Can Inspiratory Muscle Training Improve Exercise Tolerance and Lower Limb Function After Myocardial Infarction?

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: Respiratory therapy is an integral part of treatment of cardiac patients. The aim of this study was to evaluate the effect of addition of inspiratory muscle training (IMT) to second-stage cardiac rehabilitation on exercise tolerance and function of lower extremities in patients following myocardial infarction (MI).

Material/Methods: This study included 90 patients (mean age 65 years) with MI who took part in the second stage of an 8-week cycle of cardiac rehabilitation (CR). They were divided into 3 groups: group I underwent CR and IMT, group II only underwent CR, and group III only underwent IMT. Groups I and II were allocated randomly according sealed opaque envelopes. The third group consisted of patients who could not participate in standard rehabilitation for various reasons. Before and after the 8-week program, participants were assessed for maximal inspiratory and expiratory pressure (PImax and PEmax) values, exercise tolerance, and knee muscle strength.

Results: In groups I and II, a significant increase in the PImax parameters and exercise tolerance parameters (MET) were observed. Group I had increased PEmax parameters. In group III, the same changes in the parameter values that reflect respiratory muscle function were observed. All of the examined strength parameters of the knee joint muscles demonstrated improvement in all of the investigated groups, but the biggest differences were observed in group I.

Conclusions: Use of IMT in the ambulatory rehabilitation program of MI patients resulted in improved rehabilitation efficacy, leading to a significant improvement in physical condition.

MeSH Keywords: Breathing Exercises • Exercise Tolerance • Muscle Strength • Myocardial Infarction • Rehabilitation

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Background

Each year, cardiovascular disease and its complications cause more than 4 million deaths in Europe. The direct and indirect annual costs of treatment of cardiovascular disease in Europe are estimated to be approximately €192 billion [1]. Coronary heart disease, including acute myocardial infarction (AMI), is the most common cause of death among all cardiovascular diseases and is the leading cause of death in Europe in people under 75 years of age [2]. Regardless of the pharmacological treatment used, early implementation of rehabilitation is critical. Cardiac rehabilitation improves physical capacity and restores the patient to a relatively normal lifestyle [2,3]. Cardiac rehabilitation not only restores the psycho-physical capacity in patients that was lost as a result of the disease, but also acts as a secondary prevention measure that effectively combats the risks of cardiovascular complications. Regular physical activity is associated with a 15–30% reduction in relative mortality [4]. Respiratory therapy is an integral part of treatment of cardiac patients. It contributes to a better treatment prognosis, and it reduces the risk of complications related to the respiratory system. Therefore, a standard recommendation for cardiac patients is that they undergo respiratory kinesiotherapy. In recent years, evidence has emerged that inspiratory muscle training (IMT) enhances functional capacity and inspiratory muscle strength in patients with congestive heart failure (CHF), thereby reducing dyspnea and improving the strength of skeletal muscles [5].

The aim of this study was to evaluate the effect of adding inspiratory muscle training to second-stage cardiac rehabilitation on exercise tolerance and function of inspiratory muscles and lower extremities in patients after myocardial infarction. We also evaluated relationships between exercise tolerance and inspiratory and expiratory muscle strength, as well as force and velocity parameters (under isokinetic conditions) of selected lower-limb muscles.

Material and Methods

The study was approved by our local Ethics Committee (19.12.2013). Each individual gave written consent before participating in the study, according to the Declaration of Helsinki. This trial is registered with Australian and New Zealand Clinical Trials Registry (ACTRN12618001871235).

A total of 205 patients diagnosed as having had an MI were recruited to the project. An initial sample of 134 potentially eligible post-MI patients was recruited, meeting the following inclusion criteria: age range 50–75 years, clinically stable cardiovascular status, non-smoking, all patients gave written consent to participate in the project, no later than 4 weeks following hospital discharge, involvement in a rehabilitation program within the last year. Exclusion criteria were as follows: chronic respiratory disease, aortic and/or iliac artery surgery, sign of vascular damage in the central nervous system, injury of the spine or pelvis, hormone treatment, or mental
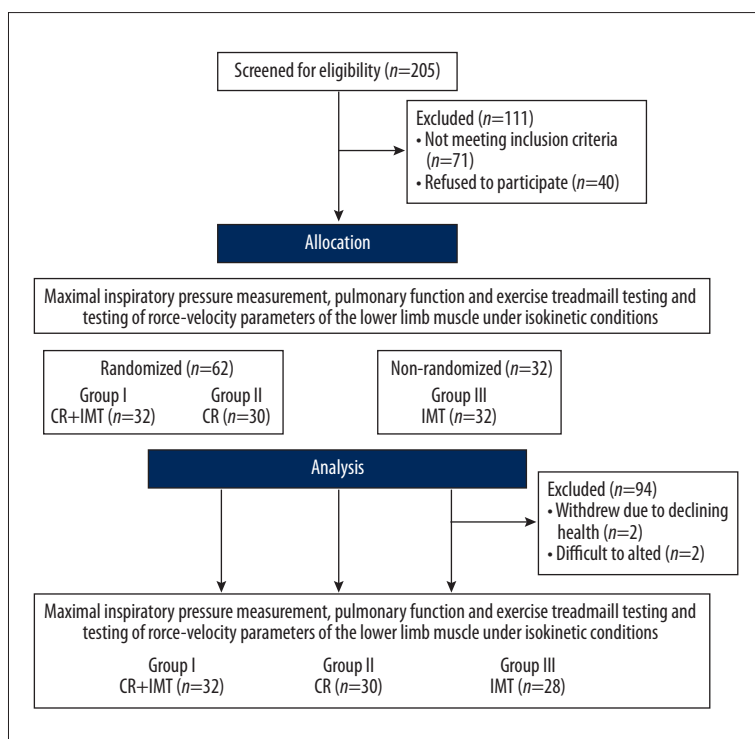

