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Exercise therapy in the correction of pectus excavatum

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Introduction

Pectus deformities are common abnormalities of the thorax and affect an estimate of 6 to 8 per 1000 children.[1] The cause of pectus deformities is accepted to be an abnormal overgrowth of cartilage between the ribs and sternum that pushes the sternum inward (pectus excavatum) or outward (pectus carinatum) causing a funnel-chest or pigeon-chest respectively. Pectus excavatum is more commonly encountered and it may impact on the pulmonary and cardiac functions in severe cases. Surgical intervention is an accepted practice of intervention for severe pectus excavatum.[2, 3] Other than surgical intervention, exercise is another treatment alternative.[4] Clinically, a number of patients were observed to benefit from exercise training although the long term effect and its physiological benefits are still unknown.

Therapeutic exercises to improve pectus excavatum deformity

In theory, the main question in managing pectus excavatum is how to pull the sunken anterior chest wall outward and forward. The inspiratory muscles that help in pulling up the chest wall should be considered. This includes the scalenus anterior and medius, and the sternocleidomastoid. The serratus anterior and pectoralis minor also participate during forced inspiration. Intercostal muscles help the elevation of the chest wall only when the first ribs fixed and elevated. All these mentioned muscles, however, cannot directly add their pull of force on the lower sternum and sunken ribs, which are commonly encountered in pectus excavatum. Their effect of pull seems limited and mainly affects the upper chest wall.

However, if the upper limbs can be supported by grasping a chair back or table, the sternal origin of the pectoralis major muscles can also assist the elevation process of the chest wall. Pectoralis major is a thick and powerful triangular muscle. Its fibers are inserted by a bilaminar tendon into the lateral lip of the bicipital groove of the humerus. It originates from the sternal half of the clavicle, the anterior sternal surface to the level of the sixth or seventh costal cartilage, the first to seventh costal cartilages, the sternal end of the sixth rib and the aponeurosis of obliquus extenus abdominus. If the insertion of the arm can be put and fixed in an upward stretched position, all these origins especially the latter four can directly and forcibly pull the sunken sternum and infolding ribs up during the muscle contraction. The concept of “reverse origin and insertion” of this muscle action is applied. The direction of pull from the stretched arm position along the sternocostal fibers of the pectoralis major acts effectively on the depressed chest wall. Pectoralis major situated in its mid range of length enables it to recruit the greatest amount of muscle fibers to exert powerful pulling force. With these in mind, it provides the direction for the design of the following suggested exercise program.

With an increase in strength and muscle tone by training, the chest wall deformity may be diminished or at least maintained. In addition, the increase in intensity of training, especially to the anterior chest wall may help to build up larger muscle bulk and a better cosmetic outlook.

Steps to improve the chest wall appearance

In order to improve the chest wall appearance, the patient need to follow the following steps in sequence in their daily exercise program. They are:

1. To increase the mobility and flexibility of the spine and chest wall.
2. To lengthen any tightened and shortened structures.
3. To strengthen muscles in elevating and expanding the depressed chest wall.
4. To restore normal posture.

The first two steps are to mobilize the articulating joints and to lengthen any tight soft tissue around the chest wall so that less impedance will be encountered during the elevation of depressed chest. Exercises of these two steps can, at the same time, serve as a warm-up. They condition the musculo-skeletal in preparing for the following vigorous exercises. These exercises will be done with intensive training to strengthen inspiratory muscles, which are essential in elevating the depressed chest wall. Training of pectoralis major, especially the sternocostal fibres, will be of utmost importance. With better chest wall mobility and muscle tone after these preparatory steps, the patient will be conditioned to learn the postural correction exercises. It is important that the patient must persist in performing these exercises.

Suggested exercise program

Mobilizing and stretching exercise

1. *Forward arm stretching in pone kneeling*
   The patient is positioned in an inclined prone kneeling position with hands stretching forward and

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supported by wall bar (about 2 to 3 feet high from ground) (Figure 1). Slowly lower his upper body and press his scapula towards the floor. Experience the stretch feeling at the front axilla and shoulder. Hold 8 seconds (may get a deep breathe and hold to increasingly stretch the chest wall) and release. Repeat for 20 times and 4 sessions per day.
Purpose: Stretch all anterior chest wall muscles especially pectoralis major and extend the upper back.

Figure 1. Forward arm stretching in pone kneeling.

