



# Associations of physical activity and quality of life in parapneumonic effusion patients

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Patients with parapneumonic pleural effusion are mostly sedentary and present poor quality of life. Increasing moderate-to-vigorous physical activity following discharge from hospital may provide meaningful improvements in quality of life. <https://bit.ly/473QCSQ>

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## Abstract

**Introduction** Little is known about activity behaviours and quality of life (QoL) of patients with parapneumonic pleural effusions (PPE) after hospital discharge. This study is a secondary analysis of a randomised trial (dexamethasone versus placebo) for hospitalised patients with PPE. We: 1) described the patients' activity behaviour patterns and QoL measured at discharge and at 30 days post-discharge; and 2) examined the association between activity behaviours and QoL scores.

**Methods** Activity behaviour (7-day accelerometry; Actigraph GT3X+) and QoL (Medical Outcomes Study Short-Form 36) were assessed. Repeated measures analysis of covariance controlling for baseline values and a series of linear regression models were undertaken.

**Results** 36 out of 53 eligible participants completed accelerometry assessments. Despite modest increases in light physical activity (+7.5%) and some domains of QoL (>2 points) from discharge to 30 days post-discharge, patients had persistently high levels of sedentary behaviour (>65% of waking wear time) and poor QoL (≤50 out of 100 points) irrespective of treatment group ( $p=0.135-0.903$ ). Increasing moderate-to-vigorous physical activity was associated with higher scores on most QoL domains ( $p=0.006-0.037$ ). Linear regression indicates that a clinically important difference of 5 points in physical composite QoL score can be achieved by reallocating 16.1 min·day<sup>-1</sup> of sedentary time to moderate-to-vigorous physical activity.

**Conclusion** Patients with PPE had low levels of physical activity and QoL at discharge and 30 days post-discharge irrespective of treatment. Moderate-to-vigorous physical activity participation was associated with higher QoL scores. Increasing moderate-to-vigorous physical activity following discharge from the hospital may be associated with improvements in QoL.

## Introduction

Pneumonia is one of the leading causes of hospitalisation, morbidity and mortality worldwide [1, 2]. Parapneumonic pleural effusions (PPEs), which complicate up to 50% of patients with pneumonia [3], represent a significant healthcare burden and are associated with a worse prognosis [1–5]. Parapneumonic effusions typically exhibit a significant pleural inflammatory response, with all-cause mortality of pleural infections remaining unacceptably high (~15% in hospital; ~25% at 3 months) [6]. Furthermore, the



economic burden associated with managing these infections surpasses USD 100 million annually [7]. The goals of PPEs management are to eradicate the infection, alleviate symptoms and quickly return patients to their normal daily living activities.

Treating PPE involves systemic antibiotic therapy and drainage of the infected pleural fluid and often requires hospital stays. Chest pain and dyspnoea are common symptoms [8], often impacting the patient's well-being and quality of life (QoL). In addition, pre-existing comorbidity is very common in these patients [9]. Up to 40% of patients with PPE [9] are affected by various conditions such as asthma, COPD, type II diabetes and chronic kidney disease, which further impede early mobilisation and overall recovery, including physical activity. In previous studies [10, 11], patients with PPE walked a range of 926 to 1356 daily steps and spent ~95% of their awake hours being sedentary following a median of 4 to 7 days after hospital admission. Importantly, greater mean daily steps during hospitalisation were associated with a ~10% reduced length of hospital stay [10], while every additional 500-step increase in daily steps after discharge was associated with a ~24% reduced 30-day mortality [11].

Advances in the field of activity behaviour quantification through accelerometry now allow assessment of patients' daily activity behaviours [10–12]. In malignant pleural effusion (MPE), it is already known that: 1) patients can adhere to accelerometry protocols [13]; 2) accelerometer-derived information such as number of steps per day reflect different performance status and survival groups [13]; and 3) accelerometry has the sensitivity to detect differences between MPE procedures [14]. However, information on activity behaviours such as sedentary, light, moderate and vigorous physical activity time and QoL is lacking in patients with PPE. Such data may help inform supportive care strategies to facilitate a faster recovery during and after hospitalisation.

