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Research

Trunk stabilising exercises promote sternal stability in patients after median sternotomy for heart valve surgery: a randomised trial

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KEY WORDS

Trunk stabilising exercises
Sternal instability
Median sternotomy
Heart valve surgery
Randomised trial

ABSTRACT

Question: What is the effect of trunk stabilising exercises on sternal stability in women who have undergone heart valve surgery via median sternotomy? **Design**: Randomised controlled trial with concealed allocation, assessor blinding and intention-to-treat analysis. **Participants**: Thirty-six women aged 40 to 50 years who had undergone heart valve surgery via median sternotomy 7 days before enrolment. **Intervention**: All participants in both groups received cardiac rehabilitation during hospitalisation and three times per week for 4 weeks after discharge. In addition, participants in the experimental group were prescribed a regimen of trunk stabilising exercises to be performed three times per week for 4 weeks. At each exercise session, each of 11 exercises were to be performed with five to ten repetitions. **Outcome measures**: The primary outcome was sternal separation (the distance between the two halves of the bisected sternum). The secondary outcome was the Sternal Instability Scale from 0 (no instability) to 3 (an unstable sternum with substantial movement or separation). Measures were taken before and after the 4-week intervention period. **Results**: After the 4-week intervention period, the experimental group had a greater decrease in sternal separation by 0.09 cm (95% CI 0.07 to 0.11). The experimental group was twice as likely to improve by at least one grade on the Sternal Instability Scale by 4 weeks (RR 2.00, 95% CI 1.07 to 3.75). The experimental group was almost three times as likely to have a clinically stable sternum (grade 0 on the Sternal Instability Scale) by 4 weeks (RR 2.75, 95% CI 1.07 to 7.04). **Conclusion**: Trunk stabilising exercises were an effective and feasible method of promoting sternal stability in women who underwent heart valve surgery via median sternotomy. **Trial registration**: NCT04632914. **[Essam El-Sayed Felaya E, Abd Al-Salam EH, Shaaban Abd El-Azeim A (2022) Trunk stabilising exercises promote sternal stability in patients after median sternotomy for heart valve surgery: a randomised trial. *Journal of Physiotherapy* 68:197–202]**

Introduction

Valvular heart disease is a growing health issue, with an overall prevalence of 2 to 5% among the general population and a prevalence of 13% in people aged > 75 years.[1,2] Heart valve surgery can potentially be a life-saving intervention for people with serious symptomatic valve disease.[1]

Up to 27% of patients undergoing valve surgery may need rehospitalisation within 30 days of discharge from hospital.[3–6] Some postoperative patients experience distress and fear regarding hospital readmission, re-operation, post-surgical complications or deconditioning,[7] which may preclude or hinder their functional recovery and affect their activities of daily living.[8]

Complications related to the surgical approach can often be identified early after heart valve surgery and increase the need for unexpected healthcare contacts and hospital readmission.[9,10] Healing complications after median sternotomy include instability in the sternum, non-union and wound infection. Although it is rare for healing complications to become major (ranging from 0.3 to 5% of cases), major complications are very disruptive.[11] Sternal instability often occurs during the first 2 weeks after open heart surgery, after which healing of the sternum should lead to sternal stability.[12] Poor, incomplete or delayed healing of the divided sternum can prolong the hospitalisation of patients, increase healthcare expenditure and restrict the return of patients to work or social activities. Furthermore, delayed sternal healing increases the likelihood of infection deep in the sternal wound.[13]

A view of the underlying non-physiological motion of the edges of the divided sternum is helpful to guide recommendations for interventions to reduce excessive motion of the sternal edges and thereby usually minimise the symptoms; this situation is especially important in the case of patients whose sternum cannot be treated surgically.[14]

Trunk stabilising exercises recruit and facilitate the muscles of the abdomen and anterior chest wall to help in the stabilisation of the divided sternum, with the intention of minimising unwanted motion

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in both the sagittal and horizontal planes during trunk movements. Patients with sternal instability after open heart surgery often have symptoms of pain and restlessness; these can be minimised by reducing the amount of improper displacement between the edges of the bisected sternum, thus providing conservative therapy for post-operative sternal instability.[15]

Few studies have investigated the effects of therapeutic modalities and nonpharmacological treatment on sternal stability after heart valve surgery. Therefore, this study aimed to implement trunk stabilising exercises in patients who had undergone heart valve surgery via median sternotomy, and then evaluate the effect of this therapeutic modality on sternal stability.