2. *Upper trunk rotation in standing*
The patient is to stand obliquely to a wall. The near hand is put on the wall a bit higher than the shoulder level. The patient's pelvis turns to the opposite side while still leaving the hand fixed on the wall (Figure 2). A stretch is felt at the anterior shoulder and upper chest wall. Hold 8 second, then release and return to the original position. Take a rest and repeat on the other side. Repeat for 20 cycles and 4 sessions per day.
Purpose: Rotation gives the greatest range of movement for thoracic vertebrae allowing stretch to ligaments, muscles and joints around the chest wall in a different direction.

Figure 2. Upper trunk rotation in standing.

3. *Upper trunk side flexion in sitting*
The patient is seated on a chair. Side bend to one side with the opposite hand crossing over the head to another side (Figure 3). A stretching feeling is felt on the other side of trunk. Hold 8 seconds (may get a deep breathe and hold to increasingly stretch the chest wall) and then return to the original position. Take a rest and repeat on the other side. Repeat for 20 times and 4 sessions per day.
Purpose: Similar to the 2nd exercise.

Figure 3. Upper trunk side flexion in sitting.

Strengthening exercise

1. *Weight lifting in stretch supine lying*
The patient is positioned in supine with the upper trunk on a small foam roll around 2 to 3 inches in diameter (if patient can't tolerate, just lie flat). The arms are put in an upward stretched position. The hands should hold on a fixed wall bar (Figure 4) or hardly movable weight about 10 inches from the surface of the bed (pillows may be used to support the weight) (Figure 5). Deeply inspire and exert maximal force in lifting the wall bar or weight. Hold

Figure 4. Lifting wall bar in stretch supine lying (with foam roll).

Figure 5. Weight lifting in stretch supine lying (pillow support the weight).

8 seconds and relax. Repeat 10 times as 1 lot. Take rest then and repeat another 2 lots performing a total of 30 repetitions and 4 sessions per day.
Purpose: By the technique of "reverse origin and insertion", the arms are being fixed and the anterior chest wall is lifted up mainly by the pectoralis major and minor. Maximal force exertion allows recruitment of surrounding respiratory muscles for training. The foam roll under the upper to middle part of the trunk exerts postero-anterior force to the thoracic spine helping in extension, which mobilizes and corrects any thoracic kyphosis . The depressed chest will also be "opened" up facilitating the elevation of the chest wall. Arms, being in a mid-length muscle range, are capable to exert the greatest force to elevate the depressed chest. Tone of pectorlis major is built up for better posture and outlook.

2. *Upper trunk extension in prone lying*
The patient is positioned in prone lying with one or two pillows under the tummy (avoiding the lower anterior chest pressing on the pillow) (Figure 6). The hands are placed behind the head. The feet may be fixed on wall bar. Deeply inspire and extend the upper trunk with arms arching back. Stay and hold 8 seconds and then relax. Repeat 10 times as 1 lot. Take rest then and repeat another 2 lots. Perform a total of 30 repetitions and 4 sessions per day.
Purpose: The strengthened upper back muscles help to balance the improved muscle force of the anterior chest wall muscle. This prevents the development of thoracic kyphosis due to strong anterior muscle pull and keeps a good posture.

Figure 6. Upper trunk extension in prone lying.

3. *Push up*
The patient is positioned in prone lying and both hands are used to push up his body (Figure 7). The level of difficulty depends on the actual ability of the patients (1st level – upper trunk pushed up, 2nd level – whole body pushed up in one piece, 3rd level – push and clap both hands in mid air). Start with the 1st level and when the patient is able to finish the level easily, he may proceed to next level). Repeat 10 times as 1 lot. Take rest and then repeat another 2 lots performing a total of 30 repetitions and 4 sessions per day.
Purpose: The exercise aims at general strengthening of the chest wall. Moreover, the high intensity but low frequency impacting force may be advantageous to stimulate remodeling and shaping of the chest wall deformity. Bone mineralization may also be enhanced.

Figure 7. Push up.

4. *Hands up and down movement behind and by the sides of body (with theraband)*
The patient is positioned in sitting or standing with both arms in a stretched position. Each hand holds one end of a theraband or a spring (resistance should be set at 10 repetitive maximum, RM, i.e. the resistance that one can perform 10 repetitions but no more). Then stretch the theraband and maintain the elbows straight (Figure 8). Slowly put the hands behind and pass by the sides of body and then down below buttock. After 3 seconds rest, the hands slowly go up and along the same track to the starting position. Repeat 10 times as 1 lot. Take rest and then repeat another 2 lots performing a total 30 repetitions and 4 sessions per day.