Our recent multicentre randomised STOPPE trial [15, 16] demonstrated the feasibility and safety of administering intravenous dexamethasone for 48 h. However, the administration of adjunct systemic corticosteroid therapy did not have an impact on clinical parameters and outcomes, such as the need for pleural drainage, duration of hospitalisation, antibiotic therapy and QoL. In this study, we present the accelerometry assessment of participants from the STOPPE trial [15, 16]. The primary outcome was to describe sedentary and physical activity behaviour patterns and QoL in PPE patients treated with dexamethasone, or placebo, at the time of discharge and at 30 days after. Secondary outcomes were to examine the association of physical activity behaviour with QoL assessment scores in these patients. Because differences were not identified in any outcomes between intravenous dexamethasone and placebo in the main trial [15, 16], our hypotheses are that patients receiving intravenous dexamethasone would not present better activity behaviour or QoL compared to placebo. Our secondary hypothesis is that physical activity components would be associated with higher QoL levels in PPE patients.

## Methods

### *Settings and participants*

The present study is a follow-up analysis using data from our published multicentre randomised trial in adults with PPE (STOPPE trial, ACTRN12618000947202) [15, 16]. Participants recruited at the lead site (Sir Charles Gairdner Hospital, Western Australia) were offered accelerometry assessment. The study was approved by the Human Research and Ethics Committee of Sir Charles Gairdner and Osborne Park Healthcare Group (RGS840). All patients provided written informed consent.

### *Procedures*

Details of inclusion criteria and recruitment have been previously reported [15, 16]. Briefly, patients hospitalised for community-acquired pneumonia and with evidence of a pleural effusion were randomly assigned (2:1) to the dexamethasone or placebo group, with minimisation for Chalmers predictive score, known diabetes mellitus and size of the pleural effusion, to ensure equal representation in each group. Participants received 4 mg of intravenous dexamethasone, or saline (placebo), every 12 h for 48 h to a total of four doses. Participants were asked to complete a QoL questionnaire at discharge and 30 days post discharge and asked to wear the accelerometry device on their hip for 7 consecutive days following hospital discharge (*i.e.* days 1 to 7 following discharge) and following their 30-day post-discharge assessment (*i.e.* days ~30 to 36 post-discharge). Patients were followed up on alternate days until hospital discharge and at 30 days post-discharge. Demographic and clinical data such as age, sex, smoking status, Eastern Cooperative Oncology Group (ECOG) performance status, comorbidities and primary malignancy were collected by self-report and medical records, respectively.

### Outcome measures

Device-assessed activity behaviours were measured by Actigraph GT3X+ accelerometers (Actigraph, Pensacola, FL, USA) and the data were processed in SAS (version 9.4, Cary, NC, USA) using an established algorithm [17]. Accelerometers were programmed to record raw data at a frequency of 30 Hz. Using 60-s epoch data of counts of the vertical axis, the proportion of time spent in sedentary behaviour, light physical activity and moderate-to-vigorous physical activity were determined as  $<100$  counts·min<sup>-1</sup>,  $\geq 100$  and  $<1951$  counts·min<sup>-1</sup>, and  $\geq 1951$  counts·min<sup>-1</sup>, respectively [18, 19]. Daily steps were also recorded. Patients with at least 2 valid days of 8 h of waking wear time were included for analysis [20, 21]. Data assessors were blinded to group assignments. All variables were calculated per day and then averaged across all valid days for each patient. Data are also presented as per cent of waking wear time (*i.e.* relative sedentary time, relative light physical activity, relative moderate-to-vigorous physical activity). While there is no established minimum clinically important difference (MCID) for daily steps in patients with PPE, in drawing on other clinical populations, a MCID of 600–1000 steps has been reported in patients with COPD [22].

QoL was assessed using the 36-Item Short-Form Survey (SF-36) version 2 [23], which includes physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional and mental health domains [23], and a physical (PCS) and a mental (MCS) composite score. SF-36 scores range from 0 to 100, with higher scores representing better QoL. The MCID for components of the SF-36 PCS and the SF-36 MCS has been reported as 5 points in a range of populations [24].

### Statistical analysis

Data were analysed using SPSS Statistics (v.27; IBM Corp., Armonk, NY, USA). Normality of the distribution was assessed using Kolmogorov–Smirnov test. Data are presented as mean±SD or median (IQR) as appropriate. Changes over the follow-up period were assessed using two-way (group × time) repeated measures analysis of covariance (ANCOVA) controlling for baseline values to account for potential differences between the dexamethasone and placebo groups over time (discharge *versus* 30-day post-discharge). Bonferroni *post hoc* tests were performed when the main effect for time was significant. Data not normally distributed were log transformed (ln) for analysis. Statistical significance was set at an  $\alpha$  of 0.05.

