Gissing and Roos
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Respiratory muscle strength, pain and pulmonary complications in adult patients following median sternotomy during hospital stay: a longitudinal observational study

Cary-Anne Gissing[1] and Ronel Roos[1*]

Abstract

Background Pulmonary complications influence morbidity, mortality and hospital stay in patients following cardiac surgery. Acute post-operative pain and less than optimal respiratory muscle strength may affect a patient's ability to take deep breaths, cough and clear secretions, thereby influencing recovery after surgery. To date, few studies described patients' pain levels, respiratory muscle strength and the presence of pulmonary dysfunction preoperatively and evaluated the effect of a median sternotomy on parameters at hospital discharge. This study investigates this in patients at a private urban hospital in South Africa.

Methods Participants were consecutively sampled for this longitudinal observational study and assessed at hospital admission and discharge. The visual analogue scale provides information on participants' pain levels. Respiratory muscle strength (maximal inspiratory pressure and peak inspiratory flow) was assessed with a POWERbreathe KHI device. The presence of pulmonary complications was determined with a chest X-ray radiographic scoring tool. Descriptive and inferential analyses with significance set at $p \leq 0.05$ were performed.

Results The population consisted of 61 participants [males: $n = 47$ (77%)], and the majority underwent coronary artery bypass graft surgery ($n = 35$, 57%) and had a theatre time of 5.84 (± 1.30) h and time on cardiopulmonary bypass 2.01 (*IQR*1.14) h. Intensive care stay was 5 (*IQR* 2.75) days with mechanical ventilation time 17.33 (*IQR* 11.21) h and hospital stay 9 (*IQR* 7) days. Forty-one (67.2%) participants had weak respiratory muscles at hospital admission. Respiratory muscle strength reduced significantly between hospital admission and discharge: maximal inspiratory pressure: 55 cmH_20 vs 30.66 cmH_20, $p < 0.001$, and peak inspiratory flow: 2.70 l/s vs. 1.66 l/s, $p < 0.001$. Atelectasis ($n = 28$, 46, 6%) and pleural fluid ($n = 26$, 43, 3%) were chest X-ray abnormalities at hospital discharge. Chest X-ray scores ($Z = -5.825$, $p < 0.001$) and pain levels ($Z = -5.867$, $p < 0.001$) increased significantly over time. There was a fair, negative correlation between admission maximal inspiratory pressure and chest X-ray scores, which was statistically significant ($r = -0.356$, $p = 0.004$).

Conclusions Respiratory muscle weakness, abnormal chest X-ray findings and persistent pain were noted in study participants. This study highlights the need for continued rehabilitation services to optimise patient outcomes as it relates to ventilation and pain management.

*Correspondence:
Ronel Roos
ronel.roos@wits.ac.za
Full list of author information is available at the end of the article

Keywords Breathing dysfunction, Median sternotomy, Pain, Physiotherapy, Pulmonary complications, Respiratory muscle strength

Background

Individuals diagnosed with cardiovascular disease, e.g. coronary artery disease, and heart valve abnormalities are often managed with a surgical procedure such as a median sternotomy when conservative strategies are not successful. Pulmonary complications may develop in patients following surgery and lead to increased morbidity, mortality and longer hospital stays that elevate healthcare costs [1]. It is estimated that the incidence of pulmonary complications following major surgery can range from 1 to 35%, and having a sternotomy procedure is a risk factor for pulmonary complications [2]. Atelectasis, pneumonia, respiratory failure, pleural effusion, pneumothorax and bronchospasm are examples of pulmonary complications [3]. The presence of pulmonary complications results in an alteration in patients' respiratory symptoms such as cough frequency, sputum production and degree of dyspnoea that influence patients' physical function to variable degrees [3].

Acute post-sternotomy pain is common following cardiac surgery and often limits patients from participating in activities that may prevent pulmonary complications. It leads to sympathetic nervous system activation and an increased hormonal response to stress [4]. These physiological responses may result in multiple complications such as myocardial ischemia, abnormal cardiac rhythms and increased coagulability [4]. Poorly controlled pain levels result in inadequate ventilation, poor cough efforts, retained sputum and most often delayed time up to walking following surgery [4]. In addition to acute dysfunction, it can have long-term consequences. Poor management of acute pain could lead to post-sternotomy pain syndrome over the long term influencing patients' sleep quality, mood, physical activity and ultimately their health-related quality of life [5, 6]. It is therefore imperative that acute pain in patients be properly managed to improve short- and long-term outcomes following cardiac surgery.

