DOI: 10.5114/kitp.2013.34309

# Functional testing of muscles in patients with *pectus excavatum* – indications for preoperative rehabilitation

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Polish Journal of Thoracic and Cardiovascular Surgery 2013; 10 (1): 72–78

## Abstract

**Introduction:** Studies of people with *pectus excavatum* usually relate to physiological abnormalities caused by the deformity, as well as its impact on posture. Little is known about muscle length disorders associated with this defect.
**Aim of the study:** Determining whether the presence of *pectus excavatum* is associated with changes in muscle length; developing guidelines for preoperative rehabilitation of *pectus excavatum* patients.
**Material and methods:** 19 patients aged 13-19 years with diagnosed *pectus excavatum* were examined and qualified for the Nuss procedure at the Wielkopolska Centre of Pulmonology and Thoracosurgery in Poznań. The control group consisted of 30 healthy boys of similar age. Each patient underwent a total of 42 functional tests measuring the length of individual muscles.
**Results:** A comparative analysis of the study and control groups in terms of muscle flexibility showed significant differences in the results of 8 tests of the 42 tests carried out (19.04%). These tests assessed the length of the pectoralis major (clavicular part, right and left), the internal rotators of both humeral joints, the iliopsoas muscle (left lower extremity) and the rectus femoris muscles (right and left), and the ischiocrural muscles (left lower extremity) – the muscles were shortened significantly more often in boys without *pectus excavatum*. Boys with this deformity had significantly lower body weight and a significantly lower BMI (body mass index) compared to boys in the control group.
**Conclusions:** When planning a physiotherapy programme for *pectus excavatum* patients, an individualized approach should be used to achieve the best possible results.
**Key words:** *pectus excavatum*, muscle length tests, physiotherapy.

## Streszczenie

**Wstęp:** Badania osób z klatką piersiową lejkowatą dotyczą zazwyczaj fizjologicznych nieprawidłowości spowodowanych wystąpieniem wady, a także jej wpływu na postawę ciała. Niewiele wiadomo na temat zaburzeń długości mięśni związanych z tą wadą.
**Cel pracy:** Ustalenie, czy występowanie klatki piersiowej lejkowatej związane jest ze zmianą długości mięśni, a także opracowanie wskazań do rehabilitacji przedoperacyjnej osób z klatką piersiową lejkowatą.
**Materiał i metody:** Zbadano 19 pacjentów w wieku 13–19 lat z rozpoznaną klatką piersiową lejkowatą zakwalifikowanych do zabiegu operacyjnego metodą Nussa w Wielkopolskim Centrum Pulmonologii i Torakochirurgii w Poznaniu. Do grupy kontrolnej zakwalifikowano 30 zdrowych chłopców w podobnym przedziale wiekowym. U każdego z badanych przeprowadzono łącznie 42 testy funkcjonalne badające długość poszczególnych mięśni, a także zgromadzono dane dotyczące masy i wysokości ciała.
**Wyniki:** Analiza porównawcza grupy badawczej i kontrolnej pod względem elastyczności mięśni wykazała istotne różnice w wynikach 8 testów spośród 42 wykonanych (19,04%). Były to testy oceniające długość mięśnia piersiowego większego (jego części obojczykowej, prawej i lewej), rotatorów wewnętrznych obu stawów barkowych, mięśnia biodrowo-lędźwiowego (kończyna dolna lewa) oraz mięśni prostych uda (prawego i lewego), kulszowo-goleniowych (kończyna dolna lewa) – mięśnie te skrócone były istotnie częściej u chłopców bez klatki piersiowej lejkowatej. Chłopcy z tą wadą charakteryzowali się istotnie mniejszą masą ciała oraz istotnie niższym wskaźnikiem masy ciała (*body mass index* – BMI) w stosunku do chłopców z grupy kontrolnej.
**Wnioski:** Planując program fizjoterapii dla osób z klatką piersiową lejkowatą, należy stosować podejście zindywidualizowane w celu osiągnięcia możliwie najlepszych efektów.
**Słowa kluczowe:** klatka lejowata, testy długości mięśni, fizjoterapia.