Single-activity, partition and isothermal substitution models were undertaken, as previously described [25–28], using linear regression to estimate the association of sedentary, physical activity and total wear time with the SF-36 domains with the physical and mental composite scores at 30 days following discharge. Accelerometer variables were scaled to 10-min increments to standardise each activity and because of its importance for health outcome improvement [29, 30]. In the single-activity model, each accelerometer variable was assessed individually without accounting for the other activities to examine the association with SF-36 domains. For the partition model, the accelerometer variables were included in the model to examine their independent association with SF-36 domains. The isothermal substitution model was applied to examine the impact of reallocating 10 min of sedentary time to 10 min of either light or moderate-to-vigorous physical activity. In this model, light and moderate-to-vigorous physical activity time and total time were held constant, while the variable being replaced (*i.e.* sedentary time) was not included. All the models were adjusted by age (continuous variable) and group (*i.e.* dexamethasone, placebo). Only complete cases were included in the analyses. Results are presented as unstandardised coefficients (B) and standard errors (SE). A comprehensive description of the models can be found in the supplementary material.

## Results

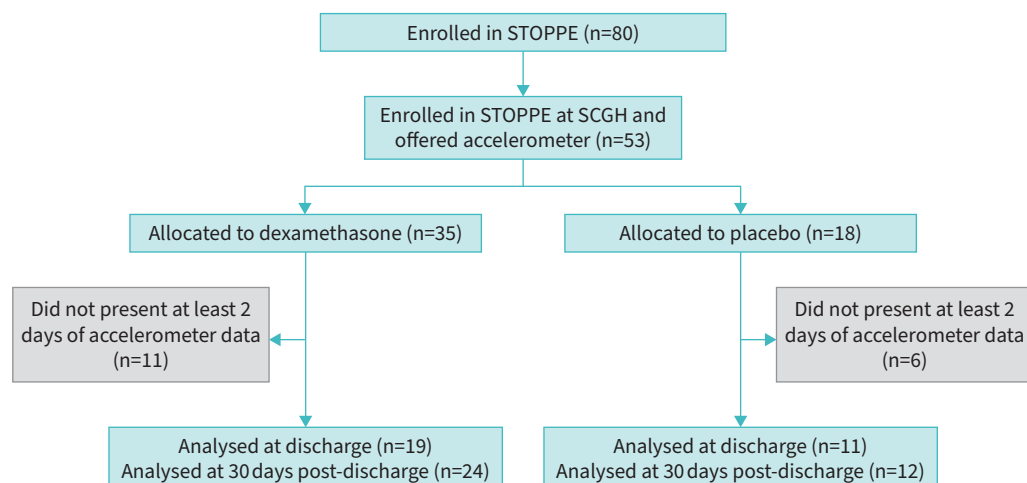
### Sample characteristics

Of the 53 participants enrolled in the lead site, 36 participants (47.2% male; age 64.6±16.6 years) completed at least 2 days of assessment (mean±SD 6.3±1.4 days) and were included for further analyses (figure 1). Most participants (80.6%) had an ECOG performance status of 0. Comorbidities, especially cardiac (63.9%) and pulmonary (44.4%) diseases, were common (table 1).

### Sedentary and physical activity behaviour and QoL at discharge and 30 days

The median waking wear time for the entire sample over 7 days following discharge and at 30 days post-discharge were 14.4 (IQR 13.1–16.0) hours and 13.9 (IQR 12.6–15.3) hours, respectively, representing a median difference of 35.6 (IQR 30.3–91.3) min·day<sup>-1</sup> ( $p=0.030$ ). No significant differences in waking wear time were observed between groups (table 2).

No significant group × time interactions were observed for relative sedentary time ( $p=0.307$ ), relative light physical activity time ( $p=0.370$ ) and relative moderate-to-vigorous physical activity time ( $p=0.205$ ).