Physical therapy services form part of the interdisciplinary team managing patients preoperatively and postoperatively following cardiac surgery. Preoperative physical therapy modalities used during patient care to improve post-operative outcomes include respiratory muscle training to optimise lung ventilation, education regarding the role of physical therapy, lifestyle modification strategies and aerobic and strengthening exercise programmes [7–9]. Preoperative respiratory muscle training has been shown to reduce the risk of pulmonary complications [10, 11] and reduce patients' hospital length of stay [11]. In addition, if individuals have weak respiratory muscles, it may influence the duration of mechanical ventilation required following cardiac surgery [12]. Post-operative modalities used in the hospital to treat patients include a variety of respiratory interventions, early mobilisation and education, e.g. exercise prescription and sternotomy precautions [13]. Continuation of cardiac rehabilitation after hospital discharge should be standard practice for patients who undergo open heart surgery, and physical therapy forms part of the team implementing this programme in many parts of the world [14]. Even though benefits of physical therapy services are well documented, referral for preoperative programmes in the African context is very poor [15, 16], and uptake of cardiac rehabilitation after hospital discharge is also lacking [16]. Few studies are currently available that provide information regarding the clinical profile of such patients and the physical therapy services offered to patients in the African context. The current study aims to contribute to the body of knowledge regarding this.

The objectives of this study were to describe the demographic and clinical profiles of adult patients who underwent median sternotomy procedures in an urban private-sector hospital in South Africa and, secondly, to establish the impact of the median sternotomy incision on participants' pain levels, respiratory muscle strength and chest X-ray findings over time using easy assessable outcome measures at the bedside of a patient. Lastly, determine whether associations between demographic and clinical parameters with respiratory muscle strength, pain levels and chest X-ray findings existed in this cohort of patients.

Methods

A longitudinal observational study was conducted at a private urban hospital in South Africa after ethical clearance requirements were met from January 2018 to May 2019. Participants for the study were identified via theatre and bed booking lists available the day before surgery in the cardiothoracic intensive care unit and cardiac ward. Participants were approached for inclusion preoperatively following hospital admission.

Consecutive sampling was done according to the following inclusion criteria: male and female patients, between the ages of 18 to 70 years of age and undergoing elective cardiothoracic surgery, which would require a median sternotomy incision. Patients were excluded if the following were identified: a previous surgery requiring a median sternotomy incision or any previous thoracic wall surgeries, patients who were admitted due to an emergency and who were unable to participate in a preoperative assessment, patients who required immediate intra-aortic balloon pump management, if a median sternotomy procedure was to be done for specific lung pathology, patients who participated in another clinical study at the time of hospital admission and lastly patients with a history of spontaneous pneumothoraxes.

The sample size for this study was calculated at $n=61$ using an online sample size calculator. Information sourced from Morsch et al. [17] was used to assist with the calculation. The authors evaluated the ventilation profile of patients undergoing coronary artery bypass graft surgery using maximal inspiratory pressure pre- and postoperatively. The authors reported the change in maximal inspiratory pressure using manovacuometry was preoperatively 65.8 (± 28.6) cmH_2O, and a significant drop was noted postoperatively to 42.4 (± 19.9) cmH_2O [15].

A pilot study, with six participants, was done before the main study of the current project to assess the intra-rater reliability of the first author when performing the physical assessments. The lowest correlation observed during the pilot study was $r=0.978$ ($p=0.001$) indicating an excellent intra-rater reliability of the assessor.

Study participants were assessed preoperatively in the hospital and again at hospital discharge before returning home. Participants were asked to sit in a chair next to their bed with their hips at a 90-degree angle, their backs supported and their feet supported on the floor. The demographic questionnaire was completed, and participants' pain levels were assessed using the visual analogue scale. To ensure participants were stable, vital signs were first reviewed before physical assessments. This included temperature, heart rate, respiratory rate, blood pressure and oxygen saturation levels. Respiratory muscle strength (maximal inspiratory pressure and peak inspiratory flow) was then assessed with a POWERbreathe KHI device.