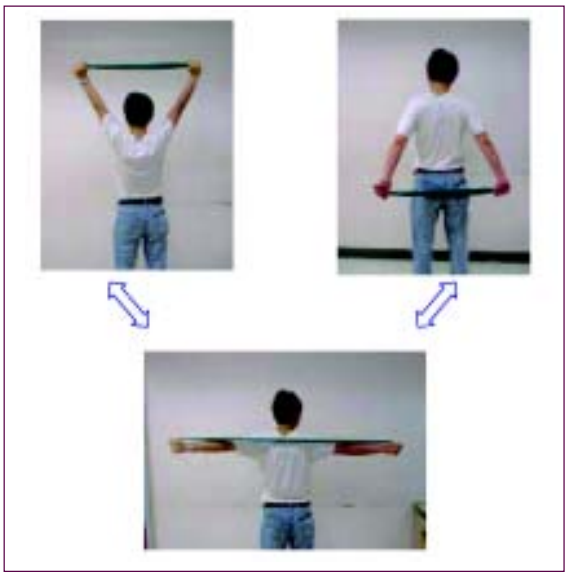

Figure 8. Hands up and down behind and by the sides of body (with theraband).

Purpose: The exercise is used to strengthen the neck, shoulder, upper back and anterior upper chest muscles. It can be treated as a kind of stabilization exercise to the upper thorax.

Postural correction

The above exercises help correct the depressed chest wall deformity and also the thoracic kyphosis. However, as the postural problems of individual patients may have different clinical presentations and causes. It is impossible to have one exercise program to suit all patients for postural correction. It would be best to consult doctors or physiotherapists in postural exercises. On the whole, the exercises should mainly concentrate on realignment of good posture, both static and dynamic. To maintain a sense of good posture in both static and dynamic work is another area to be tackled. Proprioceptive exercise training should also be introduced. In addition, the final postural exercises can act as some cool down activities.

Although some exercises have been suggested, they should preferably be done within the patient's tolerance. The suggested intensity and frequency of treatment should act as a beginning reference. The parameters should be modified whenever the conditions seem necessary. With improvement in exercise performance and effect, patients may increase their treatment frequency and intensity, under the advice from a doctor or a physiotherapist. For young patients, who can't perform these exercises, their parents may help passively to stretch their limbs similar to the described moblising and stretching exercises. For the strengthening exercises, they can try swimming in free-style. The alternate climbing action of both hands is good training for pectoralis major.

Discussion

Performance of the above exercises will see immediate elevation of chest wall. The long term effect of the exercises is unknown. However, some reviews throw light of hope that throughout life, the skeleton is continuously changing to adapt its form and structure to suit their functional needs.[5] Bone growth and maintenance is always a process between osteoblastic and osteoclastic activities. If the former activity is greater than the latter, bone grows. Otherwise bone will be resorbed and the mineral will be redistributed to build up bone against load stress in other areas.[6] This is reflected by the Wolff's law, a principle assuming that mechanical stresses influence the remodeling process of bone and subsequently the structure and strength of bone.[7] All cells participating in the remodeling process have been termed the bone multicellular unit and are thought to proceed through activation, resorption, and formation, during which a quantum of bone is exchanged. The alteration in bone shape was evidenced in a study using immature Holstein bull calves as a model, short-duration but high-intensity exercise to stimulate bone formation and altering bone shape was observed in comparison with the stalled and group-housed calves.[8] Dynamic loads trigger the adaptive response in bone.[9] Whether the shape and deformity of pectus excavatum be improved with the above exercises require further study.

Most studies show that mineralisation of bone can be developed through impacting exercises[10] to increase the bone mass density of the weight bearing bone. There is also evidence that bone developmental changes in bone strength might also be secondary to the increasing loads imposed by larger muscle forces. The results of this study are compatible with the view that bone development might be driven by muscle development.[11] This gives an implication that high intensity loading during exercise design may help to increase mineralization of the bone to maintain a reformed shape.

From the skeletal point of view, bone shaping should be done early before it is mature. Since the ossification of the chest wall begins in utero and continues to approximately the 25th year, and even earlier for the rib as ossification is completed by age 20.[12] Therefore the best training period should be started earlier than this age and childhood is probably the ideal period.

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