Figure 1. Design and flow of participants throughout the study.

Table 1. Clinical characteristics of the study groups.

Specification	Group I	Group II	Group III
n	32	30	28
Males, n (%)	18 (56.25)	18 (60)	18 (64.28)
Age in years, mean (SD)	61.03±7.4	63.60±5.1	63.67±7.59
Mass in kg, mean (SD)	82.66±11.3	86.03±9.2	84.5±8.9
Height in m, mean (SD)	1.7±0.2	1.69±0.3	1.73±0.1
BMI in kg/m^2, mean (SD)	27.54±2.84	27.68±3.2	28.06±3.1
BMI≥25 kg/m^2, n (%)	21 (65.63)	19 (63.33)	19 (67.85)
NYHA class, n (%)			
I	13 (40.63)	15 (50)	18 (64.28)
II	17 (53.13)	15 (50)	12 (42.85)
Intervention			
PCI, n (%)	14 (43.75)	17 (56.66)	15 (53.57)
CABG, n (%)	18 (56.25)	13 (43.33)	13 (46.42)
TG in mg%, mean (SD)	173.89±104.5	169.24±98.7	170.3±95.4
LDL-C in mg%, mean (SD)	119.32±46.2	123.66±39.20	125.31±38.2
HDL-C in mg%, mean (SD)	44.32±13.4	46.23±11.43	48.48±14.52
Echocardiography parameters, mean (SD)			
LVEDD in mm.	50.51±4.72	50.51±5.72	52.51±5.72
EF in%	55.75±6.41	56.75±7.47	57.75±5.71
Drugs, n (%)			
Beta-blockers	28 (87.5)	27 (90)	27 (96.43)
Statins/fibrates	25 (78.13)	21 (70)	19 (67.85)
Duretics	5 (15.63)	7 (23.33)	7 (25)
Cardiovascular risk factors, n (%)			
Hypertension	18 (51.42)	17 (56.66)	14 (50)
Lipid disorders	19 (59.38)	16 (53.33)	19 (67.85)

Group I – CR+IMT; group II – CR; group III – IMT; BMI – body mass index; NYHA – New York Heart Association classification; PCI – percutaneous coronary intervention; CABG – coronary artery bypass graft; TG – triglyceride; LDL-C – low-density lipoprotein; HDL-C – high-density lipoprotein; LVEDD – left ventricular end-diastolic dimension; EF – ejection fraction.

disorder affecting cooperation or patient contact. Following screening for inclusion and exclusion and confirmation for eligibility by a cardiologist, the baseline sample included 94 patients, and 90 of those patients completed the assessable second stage of cardiac rehabilitation and were divided into 3 groups (Figure 1, Table 1).

Groups I and II were randomly allocated using sealed opaque envelopes. The third group consisted of patients who could not participate in standard rehabilitation for various reasons

(e.g., distance between the place of residence and place of training, missed work days, patients still working). Details of study design and flow of participants throughout the study is presented in Figure 1.

On the basis of the results of exercise tests, patients were allocated to appropriate rehabilitation models – A, B, or C – in line with the Cardiac Rehabilitation Standards [6,7].

Exercise tolerance test

The electrocardiographic exercise test was performed on a treadmill using the Aster CardioTEST Alfa System (System B612v) from Aspel S.A., in a suitably equipped exercise testing laboratory. The exercise tolerance test was performed by a cardiologist. The test was carried out using a modified Bruce protocol. The test intensity was limited to submaximal values. Heart rate limits were set at 85% of the maximum heart rate that was appropriate to the age of the patient. The system calculated the maximum heart rate based on the patient's age using the following formula: $119,375 – 1,175 \times$ the patient's age. The test was preceded by a statement from the patient's doctor declaring the absence of medical contraindications for exercise, and the test began with a recording of resting electrocardiogram (ECG), heart rate, and blood pressure. All patients were informed of the study protocol and of the need to report any complaints that occurred during the trial. The exercise load used was expressed in metabolic equivalent (MET) units, at which the test was stopped.