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## Introduction

It is assumed that chest wall deformities occur in 0.01-0.1% of the population [1]. *Pectus excavatum* (PE) occurs in 1 : 400 live births of the Caucasian race (mostly male); it is rarely encountered in other ethnic groups. The defect is likely to be genetically determined, although the mechanisms of its inheritance are not fully understood. Other causes of chest deformities include intrauterine pressure, muscle paralysis, inflammation, trauma causing changes in the diaphragm and abnormal growth of the ribs. A small change in the structure of collagen is observed in the costal cartilages in children with chest wall deformities, but their relationship to the formation of defects is not yet completely understood [2-5].

Chest wall deformities are diagnosed shortly after birth in 40% of patients, and in 60% only during puberty. Typically, in the first period of a child's development, the extent of changes in cartilage and bone structures of the chest is not large, but in the period of rapid growth and development of the skeletal system, the deformity is clearly visible. A typical PE is the collapse of the lower part of the sternum and the adjacent costal cartilages [6]. Children with PE are often tall, have an asthenic habitus and abnormal body posture (scoliosis is diagnosed in about 29% of PE children). In addition, there are co-existing diseases of the respiratory and cardiovascular systems. *Pectus excavatum* is often observed in children with muscular disorders, such as in children with Marfan syndrome, Ehlers-Danlos syndrome, osteogenesis imperfecta, or homocystinuria. The deformity is more common in children with congenital heart disease and in children with Down syndrome [2, 5, 7].

Patients with PE are eligible for surgery mainly for aesthetic or cosmetic reasons, due to it causing lack of acceptance of their body image, low self-esteem, fear of embarrassment, or fear of undressing on the beach or at the pool. Other symptoms, such as shortness of breath, fatigue, tachycardia, decreased physical fitness, pain in the anterior chest wall, or adolescent depression are less likely to be the reasons [2].

## Aim of the study

The main objective of this study was to determine whether PE is associated with impaired muscle function, i.e. muscle shortening, and to develop guidelines for the rehabilitation of people with PE prior to corrective chest surgery conducted by means of the Nuss procedure. An additional aim was to compare boys with PE and boys without chest deformities in terms of basic morphological parameters, such as height, weight and body mass index (BMI).

## Material and methods

The test group consisted of 19 patients with diagnosed PE and qualified for the Nuss procedure at the Wielkopolska Centre of Pulmonology and Thoracosurgery in Poznań. The control group consisted of 30 healthy boys with no detected poor posture. The age of patients, both from the study and control groups, ranged from 13 to 19 years (Table I). In order to participate in the research programme, it was necessary to obtain written consent from potential participants or their legal guardians (this refers to adults and minors respectively). Boys with PE from across Poland who came to the Wielkopolska Centre of Pulmonology and Thoracosurgery were selected for the programme by a thoracic surgery specialist. The criteria for inclusion in the testing were: a certain age, no neurological disorders and consent to the Nuss corrective procedure. The decisive criterion to exclude a participant from the test group was the co-existence of other defects in the anterior chest wall and the presence of musculoskeletal anomalies (e.g., Marfan syndrome, connective tissue disorders). The muscle length testing was carried out once prior to surgery. In addition, data on the height and weight of all patients, from both the test group and the control group, were collected, based on which their BMI was calculated.

### *Research method*

A room with a couch was used for functional testing – testing was carried out at the Department of Kinesitherapy at the Faculty of Physical Education and Sport and Rehabilitation, University School of Physical Education in Poznań. The length of the following muscles was tested in all patients: deep cervical flexor muscle group, e.g. whether there is shortening of the sternocleidomastoid muscles and scalene muscles [8]; the descending part of the trapezius; latissimus dorsi; pectoralis major (clavicular part, sternocostal part, abdominal part) [9]; the external and internal rotators of the humeral joint, serratus anterior, iliopsoas, rectus femoris, thigh adductors and abductors [8]; piriformis muscles [9]; ischiocrural muscle group [9], gastrocnemius [9], and soleus