Therefore, the research question for this randomised trial was:

What is the effect of trunk stabilising exercises on sternal stability in women who have undergone heart valve surgery via median sternotomy?

Method

Design

An assessor-blinded, parallel, two-group, randomised controlled trial enrolled patients who underwent heart valve surgery via median sternotomy. On day 7 after surgery, participants were randomly allocated to one of two groups via a computer-generated, concealed allocation schedule. Participants allocated to the experimental group were taught and prescribed trunk stabilising exercises in addition to a cardiac rehabilitation program. Participants allocated to the control group received the cardiac rehabilitation program only. Both groups received the same medical care and physical rehabilitation program during their hospitalisation period. Clinical data were measured at baseline and 4 weeks after the baseline measure. Data measurement and extraction were each carried out without knowledge of the group to which each participant belonged.

Participants, therapists, centres

This research was conducted at the National Heart Institute in Giza, Egypt, on patients who were undergoing heart valve surgery. All the patients referred to the National Heart Institute between November 2020 and January 2021 for heart valve surgery were screened for possible participation in this study if they met the inclusion criteria. Patients at the National Heart Institute who undergo elective heart valve surgery receive a longitudinal median sternotomy and a period of extracorporeal circulation.

The inclusion criteria were: age between 40 and 50 years; female gender; haemodynamic stability; body mass index (BMI) between 25 and 29.9 kg/m^2; and acute sternal instability following cardiac surgery. The presence of sternal instability was based on the patients having had recent median sternotomy and then confirmed as sternal separation measured by ultrasound at baseline. The exclusion criteria were: previous thoracic surgery; elective and urgent coronary artery bypass surgery; respiratory insufficiency after surgery, manifesting as hypoxaemia (partial pressure of oxygen in arterial blood < 60 mmHg);[13] renal insufficiency after surgery (serum creatinine ≥ 1.8 mg/dl);[16] low cardiac output syndrome with ST-segment elevation in multiple electrocardiogram leads, cardiac arrhythmias or hypotension according to the American College of Cardiology Foundation and American Heart Association;[17] other medical conditions such as diabetes, uncontrolled hypertension and obesity; and a history of conditions that may have affected the provision of physiotherapy interventions such as severe asthma, chronic airflow limitation, bronchiectasis, ankylosing spondylitis or lumbar disc prolapse.

Intervention

Experimental group

The experimental intervention consisted of trunk stabilising exercises in addition to a routine cardiac rehabilitation program provided by a trained physiotherapist. Trunk stabilising exercises commenced on the seventh day after surgery and were administered to every patient from different positions (supine, sitting and standing). Participants were prescribed 5 to 10 repetitions of each exercise, one session per day, 3 days per week, for 4 consecutive weeks. El-Ansary and colleagues (2007), who conducted a study to correlate pain with upper limb movement in patients suffering from sternal instability after cardiac surgery, reported that the degree of sternal separation was not correlated with the type of upper limb activity, but both unilateral and unilateral loaded upper extremity movements were associated with more sternal pain than bilateral movements.[18] Accordingly, the trunk stabilising exercises were applied to the patients in line with the recommendations from that study. The trunk stabilising exercises are presented in Appendix 1 on the eAddenda. Participants in the experimental group also underwent a routine cardiac rehabilitation program, described below.