Respiratory muscle strength

Inspiratory (PImax) and end-expiratory (PEmax) muscle strength were assessed using an ambulatory spirometer (Flowscreen models 780 and 578, ver. 1.3, Jaeger, Germany) with the addition of a special accessory. All procedures were performed in accordance with ATS/ERS guidelines [8]. Verbal encouragement was provided to motivate the participant to perform a maximal forced inhalation for 2–3 s. This procedure was repeated to obtain 5–10 (depending on participant ability) valid measurements. The 3 highest measures (difference below 5% or 5 cmH_2O) were averaged to determine PImax. Baseline PImax was used to calculate the inspiratory load applied in IMT [9].

Assessment of occurrence of inspiratory muscle disorders.

For the assessment of inspiratory muscle disorders, we used the criterion according to Enright et al. and Wilson et al. based on the assessment of the PImax value expressed in a unit of cm H_2O below 80 [10,11].

Function of lower-limb muscles

A study of the function of flexor and extensor muscles of the knee joint of the right (R) and left (L) lower extremities was performed using the isokinetic Biodex Multi-Joint System 4 in the Laboratory of Functional Studies. Evaluation of the function of lower-limb muscles was performed by a physiotherapist/biomechanic under the supervision of a physician.

Muscle torque was tested at an angular velocity of 60°/s for 5 repetitions, and at an angular velocity of 180°/s for 20 repetitions. There was a 2-minute break between the 2 trials. Each measurement was preceded by a warm-up exercise. A measurement of flexion and extension of the knee joint was recorded at maximum force in the shortest possible time at each angular velocity. The torso and thighs were stabilized with straps attached to the chair to eliminate any supportive movements. The starting position was set in a neutral position. The analysis of strength-velocity parameters included the following: peak torque of extensor muscles of the knee joint (PTE 60 and PTE 180) and flexor muscles of the knee joint (PTF 60 and PTF 180) [Nm], total work of all repetitions of the extensor muscles (TWE 60 and TWE 180) and flexor muscles of the knee joint (TWF 60 and TWF 180) [J], and average power (AVGP 60 and AVGP180) [W]. The analyses included results of the dominant limb.

Model of the cardiac rehabilitation process

In group I, a cardiac rehabilitation cycle was used that included interval endurance training on a cycle ergometer 3 times per week, general rehabilitation exercises (models A, B and C), resistance training (models A and B 2 times per week), and IMT. Group II included patients undergoing only a cardiac rehabilitation cycle. In group III, subjects performed only IMT (men and women) [12]. The training for group III was performed by each patient individually at home 4 days per week and 1 day under supervision of a therapist at the Rehabilitation Center. Patients in groups I and III carried out IMT using Threshold IMT equipment from Respironics.

Inspiratory muscle training (IMT)

Prior to the start of training, the strength of inspiratory and expiratory muscles was measured by Jaeger's FlowScreen equipment (780, 578, version 1.3) with the addition of a special attachment [13]. The results were expressed as PImax and PEmax values. Training of the inspiratory muscles was conducted 5 times per week, including 4 sessions at home and 1 session under the supervision of a physiotherapist at the Rehabilitation Center. Prior to commencing the training program, patients performed instructional exercises to learn the proper technique for using the Threshold IMT device while maintaining proper breathing techniques. The training took place in a standing position. After setting the individual resistance, the subjects put a clip on the nose and then tightly placed the mouth on the mouthpiece. The inspiratory phase was characterised by rapid, vigorous, and short inhalation using the diaphragm. The exhale was free, calm, and long and had to last until the residual volume (RV) was reached. The reason for exhaling until the RV was reached was because each subsequent inhalation was meant to begin at that level [14,15]. Subjects performed the exercises alone on their personal training devices. After the initial PImax was measured, the individual training

Figure 2. Inspiratory muscle training (IMT) using a Threshold IMT device.

load level was determined. The inspiratory muscle strength was expressed in kPa and, for training purposes, it was converted to cm H_2O according to the formula 1 kPa=10.2 cm H_2O; based on this formula, the appropriate training load was calculated. Training began with a 30% PImax load [16,17]; the session length was 5 min, and 2 sessions were completed each day. In the weeks that followed, the load and the duration of exercises during the day were increased according to the detailed IMT program shown in Figure 2.