Information from Lee et al. [18] and Minahan et al. [19] guided the process followed by maximal inspiratory pressure and peak inspiratory flow assessments. Participants remained in the seated position, and a nose piece was placed over the nose to ensure no leakage of air. Participants were instructed to place their mouths over the mouthpiece and seal their lips tightly. Maximum inspiratory pressure was measured first, and the participants were instructed to exhale or empty their lungs fully and then take a deep breath lasting for 2 to 3 s. One practice effort was allowed to familiarise themselves with both of the tests. The tests for both maximal inspiratory pressure and peak inspiratory flow were performed three times, and an average score and a predicted score were calculated to compare results.

The predicted maximal inspiratory pressure of participants was calculated using the following equations: male — maximal inspiratory pressure = 120–(0.41 × age) and female — maximal inspiratory pressure = 108–(0.61 × age) [20]. Inspiratory muscle weakness was defined as a maximal inspiratory pressure value below 70% of the predicted value [21].

A review of clinical records was done to determine the type of surgery, theatre information, intensive care unit length of stay, mechanical ventilation time and hospital length of stay.

Study participants' chest X-rays were evaluated using a radiographic tool sourced from Ragnarsdóttir et al. [22]. This tool is of value for physical therapy practice as it contains descriptive categories that are easily implementable during patient care at the bedside. The tool contains three sections: atelectasis of the left lung, the presence of pleural fluid and the position of the left diaphragm. Each section is then subdivided into scoring categories of 'none', 'minor', 'medium' and 'major' with specific descriptions for easy selection and scoring. A score of 1 indicates no pleural effusion, atelectasis or elevated left diaphragm, respectively, and a score of 4 indicates noticeable signs of one or more of the aforementioned. The total scoring of the chest X-ray is thus out of 12. The chest X-ray scoring tool was used to determine whether study participants developed pulmonary complications.

During the study, the study participants continued with standard physical therapy care that consisted of individualised inpatient management in the cardiothoracic intensive care unit and hospital wards.

The results of the study were evaluated using descriptive and inferential analysis using IBM Statistical Package for the Social Sciences version 24. Data were first evaluated to determine whether it was normally distributed using a Shapiro-Wilks test. Demographic and clinical parameters and respiratory muscle strength findings are presented as frequencies (%) and medians (interquartile range [IQR]) and/or mean (± standard deviation [SD]). To determine pre- and post-test results, a paired samples T-test was used for parametrical data, and a Wilcoxon signed-rank test was used for non-parametrical data. Subsequently, to calculate correlations, Spearman's rank-order correlations were calculated for non-parametrical data and Pearson's product-moment correlations for parametrical or normally distributed data. The significance level was set at a p-value less than 0.05.

Table 1 Demographic and clinical profile of study participants ($N = 61$)

Variable	Frequency (%)/ median (IQR)/mean (± SD)
Age, years	59 (22)
Gender - Males - Females	44 (72.10%) 17 (27.90%)
Height, metres	1.72 (± 0.09)
Weight, kilograms	81.99 (± 15.39)
Body mass index, kg/m^2	26.42 (6.67)
Surgery type - CABG - Valve - CABG & valve - Pulmonary endarterectomy - Other	35 (57%) 15 (25%) 2 (3.27%) 5 (8.19%) 4 (6.55%)
Surgical drains - Mediastinal - Pericardial - Pleural No drain Left Left & right	61 (100%) 61 (100%) 22 (36.10%) 33 (54.10%) 6 (9.80%)
Theatre time, hours	5.84 (± 1.30)
Time on bypass, hours	2.01 (1.14)
Time on aortic clamp, hours	1.36 (0.85)
Mechanical ventilation time, hours	17.33 (11.21)
ICU stay, days	5 (2.75)
Hospital stay, days	9 (7)

CABG (coronary artery bypass graft), *ICU* (intensive care unit), *kg/m^2* (kilograms per metres squared)

Results

Ninety-two patients were screened for potential inclusion in the study. Forty-one patients were excluded due to the following reasons: intra-aortic balloon pump ($n = 4$), previous open-heart surgery ($n = 3$), lung surgery ($n = 2$), older than 70 years of age ($n = 10$) and heart transplantations ($n = 12$). Sixty-one study participants were assessed preoperatively and 57 (93%) at hospital discharge. Four study participants were not assessed at hospital discharge due to the following: death ($n = 1$) and refused discharge assessment ($n = 1$), and two were discharged early before physical assessments could be done.