**FIGURE 1** Participants' flow through the trial assessments. SCGH: Sir Charles Gairdner Hospital.

(table 2). At discharge, participants spent 11.0 (IQR 9.7–11.4) hours (73.6±10.1%) of waking wear time in sedentary behaviour, 3.9±1.9 hours (25.5±9.9%) in light physical activity and only 3.4 (IQR 1.3–9.1) min (0.4%, IQR 0.2%–0.8%) in moderate-to-vigorous physical activity. Physical activity levels increased between discharge and the 30-day assessment. As a result, sedentary time was reduced by 8.2% to 65.4±10.3% of the waking wear time while light physical activity was increased by 7.5% to 33.0±10.0% of waking wear time ( $p<0.001$ ). No significant changes were observed in moderate-to-vigorous physical activity relative to waking wear time ( $p=0.179$ ). The mean steps walked per day rose from 6368±3840 to

**TABLE 1** Baseline demographic and clinical characteristics

	Total	Dexamethasone	Placebo
<b>Participants n</b>	36	24	12
<b>Age years, mean±sd</b>	64.6±16.6	63.5±18.5	66.8±12.6
<b>Sex, male, n (%)</b>	17 (47.2)	11 (45.8)	6 (50.0)
<b>Smoking status, n (%)</b>			
Current	2 (5.6)	2 (8.3)	0 (0.0)
Former	17 (47.2)	9 (37.5)	8 (66.7)
Nonsmoker	17 (47.2)	13 (54.2)	4 (33.3)
<b>ECOG performance status scale, n (%)</b>			
0	29 (80.6)	20 (83.3)	9 (75.0)
1	4 (11.1)	2 (8.3)	2 (16.7)
2	3 (8.3)	2 (8.3)	1 (8.3)
<b>Comorbidities, n (%)</b>			
Pulmonary <sup>#</sup>	16 (44.4)	13 (54.2)	3 (25.0)
Cardiac <sup>¶</sup>	23 (63.9)	16 (66.7)	7 (58.3)
Renal	3 (8.3)	2 (8.3)	1 (8.3)
Diabetes mellitus	8 (22.2)	4 (16.7)	4 (33.3)
Liver cirrhosis	1 (2.8)	0 (0.0)	1 (8.3)
Depression/anxiety	11 (30.6)	7 (29.2)	4 (33.3)
<b>Type of primary malignancy, n (%)</b>			
Breast	3 (8.3)	1 (4.2)	2 (16.7)
Skin	2 (5.6)	1 (4.2)	1 (8.3)
Lymphoma	1 (2.8)	1 (4.2)	0 (0.0)
Prostate	1 (2.8)	0 (0.0)	1 (8.3)
Uterine	1 (2.8)	0 (0.0)	1 (8.3)

ECOG: Eastern Cooperative Oncology Group. <sup>#</sup>: COPD, asthma, interstitial lung disease, pulmonary embolism, pulmonary hypertension and others; <sup>¶</sup>: hypertension, ischaemic heart disease, congestive cardiac failure, atrial fibrillation, pericardial effusion and others.

TABLE 2 Sedentary and physical activity behaviour at discharge and 30 days following discharge from hospital

Outcome	Discharge	30 days	Time	Group×Time
<b>Steps per day</b>				
Both groups	6368±3840	8345±3727 <sup>¶</sup>	F=16.9	F=0.3
Dexamethasone	6524±4210	8286±4167	p<0.001	p=0.619
Placebo	6099±3276	8448±3003		
<b>Waking wear time per day, h<sup>#</sup></b>				
Both groups	14.4 (13.1–16.0)	13.9 (12.6–15.3) <sup>¶</sup>	F=13.9	F=1.1
Dexamethasone	14.5 (13.1–16.0)	14.1 (12.7–15.4)	p<0.001	p=0.294
Placebo	14.0 (12.6–18.0)	13.5 (12.1–13.9)		
<b>Sedentary time per day, h<sup>#</sup></b>				
Both groups	11.0 (9.7–11.4)	9.1 (7.8–10.4)	F=1.7	F=2.4
Dexamethasone	10.8 (9.4–11.4)	9.3 (7.9–10.6)	p=0.208	p=0.135
Placebo	11.0 (10.5–11.2)	8.3 (7.5–10.1)		
<b>Light physical activity time per day, h</b>				
Both groups	3.9±1.9	4.6±1.5 <sup>¶</sup>	F=26.6	F=0.0
Dexamethasone	3.8±1.8	4.5±1.6	p<0.001	p=0.903
Placebo	4.0±2.1	4.7±1.4		
<b>Moderate-to-vigorous physical activity time per day, min<sup>#</sup></b>				
Both groups	3.4 (1.3–9.1)	6.1 (1.4–24.1)	F=1.6	F=0.8
Dexamethasone	2.6 (0.8–11.8)	5.5 (1.3–21.6)	p=0.218	p=0.388
Placebo	3.9 (1.8–8.7)	6.8 (1.8–29.0)		
<b>Relative sedentary time per day, %</b>				
Both groups	73.6±10.1	65.4±10.3	F=3.5	F=1.1
Dexamethasone	73.4±11.1	66.5±10.8	p=0.072	p=0.307
Placebo	73.8±8.6	63.3±9.5		
<b>Relative light physical activity time per day, %</b>				
Both groups	25.5±9.9	33.0±10.0	F=19.2	F=0.8
Dexamethasone	25.5±10.7	31.9±10.2	p<0.001	p=0.370
Placebo	25.6±8.8	34.9±9.8		
<b>Relative moderate-to-vigorous physical activity time per day, %<sup>#</sup></b>				
Both groups	0.4 (0.2–0.8)	0.7 (0.2–2.7)	F=1.9	F=1.7
Dexamethasone	0.3 (0.1–1.3)	0.7 (0.2–2.4)	p=0.179	p=0.205
Placebo	0.5 (0.2–0.8)	0.8 (0.3–3.8)		