**Tab. I.** Characteristics of the test group (T) and the control group (C) in terms of age and morphological features

| | | *n* | Mean | Median | Max. | Min. | Lower quartile | Upper quartile | Standard deviation |
|---|---|---|---|---|---|---|---|---|---|
| age (years) | T group | 19 | 15.9 | 16 | 19 | 13 | 15 | 17 | 1.49 |
| | C group | 30 | 16.9 | 17 | 19 | 14 | 16 | 18 | 1.36 |
| body weight (kg) | T group | 19 | 60.4 | 57 | 76 | 46 | 55 | 68 | 8.62 |
| | C group | 30 | 71.9 | 71 | 101 | 54 | 61 | 79 | 11.36 |
| body height (m) | T group | 19 | 1.8 | 1.8 | 1.94 | 1.57 | 1.74 | 1.84 | 0.09 |
| | C group | 30 | 1.8 | 1.79 | 1.93 | 1.72 | 1.77 | 1.82 | 0.05 |
| BMI | T group | 19 | 18.71 | 18.17 | 22.86 | 15.43 | 17.54 | 20.44 | 2.03 |
| | C group | 30 | 22.15 | 21.65 | 31.88 | 16.67 | 19.92 | 23.72 | 3.51 |

BMI – body mass index

muscle [8]. The eccentric strength of the abdominal muscles was also evaluated. In addition, the Apley scratch tests and Matthias test were applied [10], and the Thompson test was also performed [11]. Taking into account the necessity of testing the muscles on the right and left sides of the body, as well as the examination of specific synergistic units of selected muscles, each time 42 tests were performed.

### Statistical analysis

All data obtained during the testing were entered into a spreadsheet and basic descriptive statistics were calculated for the analysed variables: mean, median, maximum and minimum, upper and lower quartile, standard deviation. The test group was compared with the control group in terms of morphological characteristics, such as body weight, body height and the BMI calculated on this basis, using the Mann-Whitney U test. Pearson's $\chi^2$ test was used to test for a relationship between muscle flexibility and the presence of PE. The statistical analyses were performed using Statistica 10 (StatSoft).

## Results

Measurements of morphological features of the boys tested showed that the average weight of boys with PE (60.4 ±8.62 kg) was significantly lower ($p$ = 0.0006) than in the control group (71.9 ±11.36 kg). The average height of the body of boys from the test group and the control group did not differ significantly (respectively 1.8 ±0.09 m and 1.8 ±0.05 m). The average BMI in boys with PE (18.71 ±2.03) was significantly lower ($p$ = 0.0002) than in the control group (22.15 ±3.51) (Table I).

A comparative analysis of the study and control groups in terms of muscle flexibility showed significant differences in the results of 8 tests of the 42 carried out (19.04%). These were tests assessing the length of the pectoralis major (clavicular part, right and left), the internal rotators of both humeral joints, iliopsoas (left lower extremity) and rectus femoris (right and left), and ischiocrural muscles (left lower extremity).

A statistical analysis showed that the pectoralis major muscles (right and left clavicular part) were significantly more often (respectively $p$ = 0.01217 and $p$ = 0.03667) shortened in the control group than in the test group. This test showed that in the control group 44.83% of people had a shortened pectoralis major of the clavicular part on the right side of the body, and 37.93% on the left side of the body, whereas in the test group the proportion was 10.53% on the right side of the body, and 10.53% on the opposite side of the body. Internal rotators of the humeral joints (right and left) were shortened significantly less often (respectively $p$ = 0.01551 and $p$ = 0.00858) in the test group compared with the control group. The test result for the length of the internal rotators of the right humeral joint was positive (muscle shortening was observed) in 15.79% of people, and the left humeral joint in 10.53% of people from the test group, while in the control group the percentage was respectively 50% and 46.67% of patients.