All study participants were independently mobile without an assistive device preoperatively, but at the time of hospital discharge, five individuals required a walking aid. All participants were discharged to their respective homes. The demographic and clinical profiles of study participants are presented in Table 1.

Most participants were male ($n = 44$, 72.10%), had an elevated body mass index (26.42, *IQR* 6.67 kg/m^2), underwent coronary artery bypass graft surgery ($n = 35$, 57%) and exited surgery with a mediastinal ($n = 61$, 100%), pericardial ($n = 61$, 100%) and left pleural drain ($n = 33$, 54.10%) (Table 1). Other surgeries included thymectomies, mitral valve aneurysm repair and atrioseptal defect repair. Table 2 contains the vital signs and respiratory muscle strength parameters of study participants at hospital admission and hospital discharge assessment.

Oxygen saturation ($p < 0.001$), temperature ($p < 0.001$) and diastolic blood pressure ($p = 0.004$) were significantly different from hospital admission to hospital discharge

Table 2 Study participants' vital signs and respiratory muscle strength over time

Variable	Preoperative median (IQR)/mean (± SD)	Hospital discharge Median (IQR)/mean (± SD)
Vital signs		
Respiratory rate, *breaths per minute*	16.43 (± 2.34)	16.70 (± 1.97)
Heart rate, *bpm*	77.98 (± 16.01)	80.21 (± 9.90)
Blood pressure, *mmHg* • Systolic • Diastolic	121.57 (± 17.12) 72.97 (± 10.90)	118.42 (± 14.62) 68.26 (± 9.61)
Oxygen saturation, *%*	95.34 (± 2.81)	93.35 (± 2.77)
Temperature, *°C*	36.28 (± 0.47)	36.63 (± 0.45)
Respiratory muscle strength		
MIP, *cmH$_2$O*	55 (39.50)	30.66 (20)
Percentage predicted MIP value achieved, *%*	58.66 (37.12)	33.26 (22.46)
Predicted MIP, *cmH$_2$O*	94.69 (± 12.16)	94.69 (± 12.16)
PIF, *l/s*	2.70 (1.81)	1.66 (1.07)

[*] *bpm* (beats per minute), *cmH$_2$O* (centimetres of water), *l/s* (litres per second), *MIP* (maximal inspiratory pressure), *mmHg* (millimetres of mercury), *PIF* (peak inspiratory flow), % (percentage)

(Table 2). Oxygen saturation was below the suggested normal range for adults at hospital discharge and therefore of clinical significance (Table 2). Forty-one (67.2%) participants had weak inspiratory respiratory muscles (percentage maximal inspiratory pressure achieved less than 70%) preoperatively. Only 1 of the 57 participants assessed at hospital discharge had respiratory muscle strength more than 70% of his/her predicted value indicating 'normal' respiratory muscle strength.

There was a statistically significant change for maximal inspiratory pressure in study participants when discharged values were compared with admission findings ($Z = -4.75$, $p < 0.001$) and for the difference of the change for the percentage of the predicted maximal inspiratory pressure achieved at discharge ($Z = -5.94$, $p < 0.001$). The findings reduced over time. There was also a significant difference in peak inspiratory flow between admission and discharge ($Z = -4.75$, $p < 0.001$) also indicating a reduction over time. Table 3. outlines the chest X-ray abnormalities of participants as assessed at hospital admission and discharge.

Most chest X-ray changes observed at hospital discharge were lung atelectasis ($n = 20$, 33.3% minor; $n = 8$, 13.3% medium), intra-pleural filling of the costo-phrenic angles ($n = 26$, 43.3%) and elevation of the diaphragm ($n = 16$, 26.6% — left slightly more than right), but these were of minor severity (Table 3). Eight (13.3%) participants however had medium atelectasis of the basal segments of the left lung and in the retrocardial area, and only one participant had medium changes in the diaphragm height where the left diaphragm elevated up to half of the height of the left heart border (Table 3). The difference between the chest X-ray total scores from admission to discharge changed from a median of 3 out of 12 to 4 out of 12; this elicited a statistically significant change ($Z = -5.825$, $p < 0.001$) over time, thereby indicating poorer chest X-ray findings at discharge. Participants' pain levels as assessed with the visual analogue scale are presented in Table 4 below.