Control group

Participants in the control group were not shown, taught or prescribed the trunk stabilising exercises that were prescribed for the experimental group. Participants in the control group underwent a routine cardiac rehabilitation program only. Inpatient cardiac rehabilitation (phase I) was conducted for patients during the hospitalisation period; it comprised early progressive mobilisation of the patient to be independent in basic household activities. The program also provided concise instructions on: the nature of the disease, rehabilitation, control of risk factors and follow-up scheduling.[19] After discharge, the patients commenced the outpatient phase (phase II) of the cardiac rehabilitation program for 40 to 60 minutes, three times per week for 4 consecutive weeks. The exercise undertaken during this phase used an arm ergometer, a leg ergometer and a treadmill. As described by Bartels,[20] a moderate-intensity program was prescribed by establishing a target heart rate (in beats/minute) of 75 to 80% of maximum heart rate (defined as 220 – age in years). In the presence of β-blockers, the target HR was 20 beats/minute above the resting heart rate. Each patient's heart rate during the cardiac rehabilitation sessions was monitored via a telemetry system.[20]

Outcome measures

The baseline characteristics collected for each participant were age, weight, height and BMI.

Primary outcome

The primary outcome was sternal separation. An ultrasound unit was used to assess the transverse sternal separation distance (ie, between the two halves of the sternum). The point of greatest separation of the two halves of the sternum was marked for each patient in the supine lying position with the head of the treatment bed at 30° inclination.[18,21,22] The separation at this point was then quantified in centimetres from the projected images of the ultrasound unit, as shown in Figures 1 and 2.

Secondary outcome

The Sternal Instability Scale is a clinical physical evaluation instrument that is designed to evaluate the integrity of the sternum and transfer the results of the assessment to an acceptable grade. It consists of a 4-point scale bounded by grade 0 (a clinically stable sternum with no noticeable motion or separation of the edges of the sternum) and grade 3 (a separated sternum with substantial movement or separation between the two halves of the sternum).[21]

Data analysis

The number of participants required for this trial was calculated using commercial software[a], based on identifying a standardised effect size of 1.05, with the anticipated standard deviation calculated from the pilot study on 10 patients.

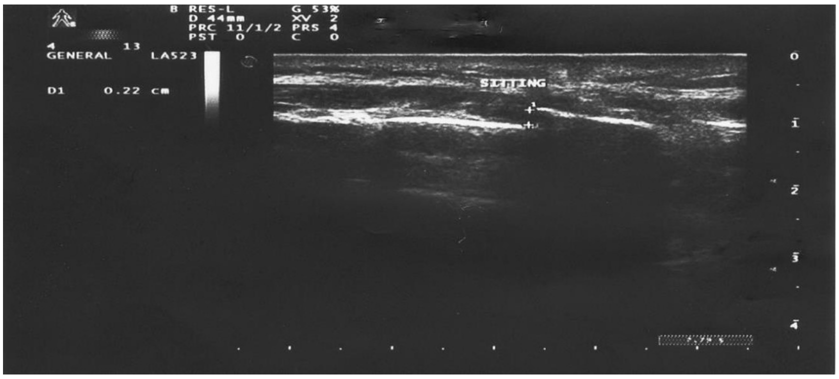

Figure 1. Pre-treatment ultrasound assessment.

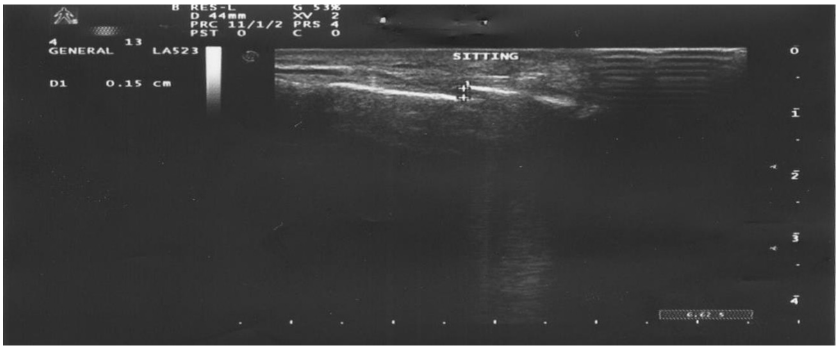

Figure 2. Post-treatment ultrasound assessment.