The rectus femoris muscles had impaired length significantly less often ($p$ = 0.00002 for both lower extremities) in the test group than in the control group. The test showed that in 31.58% of persons shortened muscles were observed in the right and left lower extremity, and in the control group the percentage for both limbs was 90%. The measurements of the iliopsoas muscle length of the left lower extremity showed that it was significantly less often ($p$ = 0.04283) shortened in the test group than in the control group. Muscle shortening on the right side was also observed less frequently in the test group than in the control group, although the difference was not statistically significant ($p$ = 0.90698). The iliopsoas muscle in the test group was reduced in 68.42% of persons in the right lower extremity, and in the control group the percentage was 70%. However, the iliopsoas length disorder in the left limb was observed in 52.63% of persons in the test group and 80% in the control group. The ischiocrural muscle group of the left lower extremity was significantly less frequently ($p$ = 0.04939) shortened in the test group compared with the control group. Right side muscle shortening also occurred less frequently in the test group than in the control group, although in this case the difference was not statistically significant ($p$ = 0.09514). In 57.89% of persons in the test group a positive length test result for both lower extremities was reported, while the proportion in the control group was 80% (right extremity) and 83.33% (left extremity) of people.

The differences between boys with PE and the control group were also observed in other muscle test results, although they were not statistically significant. In the test group, latissimus dorsi muscle shortening was observed more frequently ($p$ = 0.71074) than in the control group, respectively in 31.58% and 26.67% of persons studied. The gastrocnemius muscle was more frequently ($p$ = 0.71074 for the right lower extremity and $p$ = 0.52321 for the left lower extremity) shortened in the test group compared with the control group. The test showed that 84.21% of the test group members had shortened gastrocnemius muscles in both legs, whereas in the control group the percentage was 80% for the right limb and 76.67% for the left limb. Studies on the piriformis muscle length in the test group showed that it was shortened less frequently ($p$ = 0.71545 for the piriformis muscle on the right side, $p$ = 0.18051 for the same muscle on the opposite side) than in the control group. In the test group, the test for the piriformis muscle length on the right side showed that in 31.58% of persons this muscle was shortened, and on the left side in 47.37%. In the control group, 36.67% of people had a shortened piriformis muscle on the right side and 66.67% on the left side (Table II).

## Discussion

*Pectus excavatum* incidence is 1 : 1000 births and it is more often found in boys than in girls, in a ratio of 4 : 1. This is confirmed by studies of postural assessment of children aged 13-15 conducted by Kania-Gudzio and Wiernicka

**Tab. II.** The results of functional testing carried out in boys with *pectus excavatum* (test group) and without the deformity (control group)