Patients in groups I and II underwent a cardiac rehabilitation cycle that included interval endurance training on a cycle ergometer 3 times per week and general (models A, B, and C) and resistance (excluding model C patients) rehabilitation exercises 2 times per week. Training was held for 8 weeks in an outpatient setting under the supervision of a physician. During one 45-min workout, the patient performed cycles: exercise for 4 min and rest for 2 min while still experiencing a load of 0–5 W. The intensity of the exercise gradually increased in the first half of the training and then decreased when the peak intensity was reached. Each training session started with a warm-up and ended with relaxation (that is, 3 min riding on a cycle ergometer without any load). The training load was calculated individually for each patient on the basis of the result obtained during the exercise test. The training load was increased by no more than 10W every 4 training sessions on a cycle ergometer [12].

Data analysis

The results of the study were analyzed using STATISTICA PL V.9.1. The arithmetic mean and standard deviation were calculated as part of the basic descriptive characteristics for the measurable data. The normal distribution of the parameters was examined in all groups using the Shapiro-Wilk test. There were no grounds for rejecting the hypothesis of normal distribution. The difference in mean values was assessed by a one-way analysis of variance (ANOVA). To make comparisons within a particular group and between the examined groups, variance analysis for repeated measurements and a least significant difference post hoc test was used. Spearman rank correlation coefficients were calculated to demonstrate relationships of the investigated parameters. In the applied statistical tests,
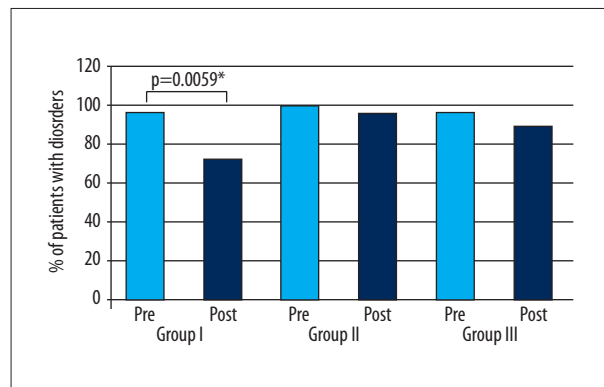

Figure 3. Assessment of occurrence of inspiratory muscle disorders in the examined groups.

values of tests and coefficients at a level of $p < 0.05$ were considered statistically significant. The results are presented in tables and illustrated in figures below, and statistically significant results are in bold.

Results

The basic characteristics of the parameters of respiratory muscle strength and metabolic equivalent in each group are presented in Table 2 (parameters of normal distribution).

In assessing the effects of training carried out in the 3 groups, we found that in group I and III, there was a statistically significant increase in the parameters of respiratory muscle function – PImax and PEmax – after the training was completed. However, in group II, where only endurance and resistance training was used, there was only a significant increase in the PImax parameter.

The occurrence of inspiratory muscle strength disorders was also assessed using the Enright assessment criterion.

In group I, a significant reduction in the number of people with inspiratory muscle strength below the norm was observed (Figure 3). In groups II and III, there were no significant changes in the number of people with disturbances of this parameter.

Table 2. Characteristics of respiratory muscle strength and metabolic equivalent in studied groups, before and after exercise.

Variable	Group I			Group II			Group III		
	Pre mean ±SD	Post mean ±SD	P	Pre mean ±SD	Post mean ±SD	P	Pre mean ±SD	Post mean ±SD	P
PImax (kPa)	2.82±1.22	6.02±2.25	0.0000**	2.95±1.35	5.27±2.42	0.0467*	3.02±1.27	5.69±1.85	0.0000**
PEmax (kPa)	4.69±1.72	6.76±2.28	0.0000**	5.27±2.42	5.67±2.24	0.2111	5.37±2.34	7.46±1.84	0.0000**
MET	6.82±1.9	8.46±2.34	0.0000**	6.61±1.98	8.17±2.01	0.0000**	7.62±2.23	8.10±2.34	0.1106