Most participants experienced some level of pain at hospital discharge with the most ($n = 21$, 34.4%) experiencing a level of 4/10 on the visual analogue scale (Table 4). Participants that did experience pain described pain centrally over their median sternotomy incision, especially when taking a deep breath or when coughing. A statistically significant change in pain levels of participants occurred from pre-operative to hospital discharge ($Z = -5.867$, $p < 0.001$) as seen in Table 4. Table 5 outlines the correlations as for respiratory muscle strength, pain levels and chest X-ray findings. No correlations were identified when reviewing hospital and intensive care length of stay mechanical ventilation time and theatre information with these parameters.

There was a fair, negative correlation between admission peak inspiratory flow and maximal inspiratory pressure with chest X-ray total scores at admission, which was statistically significant (peak inspiratory flow; $r = -0.278$, $p = 0.03$) (maximal inspiratory pressure; $r = -0.356$, $p = 0.004$) (Table 5).

Discussion

Participants' maximal inspiratory pressure (55 (*IQR* 39.50) cmH2O) at preoperative assessment (hospital admission) was only 58.66% of their predicted value

Table 3 Chest X-ray abnormalities of study participants over time

	Pre-operative (*n*, %) *N* = 61	**Hospital discharge (*n*, %)** *N* = 60
CXR — atelectasis of the left lung		
- **None**	61 (100%)	32 (53.3%)
- **Minor**	-	20 (33.3%)
- **Medium**	-	8 (13.3%)
- **Major**	-	-
CXR — pleural fluid		
- **None**	57 (93.4%)	34 (56.7%)
- **Minor**	4 (6.6%)	26 (43.3%)
- **Medium**	-	-
- **Major**	-	-
CXR — position of the left diaphragm		
- **None**	59 (96.7%)	43 (71.7%)
- **Minor**	2 (3.3%)	16 (26.6%)
- **Medium**	-	1 (1.6%)
- **Major**	-	-

CXR (chest X-ray)

Table 4 Visual analogue pain scores of study participants at admission and discharge from hospital

VAS score	**Pre-operative (*n*, %)**	**Hospital discharge (*n*, %)**
0	58 (95.1%)	5 (8.2%)
1	-	1 (1.6%)
2	2 (3.3%)	7 (11.5%0
3	-	8 (13.1%)
4	-	21 (34.4%)
5	-	6 (9.8%)
6	-	3 (4.9%)
7	-	3 (4.9%)
8	-	2 (3.3%)
9	1 (1.6%)	1 (1.6%)
10	-	-
Total	61 (100%)	57 (100%)

VAS (visual analogue scale)

Table 5 Correlations observed between age, respiratory muscle strength, chest X-ray scores and pain levels

Variables	Correlation coefficient (*p*-value)
Pre-operative	
Age with predicted MIP	**−0.319 (0.012)**
Age with percentage predicted MIP achieved	**0.739 (0.044)**
MIP with PIF	**0.698 (0.001)**
CXR score with PIF	**−0.278 (0.03)**
CXR score with MIP	**−0.367 (0.004)**
VAS with PIF	0.14 (0.913)
VAS with MIP	−0.051 (0.697)
Hospital discharge	
MIP with PIF	**0.831 (0.001)**
CXR score with PIF	0.037 (0.776)
CXR score with MIP	0.003 (0.984)
VAS with PIF	0.073 (0.587)
VAS with MIP	0.08 (0.552)

* *CXR* (chest X-ray), *MIP* (maximal inspiratory pressure), *PIF* (peak inspiratory flow)

when considering their age and gender indicating some degree of respiratory muscle weakness. Sixty-seven percent of the population had weak respiratory muscles preoperatively as defined by a maximal inspiratory pressure value less than 70% of their predicted values. In addition, an association between preoperative maximal inspiratory pressure and peak inspiratory flow findings with participants' chest X-ray scores was highlighted. The respiratory muscle findings in the study are concerning when reviewing the international trends of respiratory muscle strength of adults having a median sternotomy procedure. Urell et al. [23] in their study found that Swedish adults with a mean age of 67 (± 10) years undergoing cardiac surgery had preoperative maximal inspiratory pressure finding of 78 (± 24) cmH_2O which was close to their suggested normal. Additionally, Naseer et al. [24] noted that their study population of adults in India had near-normal values of maximal inspiratory pressure with a mean age of 65 (± 7) years and maximal inspiratory pressure finding being 81.75 (± 22.04) cmH_2O preoperatively. Physical performance and participation in physical activity could be a predictor of respiratory muscle strength.