Data are presented as mean±SD, unless otherwise indicated. <sup>#</sup>: statistical analysis based on log transformed data and presented as median (IQR); <sup>¶</sup>: p-value <0.05 derived from pairwise comparison between discharge and 30 days following discharge from hospital.

8345±3727, representing a mean increase of 31.0% or 2041 steps per day (95% CI 1070–3012 steps; p<0.001).

35 participants completed the SF-36 questionnaires at both time points (table 3). No significant group × time interactions were observed for SF-36 domains. A significant improvement in bodily pain from 38.2 (IQR 30.6–46.7) to 46.7 (IQR 38.2–62.0) points (p<0.001) and physical composite score from 35.6 (IQR 28.8–41.6) to 44.2 (IQR 32.9–50.0) points (p=0.003) was observed from discharge to 30-day assessment in the overall cohort.

#### Single-activity, partition and isothermal substitution model

Results from single-activity and partition models were similar and are presented in table 4. In summary, 10 min of moderate-to-vigorous physical activity per day was associated with higher scores of physical functioning, role physical, general health, social functioning, role emotional, mental health and physical composite scores, with scores ranging from 2.1 to 4.3 points (p<0.001–0.034). No consistent relationship was observed between QoL domains and 10 min of sedentary or light physical activity.

Results from the isothermal substitution model are presented in table 5. Based on this hypothetical model, if an individual replaces 10 min of sedentary time with moderate-to-vigorous physical activity, this would result in higher scores on physical functioning, role physical, general health, social functioning, mental health and physical composite score at 30 days post-discharge, with values ranging from 2.2 to 3.8 points (p=0.006–0.037). To meet a MCID of 5 points for SF-36 physical composite score, adults with PPE would need to reallocate 16.1 min of sedentary time per day to moderate-to-vigorous physical activity. No