PImax – inspiratory muscle strength; PEmax – expiratory muscle strength; MET – metabolic equivalent, * P<0.05; ** P<0.005.
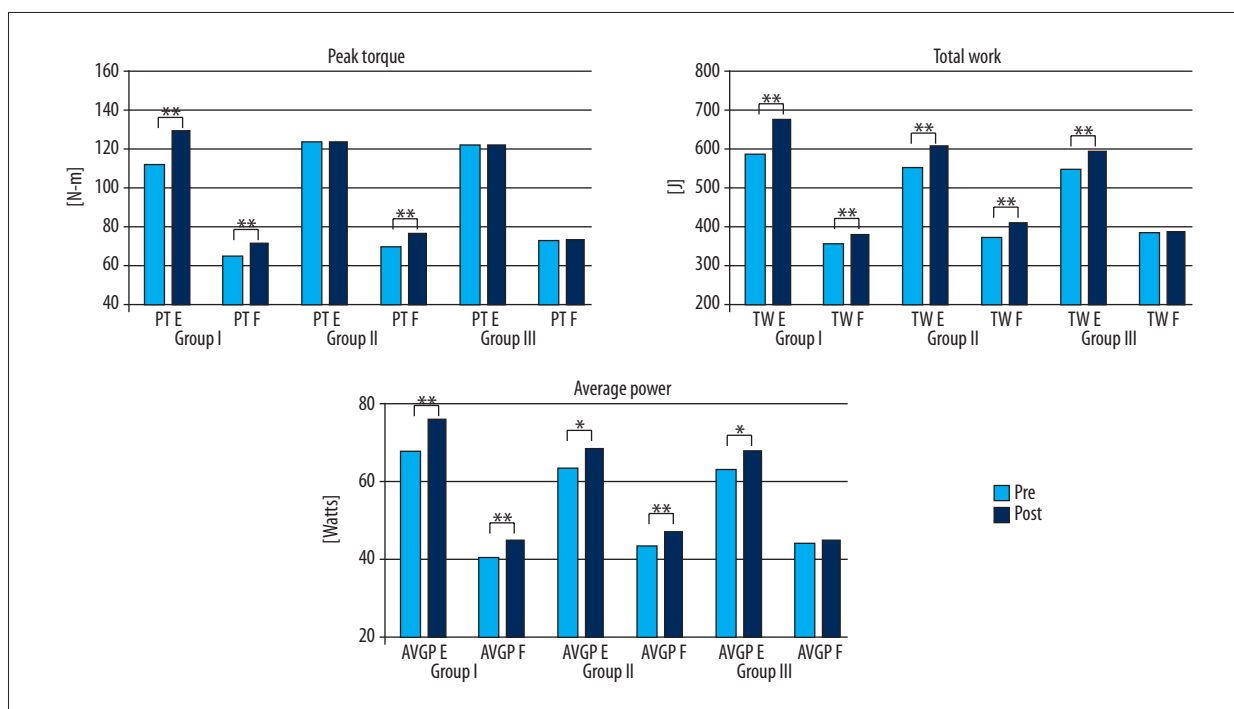

Figure 4. Changes in force-velocity parameters (60°/s) of dominant lower-limb muscles before and after trainings. PT E – peak torque extensors; PT F – peak torque flexors; TW E – total work extensors; TW F – total work flexors; AVGP E – average power extensors; AVGP F – average power flexors; * *P*<0.050; ** *P*<0.005.

Exercise tolerance assessment in the studied groups showed a statistically significant increase in MET values in groups I and II after rehabilitation (Table 2).

The next step was to evaluate the functions of flexor (F) and extensor (E) muscles that act on the knee joint (Figures 4, 5).

In group I, all of the examined right (R) and left (L) limb parameters of force – velocity of the knee joint muscles showed improvement at both velocities tested. In group II, only the PTER 60 did not increase significantly, whereas in group III, the least significant changes were recorded in 6 of the 12 parameters measured (TWE R60, AVGP R60, PTF R180, PTE R180, TWF R180, AVGP R180). The above results demonstrate that at higher testing velocities, changes were more favourable for most of the

measured parameters. Also, the highest increases were recorded in group I, in which IMT was introduced as an addition.

In group I, a significant correlation was observed between inspiratory muscle strength (PImax) after 8 weeks of training and exercise tolerance (MET), as well as with the following functional parameters of lower limb muscles: peak torque, average power, and total work. There was a significant association between exercise tolerance and all of the force-velocity parameters of lower-limb muscles (Table 3).

In group II, the inspiratory muscle strength (PImax) was only correlated significantly with functional parameters of the lower limb, such as peak torque and average power. There was a significant relationship between exercise tolerance and