Analyses were performed using commercial software[a]. The continuous data (age, height, weight, BMI and sternal separation) were subjected to a test of normality (Shapiro-Wilk test). All data were normally distributed within each group. Therefore, the continuous variables were summarised using means and standard deviations. The effect of the intervention on sternal separation was estimated as the mean between-group difference with a 95% confidence interval. The Sternal Instability Scale provides ordinal data, so this was analysed by comparing the proportion of participants in each group who improved by at least one grade on the scale by Week 4 and who exhibited a Grade 0 (stable sternum) at the Week 4 assessment. These proportions were compared between groups and reported as relative risk with a 95% confidence interval.

Results

Flow of participants through the trial

Figure 3 shows the design of the trial and flow of participants through the trial. A total of 43 female patients were screened for this study. During the screening for eligibility, seven patients were excluded for the reasons shown in Figure 3. A total of 36 patients met the selection criteria and were randomly assigned to one of two groups using the random ordered allocations in the sealed envelopes, which had a 1:1 ratio of experimental:control allocations.

Characteristics of the participants

The two groups were similar at baseline regarding age, weight, height, and BMI (Table 1). The two groups were also similar regarding their baseline sternal separation (see the first two columns of data in Table 2) and their baseline scores on the Sternal Instability Scale (Table 1).

Effect of the intervention

Primary outcome

At Week 4, sternal separation had improved by 0.10 cm (SD 0.04) in the experimental group and 0.01 cm (SD 0.02) in the control group. Therefore, the between-group difference in change provided an estimate of the effect of the exercise regimen on sternal separation: MD 0.09 cm (95% CI 0.07 to 0.11) less separation in the experimental group (Table 2).

Secondary outcomes

When the Sternal Instability Scale scores were used to assess the proportion of participants in each group who improved by at least one grade by Week 4, those in the experimental group were twice as likely to demonstrate this degree of improvement: RR 2.00 (95% CI 1.07 to 3.75).

When the Sternal Instability Scale scores were used to assess the proportion of participants in each group that had a grade 0 (stable sternum) at Week 4, those in the experimental group were almost three times as likely to demonstrate this degree of improvement: RR 2.75 (95% CI 1.07 to 7.04). These results are presented in Table 3 and individual participant data are presented in Table 4 on the eAddenda.

Discussion

This randomised clinical trial is the first to analyse the effects of early postoperative trunk stabilising exercises on sternal instability and separation in patients who underwent median sternotomy for cardiac valve surgery. The analyses of the trial's data estimate that the average effect of the exercise program in this population is to reduce sternal separation by about 0.1 cm and to double the likelihood of improving by at least one grade on the Sternal Instability Scale. Furthermore, the exercise program leads to an almost threefold increase in the likelihood of having a clinically stable sternum 4 weeks after median sternotomy. Therefore, the exercise program could play a major role in increasing sternal stability after median sternotomy