Kaneko [25], when investigating the respiratory muscle strength in community-dwelling older adults (age: 78 ± 6 years) in Japan, noted that sedentary behaviour results in reduced respiratory muscle strength. The authors reported that their study participants had a mean maximal inspiratory pressure value of 53.3 (± 26.6) cmH_2O which is similar to the current study's findings in a much younger population. Physical inactivity is one of the known modifiable risk factors for cardiovascular disease and remains an issue in the South African context [26–29]. A national-based population survey revealed that 57.4% of South Africans are not physically active [27]. Not meeting physical activity recommendations may be related to one's gender, older age, having a higher socio-economic status, obesity and lower functional capacity [28]. The built environment also plays a role in how much leisure-time physical activity and transport-related physical activity can be attained by older adults living in an urban setting in South Africa [29]. Even though information on study participants' preoperative physical activity levels was not collected, considering the national trend of sedentary behaviour reported in the literature, it is highly likely that participants' preoperative physical activity had room for improvement. Additionally, participants did not receive a form of prehabilitation where focus was placed on respiratory muscle training, optimising physical activity and enhancing exercise capacity which may also explain why the respiratory muscle findings of the participants were so much lower than international reports.

Winkelmann et al. [12] determined that preoperative inspiratory respiratory muscle strength of adults may predict the length of time spent on mechanical ventilation following cardiac surgery. The authors reported that individuals with weak preoperative respiratory muscles spend a significantly ($p = 0.008$) longer time on mechanical ventilation compared with individuals with adequate respiratory muscle strength. In the current study, no association between respiratory muscle strength and time spent on mechanical ventilation was observed.

A significant reduction in inspiratory respiratory muscle strength occurred in participants from hospital admission to discharge. This could be due to multiple factors of which post-operative pain is one. Pain is very subjective, and therefore, patients may experience this symptom differently. Literature suggests that most pain after a sternotomy occurs due to tissue damage of the skin, subcutaneous tissue, bone and cartilage [4]. In the current study, participants who experienced pain at discharge from the hospital attributed this to pain at the median sternotomy incision when taking a deep breath or coughing. It is therefore plausible that if patients experienced pain, as demonstrated in study findings, it could result in patients favouring a shallower breathing pattern that then would result in a further reduction in respiratory muscle strength until such time that nociceptor irritation seized.

Literature suggests that inadequate management of post-operative pain could result in pulmonary complications, cardiac complications such as arrhythmias and post-sternotomy pain syndrome long term [5].

Post-sternotomy pain syndrome is defined as persistent pain that remains for at least 3 months following sternotomy and has no apparent cause [30]. Factors reported in the literature that may influence the development of post-sternotomy pain syndrome are being younger than 60 years of age, an elevated body mass index, previous percutaneous coronary intervention, an ejection fraction less than 50% and internal mammary artery harvesting [30]. Different pharmacological means of managing post-operative pain are known, but few non-pharmacological options are documented. A recent systematic review and meta-analysis indicated that offering music therapy to patients following cardiac surgery during hospital stays significantly reduces patients' post-operative pain and anxiety levels [31]. Another non-pharmacological option is the use of massage therapy. Braun et al. [32], in a randomised control trial, indicated the benefits of implementing massage therapy. The massage therapy consisted of 20 min of treatment, implemented in a semi-reclined position in bed or sitting upright in a chair depending on the patient's presentation and preferences. Areas treated were the shoulders, back, neck, scalp, hands, feet or legs depending on patients' preference according to discomfort reported at that particular time. Swedish massage, consisting of moderate pressure, using gliding and kneading techniques was incorporated. The authors noted that adding this non-pharmacological strategy to standard care was beneficial in effectively reducing pain levels, anxiety and muscle tension of patients over time during hospital stay [32]. Implementing and evaluating the feasibility and effects of these non-pharmacological strategies on patient outcomes following cardiac surgery in the South African context require further investigation.