TABLE 3 SF-36 domains at discharge and 30 days following discharge from hospital

Outcome	Discharge	30 days	Time	Group×Time
<b>SF-36: Physical functioning<sup>#</sup></b>				
Both groups	36.5 (28.8–48.9)	46.1 (29.8–51.8)	F=7.9	F=0.1
Dexamethasone	36.5 (28.8–48.0)	38.4 (30.8–53.7)	p=0.008	p=0.723
Placebo	39.4 (26.0–52.8)	46.1 (28.8–49.9)		
<b>SF-36: Role physical</b>				
Both groups	35.2±11.5	36.6±9.8	F=34.2	F=0.2
Dexamethasone	34.7±11.2	36.1±10.2	p<0.001	p=0.674
Placebo	36.2±12.6	37.8±9.1		
<b>SF-36: Bodily pain<sup>#</sup></b>				
Both groups	38.2 (30.6–46.7)	46.7 (38.2–62.0) <sup>¶</sup>	F=26.1	F=0.2
Dexamethasone	38.2 (30.6–46.7)	46.7 (38.2–55.6)	p<0.001	p=0.631
Placebo	32.4 (25.3–47.9)	50.7 (37.2–62.0)		
<b>SF-36: General health</b>				
Both groups	42.5±9.7	44.4±10.1	F=9.2	F=1.0
Dexamethasone	40.5±9.3	42.3±10.1	p=0.004	p=0.335
Placebo	46.8±9.5	48.9±8.7		
<b>SF-36: Vitality</b>				
Both groups	41.8±10.8	42.9±10.3	F=13.7	F=1.6
Dexamethasone	40.4±10.3	43.3±11.1	p<0.001	p=0.210
Placebo	45.0±11.7	42.0±8.3		
<b>SF-36: Social functioning<sup>#</sup></b>				
Both groups	37.3 (27.3–47.3)	42.3 (27.3–49.8)	F=15.9	F=0.1
Dexamethasone	32.3 (27.3–42.3)	37.3 (27.3–52.3)	p<0.001	p=0.742
Placebo	42.3 (27.3–53.6)	44.8 (29.8–48.6)		
<b>SF-36: Role emotional<sup>#</sup></b>				
Both groups	45.7 (26.6–56.2)	45.7 (31.8–52.7)	F=6.9	F=0.3
Dexamethasone	42.2 (24.8–56.2)	45.7 (31.8–56.2)	p=0.012	p=0.585
Placebo	45.7 (27.4–56.2)	44.0 (27.4–50.1)		
<b>SF-36: Mental health</b>				
Both groups	46.5±10.7	47.7±9.9	F=17.9	F=1.7
Dexamethasone	45.9±10.2	46.3±9.6	p<0.001	p=0.195
Placebo	47.7±12.1	50.7±10.4		
<b>SF-36: Physical composite score<sup>#</sup></b>				
Both groups	35.6 (28.8–41.6)	44.2 (32.9–50.0) <sup>¶</sup>	F=10.3	F=0.4
Dexamethasone	35.6 (30.5–39.9)	40.3 (32.8–49.3)	p=0.003	p=0.530
Placebo	35.1 (28.4–46.3)	46.7 (33.0–50.5)		
<b>SF-36: Mental composite score</b>				
Both groups	44.8±11.9	44.6±10.8	F=11.6	F=0.3
Dexamethasone	43.7±11.6	44.4±10.9	p=0.001	p=0.614
Placebo	47.2±12.6	45.2±11.0		

Data are presented as mean±SD, unless otherwise indicated. SF-36: Medical Outcomes Study Short-Form 36. <sup>#</sup>: statistical analysis based on log transformed data and presented as median (IQR); <sup>¶</sup>: p-value <0.05 derived from pairwise comparison between discharge and 30 days following discharge from hospital.

significant associations of SF-36 domains were observed when reallocating 10 min of sedentary time to light physical activity (p=0.347–0.828).

## Discussion

This sub-analysis of the STOPPE trial presented important data showing a low level of physical activity and QoL scores in patients with PPE both at the time of hospital discharge and after 30 days, despite some interval improvement. Dexamethasone did not improve these parameters. Although a significant improvement was observed in light physical activity time, we did not observe increases in moderate-to-vigorous physical activity. Exploratory modelling suggested that significant improvements in QoL scores may be hypothetically achievable if patients spend ~16 min a day in moderate-to-vigorous physical activity instead of being sedentary. Thus, we highlight a neglected area in the management of PPE and the need to understand the reasons underlying the poor physical activity levels and QoL in order to develop therapeutic interventions.

**TABLE 4** Associations of 10 min of sedentary time, light physical activity, moderate-to-vigorous physical activity and total time with SF-36 domains and physical and mental composite scores in the single-activity and partition models in adults with pneumonia-related pleural effusion at 30 days following discharge (n=36)