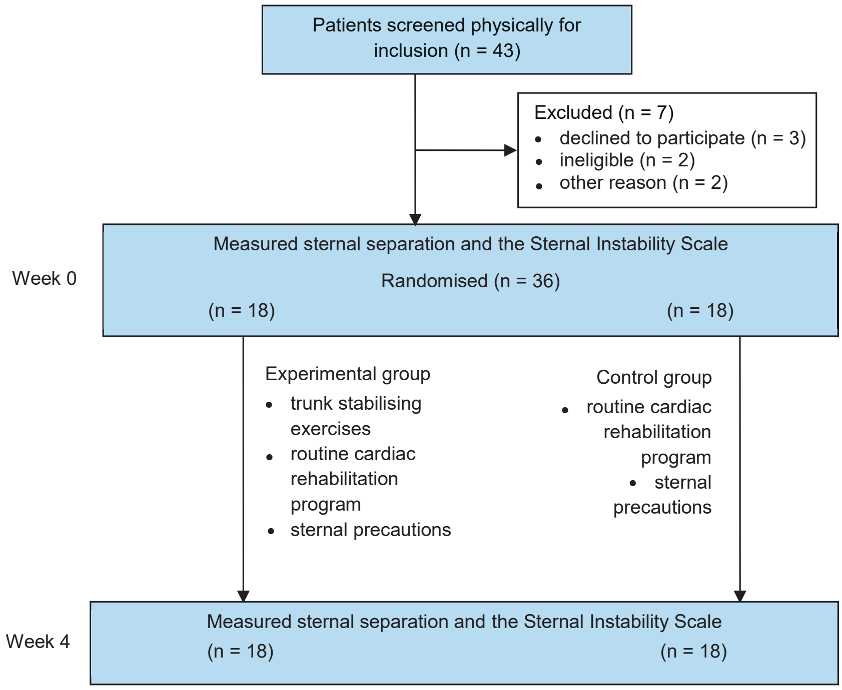

Figure 3. Design and flow of participants through the trial.

Table 1
Baseline characteristics of the participants.

Characteristic	Groups	
	Exp (n = 18)	Con (n = 18)
Age *(y)*, mean (SD)	46 (3)	48 (2)
Height *(cm)*, mean (SD)	166 (7)	167 (12)
Weight *(kg)*, mean (SD)	79 (6)	78 (12)
BMI *(kg/m²)*, mean (SD)	28.5 (1.4)	27.8 (1.2)
SIS score *(0 to 3)*, n (%)		
0	4	6
1	14	12
2	0	0
3	0	0

BMI = body mass index, Con = control group, Exp = experimental group, SIS = Sternal Instability Scale.

for cardiac valve surgery, which should help the patient to regain their independence and re-commence activities of daily living.

It is important to consider the magnitude and precision of these estimates of the treatment effects. The estimate of the effect on sternal separation (0.09 cm) had a very narrow confidence interval (0.07 to 0.11), so the average effect in the wider population of people undergoing valve surgery via median sternotomy is fairly certain to be about 0.1 cm less sternal separation. While this may seem very small, the average amount of separation was only a little over 0.2 cm in both groups at baseline. The analyses of the Sternal Instability Scale strongly favoured the trunk stabilising exercises but there was greater uncertainty in the estimates. For example, although the experimental group was twice as likely to improve by at least one grade on the Sternal Instability Scale (RR 2.00), the confidence interval (1.07 to 3.75) shows that the true average effect in the wider population may lie somewhere between a very slight increase or almost a fourfold increase in the likelihood of improving by at least one grade. Participants in the experimental group were almost three times as likely to have a clinically stable sternum at Week 4, compared with those in the control group (RR 2.75). Again, the confidence interval spanned from a very slight improvement to a very large increase in the likelihood of having a clinically stable sternum at Week 4 (1.07 to 7.04).

These enhancements in the trunk stabilising exercise group may be attributed to the bracing effect of the anterior trunk muscles that are oriented in the transverse direction. Therefore, in the lower trunk, the sacroiliac joint was efficiently locked.[23–25] It was also suggested that the contraction of these transversely oriented muscles, such as the transverse abdominis, can create forces that produce a 'corset-like' motion, which effectively retains sacroiliac joint stability and decrease its laxity.[23–25] Additionally, trunk stabilising exercises recruit muscles in a horizontal direction, such as the transverse abdominis muscle, which operates perpendicularly to the sagittal plane in which the sternotomy incision and the SIJ are similarly directed, thereby preserving the stability of the trunk, particularly the bisected sternum, as well as reducing sternal motion and separation.[23–25]