| Muscles | Test group | | Control group | | Significance |
|---|---|---|---|---|---|
| | – [%] | + [%] | – [%] | + [%] | |
| right scalenus anterior | 100 | 0 | 100 | 0 | n.s. |
| left scalenus anterior | 100 | 0 | 100 | 0 | n.s. |
| right scalenus medius | 100 | 0 | 100 | 0 | n.s. |
| left scalenus medius | 100 | 0 | 100 | 0 | n.s. |
| right scalenus posterior | 100 | 0 | 100 | 0 | n.s. |
| left scalenus posterior | 100 | 0 | 100 | 0 | n.s. |
| sternocleidomastoid | 94.74 | 5.26 | 100 | 0 | n.s. |
| right trapezius, descending part | 94.74 | 5.26 | 100 | 0 | n.s. |
| left trapezius, descending part | 94,74 | 5.26 | 100 | 0 | n.s. |
| latissimus dorsi | 68.42 | 31.58 | 73.33 | 26.67 | n.s. |
| right pectoralis major 120 | 89.47 | 10.53 | 55.17 | 44.83 | $p = 0.01217$ |
| left pectoralis major 120 | 89.47 | 10.53 | 62.07 | 37.93 | $p = 0.03667$ |
| right pectoralis major 90 | 100 | 0 | 86.21 | 13.79 | n.s. |
| left pectoralis major 90 | 89.47 | 10.53 | 86.21 | 13.79 | n.s. |
| right pectoralis major 45 | 100 | 0 | 80 | 20 | n.s. |
| left pectoralis major 45 | 100 | 0 | 80 | 20 | n.s. |
| right external rotators | 94.74 | 5.26 | 90 | 10 | n.s. |
| left external rotators | 94.74 | 5.26 | 93.33 | 6.67 | n.s. |
| right internal rotators | 84.21 | 15.79 | 50 | 50 | $p = 0.01551$ |
| left internal rotators | 89.47 | 10.53 | 53.33 | 46.67 | $p = 0.00858$ |
| right serratus anterior | 100 | 0 | 100 | 0 | n.s. |
| left serratus anterior | 100 | 0 | 100 | 0 | n.s. |
| right iliopsoas | 31.58 | 68.42 | 30 | 70 | n.s. |
| left iliopsoas | 47.37 | 52.63 | 20 | 80 | $p = 0.04283$ |
| right rectus femoris | 68.42 | 31.58 | 10 | 90 | $p = 0.00002$ |
| left rectus femoris | 68.42 | 31.58 | 10 | 90 | $p = 0.00002$ |
| right adductor | 94.74 | 5.26 | 100 | 0 | n.s. |
| left adductor | 100 | 0 | 100 | 0 | n.s. |
| right abductors | 100 | 0 | 63.33 | 36.67 | n.s. |
| left abductors | 100 | 0 | 66.67 | 33.33 | n.s. |
| right piriformis | 68.42 | 31.58 | 63.33 | 36.67 | n.s. |
| left piriformis | 52.63 | 47.37 | 33.33 | 66.67 | n.s. |
| right ischiocrural | 42.11 | 57.89 | 20 | 80 | n.s. |
| left ischiocrural | 42.11 | 57.89 | 16.67 | 83.33 | $p = 0.04939$ |
| right gastrocnemius | 15.79 | 84.21 | 20 | 80 | n.s. |
| left gastrocnemius | 15.79 | 84.21 | 23.33 | 76.67 | n.s. |
| right and left soleus | 100 | 0 | 68.97 | 31.03 | n.s. |
| Thompson test right | 94.74 | 5.26 | 100 | 0 | n.s. |
| Thompson test left | 89.47 | 10.53 | 96.67 | 3.33 | n.s. |
| Matthias test | 94.74 | 5.26 | 93.33 | 6.67 | n.s. |
| abdominal eccentricity | 73.68 | 26.32 | 86.67 | 13.33 | n.s. |
| Apley scratch test | 100 | 0 | 100 | 0 | n.s. |

+ shortened muscle, – non-shortened muscle, n.s. – no statistical significance

in a randomly selected primary school in Poznań in 2002. They observed the chest wall deformity, i.e. PE, in 12 of 74 boys (16.2%), while among girls the proportion was much lower (1.6%) since only 1 case of PE was found among 63 examined girls [2, 5, 12, 13]. Taking into account the above information and the fact that the best results of corrective surgery are observed in adolescents, it was decided to include boys aged 13-19 years in the study. The correctness of such a decision has also been confirmed by the results of the latest reports. Papandria *et al*. [14] found that mean age at operation was 13.5 years in a sample of 5830 children, and this increased from 11.8 years to 14.4 years over the period studied (1998-2009).

On the basis of morphological measurements of boys examined, it was revealed that body weight and BMI in boys in the test group were significantly lower than in the control group. This is consistent with observations of other authors that children with PE most commonly have an asthenic habitus [2, 3]. The relation between the body habitus and the occurrence of PE is not entirely clear. This issue requires further study.