Participants' chest X-rays were reviewed preoperatively and at hospital discharge using a radiological scoring tool proposed by Ragnarsdóttir et al. [22] to determine if participants presented with abnormalities that could reveal pulmonary complications. Abnormalities reviewed included the presence of atelectasis, the observable presence of remaining pleural fluid and a review of the level of the left hemi diaphragm. Atelectasis (n=28, 46, 6%) and fluid in the intra-pleural space (n=26, 43,3%) were the most remaining chest X-ray abnormalities observed at hospital discharge. Atelectasis is the most common pulmonary complication that occurs after cardiac surgery and is estimated to develop in 54 to 92% of patients [33]. Left lower lobe atelectasis may be related to phrenic nerve injury, inadequate clearance of pulmonary secretions, lung collapse, inadequate use of positive end-inspiratory positive pressure during surgery, damage to the pulmonary endothelial due to cardioplegia solution and longer duration of cardiopulmonary bypass [33]. Risk factors for remaining fluid in the pleural space reported in the literature are the female gender, the presence of heart failure prior to surgery, arterial fibrillation and preoperative diagnosis of peripheral vascular disease, receiving therapy with an anticoagulant or antiarrhythmic drug [33]. Additionally, Naveed et al. [34] found that the main risk factors for pulmonary complications after surgery utilising cardiopulmonary bypass are advanced age (individuals older than 60 years of age), prolonged time on cardiopulmonary bypass (more than 120 min) and intraoperative phrenic nerve injury. Some of the risk factors listed above were present in the demographic and clinical profile of the study participants. Even though pulmonary abnormalities were still present at hospital discharge, when reviewing the effect on patients' resting vital signs, the only abnormality noted was a reduced level of oxygen saturation. In the current study, information related to dyspnoea at rest and during activity was not collected. Additionally, a review of exercise capacity concerning functional performance at hospital discharge was also not assessed. Both these outcomes may have provided valuable information on how participants' activity at hospital discharge may have been impacted by the remaining pulmonary complications and respiratory muscle weakness present. Further research is warranted.

Conclusion

The study highlights that the preoperative respiratory muscle strength of an urban population, receiving care at a private facility in South Africa, is significantly less than predicted values for their age and gender, and this might be related to less-than-optimal levels of physical activity and the absence of participation in prehabilitation before cardiac surgery. Cardiac surgery in older adults is on the increase and places a higher demand on resources and results in longer hospital stays [35]. Prehabilitation consisting of respiratory muscle training, general strength training, aerobic exercise interventions and optimising nutrition and psychosocial status may result in significant post-operative benefits in vulnerable populations such as older adult [36]. The implementation and evaluation of such programmes in the South African context are needed. Several participants reported median sternotomy pain at hospital discharge. Due to the known risk of developing post-sternotomy pain syndrome over the long term, it is advised to screen high-risk individuals after hospital discharge to identify, educate and implement rehabilitation strategies as needed. The need for continued rehabilitation after hospital discharge was highlighted: ventilation abnormalities (respiratory muscle weakness and atelectasis), lower oxygenation levels and participants requiring a walking device for mobility which were not needed at hospital admission. Cardiac rehabilitation is a known management strategy that could improve activity limitations and community reintegration and optimise participation.

Abbreviations

CABG	Coronary artery bypass graft
CXR	Chest X-ray
IBM	International Business Machines Corporation
IQR	Interquartile range
ICU	Intensive care unit
MIP	Maximal inspiratory pressure
PIF	Peak inspiratory flow
SD	Standard deviation
VAS	Visual analogue scale

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Authors' contributions
CAG, conceptualization of the study, data collection and analysis, and review and editing of the manuscript. RR, co-conceptualization of the study, data capture and analysis verification, supervision, writing of the manuscript, and final formatting and submission to the journal.

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Availability of data and materials
The data that support the findings of this study are available from the first author upon reasonable request.

Declarations

Ethics approval and consent to participate
The study received ethical clearance from the University of the Witwatersrand Human Research Ethics Committee (Medical) (certificate number: M160957). Permissions to conduct the study at the clinical site were sought from the following entities: the research committee of the private hospital and the cardiothoracic surgeons who performed the elective surgeries. All unit managers, shift leaders, cardiologists and physicians of relevant wards and ICUs were informed of the study taking place. Study participants gave written informed consent preoperatively. Lastly, the study was registered at the South Africa National Clinical Trial Registry and received the following number: DOH-27–1217-5912.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Physiotherapy, University of the Witwatersrand, Johannesburg, Republic of South Africa.

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