El-Ansary and colleagues (2007) conducted a prospective randomised crossover trial on patients with chronic sternal instability (ie, lasting months to years after heart surgery) and found greater degrees of complicated sternal motion and separation. Their research intervention comprised trunk stabilising exercises. Their findings revealed that sternal separation reduced in the supine lying and sitting positions more during trunk stabilising exercise application than during the control period.[15] Helmy and colleagues[26] investigated the effects of low-level laser therapy versus trunk stabilising exercises on the post-sternotomy healing of 45 patients who underwent coronary artery bypass grafting surgery. Their results showed that both interventions were effective methods for healing after surgery, with the laser therapy showing superiority. Furthermore, their effects were associated with a reduction in pain and recovery of activities of daily living.[26] These previous studies reinforce the current results because they suggest that, in addition to trunk stabilising exercises after heart valve surgery accelerating sternotomy healing, it can be anticipated that they would also reduce sternal pain and prevent complications that can arise during prolonged sternal healing. A limitation of the current trial was that it did not measure pain, longer-term complications and return to

Table 2
Mean (SD) of groups, mean (SD) within-group difference and mean (95% CI) between-group difference for sternal separation.

Outcome	Groups				Within-group difference		Between-group difference
	Week 0		Week 4		Week 4 minus Week 0		Week 4 minus Week 0
	Exp (n = 18)	Con (n = 18)	Exp (n = 18)	Con (n = 18)	Exp	Con	Exp minus Con
Sternal separation *(cm)*	0.23 (0.04)	0.23 (0.11)	0.13 (0.03)	0.22 (0.10)	–0.10 (0.04)	–0.01 (0.02)	–0.09 (–0.11 to –0.07)

Con = control group, Exp = experimental group.

Table 3
Number (proportion) of participants in each group who improved their Sternal Instability Scale grade to achieve the outcomes shown, and the relative risk (95% CI) between the groups.

Outcome	Groups		Relative risk (95% CI)
	Exp (n = 18)	Con (n = 18)	Exp relative to Con
Improvement $\geq$ 1 on Sternal Instability Scale	14 (0.78)	7 (0.39)	2.00 (1.07 to 3.75)
Grade 0 on Sternal Instability Scale at Week 4	11 (0.61)	4 (0.22)	2.75 (1.07 to 7.04)

Con = control group, Exp = experimental group.

independent daily activities. However, the outcome measures that were included were analysed with complete follow-up of all randomised participants.

In conclusion, this study showed that trunk stabilising exercises are an effective and feasible method of promoting sternal stability in women who underwent heart valve surgery via median sternotomy. The estimated effect on the sternal separation was small but very precise. Although the main estimates of the effects on the clinical measures of sternal stability were very favourable, they come with substantial uncertainty.

What was already known on this topic: Sternal instability after median sternotomy is common. Delayed or incomplete healing of the divided sternum can prolong hospitalisation, increase healthcare costs and delay return to independent activities of daily living.
What this study adds: Among women who have had a sternotomy for heart valve surgery, trunk stabilising exercises commenced 7 days after surgery decreased the amount of sternal separation and increased clinical measures of sternal stability.

Footnotes: [a] G*Power version 3.1.9.2, G*Power software Inc, Kiel, Germany.
[b] SPSS version 23.0, IBM Corp, New York, USA.

eAddenda: Table 4 and Appendix 1 can be found online at https://doi.org/10.1016/j.jphys.2022.06.002

Ethics approval: This study was approved by the Institutional Ethics Committee of Physical Therapy Faculty, Cairo University, Giza, Egypt. Registration approval number: (P.T.REC/012/002895). A written declaration of informed consent was signed by all the patients after surgery for participation and publication of results. The trial was conducted according to the Declaration of Helsinki.

Competing interests: All authors completed a uniform disclosure form and declare that they have no conflicts of interest.

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