The studies of people with chest deformities conducted so far have usually related to physiological abnormalities caused by the occurrence of the defect. They showed, among others, cardiovascular system disorders, such as a limited ability to increase stroke volume, cardiac rotation and displacement of the heart to the left. Mitral valve prolapse was identified in approximately 20% of children with PE [5, 15]. The effects of the presence of PE on posture are also described, because they are usually easily noticeable. Children begin to slouch probably subconsciously, trying to hide the deformity. Apart from the visible changes in the protruding humeral joint, back muscle weakness results in a thinning of the abdominal muscles, while breathing causes paradoxical movements of the chest [4, 5]. The most preferable posture is when the body segments are arranged in a straight line and in equilibrium. Optimal posture allows for pain-free movement associated with minimal energy expenditure and is a sign of vigour, harmony and control of the body. When certain muscles are used more often, through work, or sports, they tend to increase in strength, which can lead to their shortening. Appropriate tests can help to identify and define the muscle groups that are weakened or shortened. Functional tests help determine the muscles the flexibility of which has been impaired, which may affect the muscle imbalance of the body. Muscles such as extensor muscles of the neck, upper trapezius and levator scapulae are characterized by a high tone and trigger points, easy to find by palpation. However, the opposing muscle group (long muscle of neck, long muscle of head and the ascending part of the trapezius) is generally relaxed and its strengthening is often recommended. The pectoralis major and minor muscles are usually characterized by increased muscle tone, while the infraspinatus muscle, teres minor, rhomboid, and thoracic spine extensor muscles are relaxed. The mentioned muscular imbalance leads to protrusion of the head and shoulders, increased thoracic kyphosis and flattened cervical lordosis [16]. The quoted description of the body habitus should indicate the contracture and shortening of the pectoralis major muscles [9]. This body habitus is characteristic for boys with PE, but in the control group, the clavicular part of the pectoralis major (right and left) was significantly more frequently shortened than in the test group, on both the right ($p = 0.01217$) and the left side of the body ($p = 0.03667$). Other parts of the pectoralis major muscle, i.e. sternocostal and abdominal, were also more often shortened in this group than in the test group, but the differences were not statistically significant. This result might be considered surprising, since watching the boys with PE, the reduction of these muscles could be expected in the test group, yet similar results had been previously presented by Schoenmakers *et al.* [17]. Neither pectoral muscle shortening nor upper torso muscle weakness was found in any of the 16 studied patients with PE. The percentage of weakened muscles of the thoracic spine and abdomen in the same study was 29%.

The internal rotators of both humeral joints were more often shortened (right $p = 0.0155$, left $p = 0.00858$) in boys without the deformity than in the test group, as were the external rotators, but in the latter case there were no statistically significant differences between the groups. During the tests of the internal and external rotator muscle length in the humeral joints in boys with PE, attention was paid to the very rare occurrence of disorders involving reduced mobility of the joints. No significant restrictions were reported which could be explained by the protruding humeral joints in these patients as a result of a hunched posture, or as a result of the chest wall deformity.

Similar muscle imbalance can be observed in the lumbar region of the spine and pelvis. Lumbar spinal extensors are often characterized by increased muscle tone, while the abdominal muscles are relaxed. The muscles responsible for flexion in the hip joint tend to shorten, while the gluteus maximus muscles are usually stretched, which is an obstacle to achieving the full range of motion in the hip joint during gait, as well as the causative agent of hamstring injury. Shortening of the hip-joint adductors often occurs together with gluteal muscle weakness (small and medium), which can lead to chronic groin load [16].

The iliopsoas muscle in both groups was substantially shortened in many cases, but significantly more often ($p = 0.04283$) in boys from the control group with respect to the left lower extremity (right $p = 0.90698$). Reduced flexibility of this right-limb muscle was observed in 70% of the 30 boys, and in the left limb in 80%. The strongest hip flexor was also shortened in most cases in patients examined by Kania-Gudzio and Wiernicka in 2002 [12], although it should be noted that they used a different test for the evaluation of iliopsoas muscle flexibility. Of 74 boys aged 13-15 years, 59.4% had a shortened iliopsoas muscle in the right lower extremity, and 41.9% in the left.

Other authors have also reported on the above muscle shortening in their research. Jorgensson [18] examined 60 young males and he detected reduced flexibility in 33%. Jorgensson also cited unpublished results of Barber *et al.* (1985), who observed the disorder in 35% of 20 young people, and the congress report of Hellsing *et al.* (1987) according to which the muscle shortening was found in 21.5% of 999 males and females. The iliopsoas muscle shortening in these studies was associated with an increased incidence of lumbar lordosis, which is confirmed by Rakowski [9]. Moreover, it can also cause an increase in mobility in the area of the thoracolumbar junction and upper lumbar segments, as a compensatory response. In most cases boys with PE were characterized by increased lordosis. Of 19 patients tested, 68.42% had a shortened iliopsoas in the right lower extremity, and 52.63% in the left.