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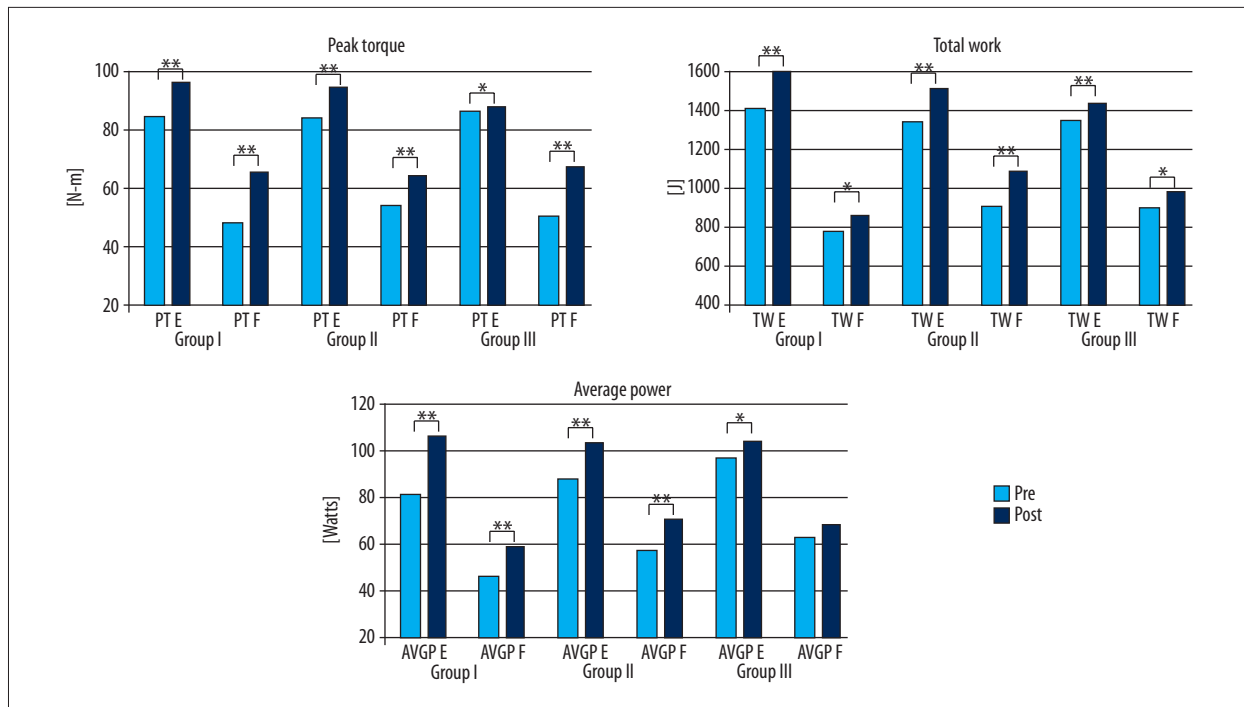
Figure 5. Changes in force-velocity parameters (180°/s) of dominant lower-limb muscles before and after trainings. PT E – peak torque extensors; PT F – peak torque flexors; TW E – total work extensors; TW F – total work flexors; AVGP E – average power extensors; AVGP F – average power flexors; * $P<0.050$; ** $P<0.005$.

the strength of expiratory muscles and with all force-velocity parameters of the lower-limb muscles at a velocity of 60°/s, corresponding to strength conditions, as well as with the extensor muscles at a velocity of 180°/s, signifying endurance conditions (Table 3).

In group III, the inspiratory muscle strength (PImax) showed minimal significant correlations with lower-limb function parameters; only the extensor muscles in both the strength and endurance conditions demonstrated a significant association. In turn, there was a significant association between exercise tolerance and inspiratory muscle strength, as well as with all of the parameters that determine the function of lower-limb muscles at velocities of 60°/s and 180°/s (Table 3).

Discussion

A review of the literature revealed that the benefits of physical training include a reduction in mortality and death caused by cardiovascular disease. A meta-analysis found that the reduction in mortality is most strongly associated with an increase in physical capacity, which results from rehabilitation [18]. The same analyses confirmed that the type of exercise program and the intensity, frequency, and duration of the training sessions are particularly important. In our own studies, we observed a significant improvement in exercise tolerance

in the group for which cardiac rehabilitation had been introduced with additional IMT, as well as in the group that had taken part only in the cardiac rehabilitation cycle. In the group that used only IMT, there was also an upward trend, but the results were not statistically significant. This could be explained by the fact that the baseline value of MET in this group was higher than in the other 2 groups; therefore, the increase in this value was lower.

Many authors have reported that inspiratory muscles get fatigued during workouts, which limits their ability to exercise [19]. On the other hand, scientific evidence has confirmed that even short-term, intensive breathing exercises have a significant positive effect on the health status of patients with cardiovascular disease [20]. This confirms the importance of placing a particular emphasis on this IMT exercise, which can lead to a significantly higher exercise tolerance [21]. Furthermore, there are many positive practicalities associated with IMT: it is not difficult to perform, the specialized training equipment is inexpensive and easily available, and it is short in duration. These aspects were noted by us in the present study, and were also emphasised by Garcia et al. [22].

In the present study, 8-week IMT led to an increase in inspiratory muscle strength in groups I and III. Similar training effects have also been observed in studies conducted on patients with respiratory, cardiovascular, and neuromuscular

Table 3. Correlation coefficients between selected parameters after training in all groups.

