized that incidence of surgical complications was inversely proportional to exercise capacity (that depends, among others, on the determined parameters VO₂ peak and METS) (12). This report was based on analysis of 20 patients among whom 13 subjects were included in the final analysis. This study also did not evaluate directly postoperative complications and mortality and did not compare the postoperative outcomes between the two groups.

In a study published in 2008 concerning correlation of preoperative respiratory training with occurrence of pulmonary complications in patients after abdominal procedures, the authors found a positive effect of prehabilitation on reduction of risk of such complications. However, this study enrolled only patients who underwent surgical treatment of abdominal aorta aneurysm. Furthermore, the study sample was small, 20 patients. However this study demonstrated a statistically significant reduction of the number of cases of atelectasis in patients from the intervention group; the intervention involved a program of respiratory exercises, 6 sessions per week, for at least two weeks before the procedure, 15 minutes each session. The improvement was achieved despite the fact that age of patients in the intervention group was significantly higher than in the control group (11). This study utilized a special device for training inspiratory muscles. Concurrently no patient was excluded from the study due to inability to perform exercises; no adverse effects of the preoperative training were found. However, differences in the mean age (70 and 59 years in the intervention and control groups, respectively) and interindividual differences in baseline MIP must be emphasized, and in particular final outcome of the intervention, number of pulmonary complications (11).

Table 1 presents results of published papers that evaluated effects of preoperative rehabilitation on parameters of fitness and/or postoperative outcomes in patients.

### Duration of preoperative rehabilitation

As studies by institutes of physiology and biochemistry demonstrate, exercises done by untrained subjects, with minimum or none athletic activity, do not provide benefits if they are shorter than one week with association with increased muscle work, change of muscle metabolism to anaerobic pathway and overproduction of lactic acid. However, this effect becomes gradually overcome after one or two weeks of training, depending on the type of activity and its frequency, because the body starts to switch its metabolism to increase...
Prerehabilitation and postoperative complications of elderly patients after abdominal operations

Table 1. Summary of publications that evaluated effects of preoperative rehabilitation on parameters of fitness or postoperative outcomes in patient

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size intervention (I)/ control (C)</th>
<th>Grupa</th>
<th>The study characteristics</th>
<th>Intervention</th>
<th>Effect</th>
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</thead>
<tbody>
<tr>
<td>Jones, 2007</td>
<td>20 (20/-)</td>
<td>Patients scheduled for lung resection due to malignant disease</td>
<td>Training sessions on a cycloergometer, average 4 sessions/week for 4 weeks</td>
<td>Improved fitness: (before vs after prehabilitation) - VO₂ peak (+2.4 ml O₂ kg⁻¹min⁻¹) (p=0.002)</td>
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<tr>
<td>Dronkers, 2008</td>
<td>20 (10/10)</td>
<td>Patients scheduled for surgical treatment of abdominal aorta aneurysm</td>
<td>Respiratory exercises utilizing a trainer 6x15 min/week for at least 2 weeks</td>
<td>Complications: Atelectasis 3 (I) vs 8 (C) (p=0.07)</td>
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<tr>
<td>Du Jun Kim, 2009</td>
<td>21 (14/7)</td>
<td>Patients scheduled for large intestine resection</td>
<td>A set of aerobic exercises at the level of 40-65% HRR once a week for approximately 4 weeks</td>
<td>Improved fitness: (submax. exercise) - oxygen consumption (-13%) - heart rate (-7%) - ventilation/min (-9%) (p&lt;0.05)</td>
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<tr>
<td>Kulkarni, 2010</td>
<td>80(20+20+20/20)</td>
<td>Patients scheduled for abdominal surgical procedures</td>
<td>gr. B – respiratory exercises gr. C - spirometer for respiratory exercises gr. D – trainer of inspiratory muscles (gr. A – control)</td>
<td>Improved fitness: (only for group D) - maximum inspiratory pressure (+17 cm H₂O) (p=0.01)</td>
<td></td>
</tr>
<tr>
<td>Valkenet, 2011</td>
<td>406 (205/201)</td>
<td>Patients scheduled for cardiac surgical procedures or surgical treatment of abdominal aorta aneurysms</td>
<td>Training of inspiratory muscles beginning at 30% max. inspiratory pressure 6-7x20 min/week for at least 2 weeks</td>
<td>Complications: Atelectasis/pneumonia 14 (I) vs 34 (C) (p=0.002)</td>
<td></td>
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<tr>
<td>Chao Li, 2013</td>
<td>87 (42/45)</td>
<td>Patients scheduled for colorectal resection</td>
<td>Aerobic and resistance training at home setting 3x20 min/week for approximately 4 weeks</td>
<td>Improved fitness: walking distance in 6 MWT (+42 m ± 41 m) (p=0.01)</td>
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</table>

energetic reserves, which allows for longer use of aerobic metabolism, increased tolerance of elevated H+ concentration and, as Schier et al. (2) have shown, positive hyperemic response to ischemia occurs in such setting (according to these authors, active hyperemia during an exercise is a surrogate marker of normal endothelial function, while endothelial dysfunction is synonymous with increased cardiovascular risk and related increased risk of postoperative complications). These changes are aimed at better preparation of patients to overcome stress related to surgical procedure. Therefore the minimum duration of preoperative rehabilitation should be two weeks (13). However, respiratory exercises alone may have beneficial effect on the risk of pulmonary complications in patients even if they are started immediately before the surgical procedure (14) (in this study pulmonary complications that included atelectasis, pneumonia or hypoxemia, occurred in only 10 of 172 patients in the intervention group and in 52 of 192 patients in the control group).

CONCLUSIONS

Objective assessment of significance of preoperative rehabilitation in patients scheduled for abdominal operations from the point of view of evidence based medicine is currently impossible due to small number of papers dealing with this subjects. However, considering the suggestions found in the identified materials, related to predicted improvement of both outcomes of surgical treatment, complications and duration of hospitalization, this is an area that should be expanded and implemented in the clinical setting.
REFERENCES