Symptoms of the shortened rectus femoris in both lower extremities in both groups are similar to those of the iliopsoas muscle; however, the reduction was significantly more frequently ($p$ = 0.00002) observed in the control group for both lower extremities. In boys with PE the muscle shortening may be caused by muscle static instability resulting from lumbar hyperlordosis, which in turn may arise through increased thoracic kyphosis [9]. The ischiocrural muscles were shortened significantly more often in the control group, while in the test group, the percentage of boys with muscular flexibility disorders was more than a half. Given the shortened rectus femoris in both groups, the ischiocrural muscles should be weakened and flabby [9], but the more frequently observed length disorders of the ischiocrural muscles can be explained by the reduction of the piriformis muscle in boys from the control group and the test group.

The results in both groups confirm the observation that children spend more and more time in a sitting position (at school, at home, in front of a computer), and too little time is spent on stretching the muscles at physical education classes, often as a result of catching up with the material or lack of appropriate facilities at school (a proper gym). When the results were developed, parents of boys in the control group, the school principal and the teacher of physical education were instructed to implement appropriate body stretching techniques, especially for the lower extremity muscles. As it turned out, there was no need to develop this type of recommendations for the boys with PE, because no relation between the deformity and the length and flexibility of the lower extremity muscles was detected. As Fonkalsrud [2] noted, people with PE are often less physically active, less lively and apathetic, and therefore the invalid state of their lower extremity muscle length most often results simply from lack of exercise.

There is no consensus in the current literature about the role of physiotherapy in the treatment of anterior chest wall deformities (PE and *pectus carinatum*). Physiotherapy aimed mainly at reducing the visible chest depression is pointless, because the only effective treatment of PE is surgery (although there are no studies on the possibility of halting the progress of the deformity through physiotherapy). The minimally invasive Nuss procedure is characterized by high efficiency for good and very good results in a sustained and stable correction of the deformity. Excellent or good results were achieved in more than 90% of cases of surgical correction [5]. However, ensuring the correct muscle length and flexibility in children with PE is extremely important so that, despite the existing poor posture, the body could grow properly. In addition, physiotherapy may prevent postoperative pulmonary complications, and finally improve the external appearance of a patient through the development of appropriate muscle groups (chest muscles, latissimus dorsi, trapezius and abdominal muscles) [1]. It is also believed that postoperative breathing exercises can prevent atelectasis and pneumonia [19].

One of the very few articles [17] devoted to the role of pre- and postoperative physiotherapy in patients with PE does not specify the type and duration of rehabilitation. It turns out that the authors believe that the patients they examined, with the exception of 4 (of 16), who experienced respiratory problems, do not differ from normal children in terms of their muscle strength and length or joint mobility. It is not clear how the authors came to this conclusion because they do not present results for healthy children in the control group. Willital *et al.* [6] claim that 87% of patients with PE have improper posture which is characterized by slumping shoulders and protuberant abdomen. This results from weak back, humeral and abdominal muscles. The authors recommend intensive training of these muscles after surgery, which is to prevent the recurrence of defects. It should be taken into account, however, that in the period immediately after surgery intensive muscle training is not possible due to severe pain. Therefore, it seems highly reasonable to recommend such training prior to surgery, in order to expect better results after surgery. Canavan and Cahalin [20] suggest the use of an integrated physiotherapy programme prior to PE corrective surgery to enhance tolerance of effort and ability to absorb oxygen through the body. The authors also point to the need for further research leading to the development of an optimal physiotherapy programme for patients with this deformity.

## Conclusions

1. It is advised to restore muscle balance within the chest in the preoperative rehabilitation of patients with PE. It seems at least equally important to take care of the function of the deep stabilizers, the so-called lower abdomen (transverse muscle, multifidus, oblique abdominal muscles).
2. A physiotherapy programme should be planned on an individual basis, taking into account the results of muscle length functional testing.
3. Proper relaxation and strengthening of the muscles located directly in the operated area can result, in the opinion of the authors, in a more favourable cosmetic result after surgery. Adequate preparation for the procedure should translate well to a faster recovery.

*This work was partially supported by an internal grant for young scientists at the Eugeniusz Piasecki University School of Physical Education.*

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