Variable	Group I			Group II			Group III		
	PI max [kPa]	PE max [kPa]	MET	PI max [kPa]	PE max [kPa]	MET	PI max [kPa]	PE max [kPa]	MET
MET	0.36*	0.12	–	0.36*	0.36*	–	0.40*	0.12	–
PImax [kPa]	–	0.74*	0.36*	–	0.59*	0.28	–	0.49*	0.40*
PEmax [kPa]	0.74*	–	0.37*	0.59*	–	0.36*	0.49*	–	0.36*
PTF R60 [Nm]	0.67*	0.54*	0.65*	0.21	0.12	0.41*	0.29	0.43*	0.56*
PTE R60 [Nm]	0.47*	0.54*	0.54*	0.48*	0.36*	0.46*	0.46*	0.52*	0.58*
PTF R180 [Nm]	0.64*	0.36*	0.64*	0.12	0.46*	0.31	0.18	0.20	0.45*
PTE R180 [Nm]	0.42*	0.58*	0.58*	0.30	0.33	0.46*	0.41*	0.36*	0.54*
AVGPF R60 [W]	0.63*	0.52*	0.60*	0.17	0.42*	0.37*	0.30	0.43*	0.61*
AVGPE R60 [W]	0.37*	0.48*	0.47*	0.54*	0.36*	0.44*	0.51*	0.39*	0.55*
AVGPF R180 [W]	0.50*	0.62*	0.58*	0.05	0.37*	0.26	0.29	0.30	0.39*
AVGPE R180 [W]	0.35*	0.30	0.52*	0.27*	0.31	0.40*	0.43*	0.57*	0.52*
TWF R60 [J]	0.55*	0.64*	0.62*	0.08	0.46*	0.42*	0.20	0.17	0.61*
TWE R60 [J]	0.36*	0.54*	0.48*	0.34	0.33	0.37*	0.20	0.21	0.48*
TWF R180 [J]	0.50*	0.36*	0.58*	0.28	0.21	0.35	0.22	0.45*	0.46*
TWE R180 [J]	0.36*	0.36*	0.49*	0.16	0.12	0.15	0.44*	0.36*	0.57*

MET – metabolic equivalent, PImax – inspiratory muscle strength, PEmax – expiratory muscle strength, PTF R60 – peak torque flexors right 60°/s; PTE R 60 – peak torque extensors right 60°/s; PTF R180 – peak torque flexors right 180°/s; PTE R 180 – peak torque extensors right 180°/s; AVGPF R60 – average power flexors right 60°/s; AVGPE R60 – average power extensors right 60°/s; AVGPF R180 – average power flexors right 180°/s; AVGPE R180 – average power extensors right 180°/s; TWF R60 – total work flexors right 60°/s; TWE R60 – total work extensors right 60°/s; TWF R180 – total work flexors right 180°/s; TWE R180 – total work extensors right 180°/s, * $P<0.0500$.

diseases [23,24]. Winkelman et al. [24] reported similar results using IMT in 24 patients with heart failure, where the training took place 7 days per week for 12 weeks with a 30% load. The 8-week training in our research involved a load that was increased from 30% to 60%. The data presented in this article confirms that regardless of the degree of load, systematic IMT results in an increase in strength of inspiratory muscles.

Another interesting issue raised by many authors is the attempt to verify relevant factors that affect the course and outcome of IMT. The effects of IMT are determined by the duration of workouts, training intensity, and how it is performed. The 8-week IMT in this research seems to be the optimal time needed to obtain positive training effects. This has been shown by studies conducted in healthy subjects [16] and those who are ill [17]. On the other hand, Newall et al. [25] conducted IMT for 8 weeks in patients with bronchiectasis. The researchers divided the patients into 3 groups (11 people in each group) – the patients in the first group underwent only pulmonary rehabilitation (PR), the patients in the second group underwent PR and IMT, and the third group was a control group. Researchers found significant improvements in aerobic capacity (VO$_2$) and endurance in groups I and II, while the inspiratory muscle strength only increased significantly in group II. In considering the similar groups and exercises undertaken, our studies confirm that the parameters of exercise tolerance significantly increased in both test groups, while the inspiratory muscle strength increased significantly only in the group with additional IMT.

Furthermore, many authors draw attention to the changes in autonomous nervous system after using IMT. Mello et al. [26] conducted a 12-week IMT program with a 30% PImax loading in patients with heart failure. They demonstrated that such training causes a reduction in sympathetic system activation, which is an important strategy for improving the capacity of heart muscle and autonomic control (peripheral vessels), as well as life quality and capacity. Chiappa et al. [27] demonstrated

positive effects of IMT on blood flow in lower limbs and, thus, improvement in their function. Similar results were obtained by Silva et al. [28], who performed IMT in elderly patients with insulin resistance.

Knee joint overload is also considered in the literature. Due to the anatomical structure and biomechanical functions of knee joints, they are among the most stressed and unstable of all joints, making them susceptible to diseases. In the scientific literature, the muscles that act on the knee joint have been subjected to a very detailed functional analysis under isokinetic conditions, mostly in young people and athletes [29]. However, there has been little research on the functional assessment of these muscle groups in patients with chronic diseases [30].

Muscular strength examinations have been performed on patients after MI and on patients with heart failure. The examinations have primarily involved large-muscle groups (such as thigh, arm, and forearm muscles). The measurement used most often involves maximal muscle torque under the isokinetic conditions using isokinetic dynamometers (for example, Biodex and Cybex) [31]. The force of the maximum muscle contraction in the knee joint flexors and extensors and in the forearm muscles were determined most frequently, at different velocities (60°/s, 90°/s, 120°/s and 180°/s). To confirm this thesis, 2 velocities were selected for in this study: 60°/s, which corresponds to strength, and 180°/s, which corresponds to endurance, defined as a percent reduction of peak torque during successively repeated contractions at a given velocity [31]. In the present study, the results of the force parameters for the muscles that act on the knee joints at both testing velocities showed improvement in all investigated groups (groups I, II, and III). Based on the least significant difference test, the changes that were observed for most of the measured parameters were statistically significant at higher testing velocities. However, the biggest differences were detected in the group with a combination of standard cardiac rehabilitation and IMT.

Our research also shows that only inspiratory muscle training is beneficial to the skeletal muscle of the lower extremities. The reason for this may be that in patients with cardiovascular and respiratory diseases, the respiratory muscles have a different load than do skeletal muscles. In the muscles of the limbs, especially the muscles of the lower limbs, weakness of the respiratory muscles and respiratory failure lead to inactivity and chronic insufficient muscle strain. This effect is caused by physiological factors, such as peripheral muscle weakness, or blood flow limitations directed to peripheral muscles and oxygen extraction during general exercise rehabilitation. Respiratory muscles must cope with increased workload to breathe and are therefore often overloaded. These muscles are also threatened by hyperinflation, caused by respiratory collapse and low elastic recoil [32–35]. The scientific evidence

on IMT at present is quite controversial. However, a meta-analysis of 17 articles on IMT [36] showed that when the training stimulus was sufficient to induce a significant improvement in respiratory muscle performance, there was a significant reduction in dyspnea and there was improved functional exercise capacity associated with a skeletal muscle strain.

Improvement of limb muscle parameters after IMT training has also been demonstrated by rowers (Griffiths et al.) [37], cyclists (Romer et al.) [38], and in patients with heart failure (Gething) [39].

We have shown that better skeletal muscle work after IMT training results from the reduction of HR at the equivalent intensity of exercise, as well as reducing the feelings of exercise (blood lactate concentration), respiratory, and/or the whole body. These physiological changes are also confirmed by other authors, showing that the improvement of exercise capacity after IMT may be the result of improved blood flow to working locomotor muscles and can delay the onset of peripheral muscle fatigue. After IMT, the improvement of blood flow to skeletal muscle delays the accumulation of lactic acid and fatigue in working muscles. Also, IMT practitioners can complete an ongoing trial, working at higher speeds for a longer time [40,41].

According to researchers, patients with heart failure have poorer muscular endurance, which is more important in everyday life than maximum strength because the capacity to repeat submaximal exertions allows you to perform basic daily tasks independently. A reduction in this capacity is felt by patients in the form of increased fatigue, which gradually limits their functional independence. A deterioration of the analysed parameters, and hence an impairment of skeletal muscle function, is already present in patients with mild heart failure that occurs after a heart attack. Suzuki et al. [42] demonstrated a relationship between strength and muscle mass and the physical capacity of patients with heart failure. The reduction of strength and skeletal muscle mass, regardless of other clinical indicators, determines a worse exercise tolerance. The results of our present study have confirmed a significant relationship between force parameters of the lower-limb skeletal muscles and exercise tolerance in all evaluated groups. The highest correlation with similar values was observed in groups I and III; in group II, in which only the cardiac rehabilitation model was applied, significant correlations were limited. These findings show that the use of IMT is an important factor that improves the working of skeletal muscles, with little physiological cost to the body.

Conclusions

The introduction of IMT into a standard cardiac rehabilitation program improved exercise tolerance of patients after MI,

as demonstrated by the MET results in group I. The number of subjects with impaired inspiratory muscle strength decreased significantly only in group I. The functional parameters of lower-limb muscles in groups I and II improved significantly after cardiac rehabilitation and after the addition of IMT. In contrast, no beneficial effects were observed in patients who received only IMT. After the applied training procedures, similar changes were observed in the studied groups in terms of the functional parameters measured in force and

endurance conditions (both velocity). The highest values for speed-strength parameters were recorded in group I. The correlation coefficient values indicate that the use of IMT resulted in better working of the skeletal muscles with fewer physiological costs to a patient following MI.

Conflicts of interests

None.

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