Variables	Sedentary time		Light physical activity		Moderate-to-vigorous physical activity		Total time	
	B±SE	p-value	B±SE	p-value	B±SE	p-value	B±SE	p-value
<b>Single-activity model</b>								
SF-36: Physical functioning	-0.1±0.2	0.620	0.4±0.2	0.064	4.3±1.2	<b>&lt;0.001</b>	0.2±0.2	0.162
SF-36: Role physical	-0.1±0.1	0.471	0.1±0.2	0.406	2.5±1.0	<b>0.019</b>	0.0±0.1	0.763
SF-36: Bodily pain	0.0±0.2	0.963	-0.0±0.2	0.921	2.4±1.4	0.088	0.0±0.2	0.920
SF-36: General health	-0.2±0.2	0.226	0.2±0.2	0.222	3.0±1.1	<b>0.011</b>	0.0±0.2	0.916
SF-36: Vitality	-0.1±0.2	0.637	0.3±0.2	0.117	2.5±1.1	<b>0.032</b>	0.2±0.2	0.282
SF-36: Social functioning	-0.2±0.2	0.183	0.1±0.2	0.522	3.2±1.3	<b>0.022</b>	-0.1±0.2	0.611
SF-36: Role emotional	-0.3±0.2	0.122	0.2±0.2	0.455	2.3±1.3	0.083	-0.1±0.2	0.530
SF-36: Mental health	-0.1±0.1	0.554	0.3±0.2	0.097	2.6±1.0	<b>0.012</b>	0.2±0.1	0.274
SF-36: Physical composite score	-0.1±0.2	0.764	0.2±0.2	0.354	3.2±1.2	<b>0.011</b>	0.1±0.2	0.455
SF-36: Mental composite score	-0.2±0.2	0.206	0.2±0.2	0.317	2.1±1.2	0.084	-0.0±0.2	0.863
<b>Partition model</b>								
SF-36: Physical functioning	0.1±0.2	0.737	0.3±0.2	0.237	3.8±1.3	<b>0.005</b>	-	-
SF-36: Role physical	-0.1±0.2	0.656	0.0±0.2	0.999	2.5±1.1	<b>0.033</b>	-	-
SF-36: Bodily pain	-0.0±0.2	0.990	-0.1±0.2	0.574	2.6±1.5	0.079	-	-
SF-36: General health	-0.1±0.2	0.403	0.0±0.2	0.857	2.9±1.2	<b>0.023</b>	-	-
SF-36: Vitality	0.0±0.2	0.837	0.2±0.2	0.305	2.2±1.2	0.080	-	-
SF-36: Social functioning	-0.2±0.2	0.213	-0.1±0.2	0.606	3.2±1.4	<b>0.029</b>	-	-
SF-36: Role emotional	-0.3±0.2	0.166	-0.1±0.2	0.743	2.2±1.4	0.110	-	-
SF-36: Mental health	0.0±0.1	0.911	0.2±0.2	0.313	2.2±1.0	<b>0.034</b>	-	-
SF-36: Physical composite score	0.0±0.2	0.927	0.1±0.2	0.790	3.2±1.3	<b>0.020</b>	-	-
SF-36: Mental composite score	-0.2±0.2	0.343	0.0±0.2	0.920	2.0±1.3	0.135	-	-

p-values given in bold are statistically significant. SF-36: Medical Outcomes Study Short-Form 36; B: non-standardised coefficient; se: standard error.

Patients with pleural infection are often elderly, have high symptom burden, significant morbidity, and require lengthy hospitalisations for systemic antibiotics and invasive drainage procedures (and/or surgery) [9]. These, coupled with high incidences of baseline cardiopulmonary comorbidity, could result in deconditioning and poor physical activity. Over the following 30 days, light physical activity levels were modestly improved, and any increase in moderate-to-vigorous physical activity observed was trivial in our

**TABLE 5** Association between replacing 10 min of sedentary time and either light physical activity or moderate-to-vigorous physical activity on SF-36 domains using the isothermal substitution model in adults with pneumonia-related pleural effusion at 30 days following discharge (n=36)

Variables	Sedentary time		Light physical activity		Moderate-to-vigorous physical activity		Total time	
	B±SE	p-value	B±SE	p-value	B±SE	p-value	B±SE	p-value
<b>Isothermal model</b>								
SF-36: Physical functioning	-	-	0.2±0.2	0.347	3.8±1.3	<b>0.006</b>	0.1±0.2	0.762
SF-36: Role physical	-	-	0.1±0.2	0.725	2.5±1.1	<b>0.031</b>	-0.1±0.2	0.677
SF-36: Bodily pain	-	-	-0.1±0.2	0.604	2.7±1.5	0.079	-0.0±0.2	0.909
SF-36: General health	-	-	0.2±0.2	0.377	3.0±1.2	<b>0.018</b>	-0.2±0.2	0.376
SF-36: Vitality	-	-	0.2±0.2	0.379	2.1±1.2	0.088	0.0±0.2	0.853
SF-36: Social functioning	-	-	0.1±0.2	0.597	3.5±1.4	<b>0.020</b>	-0.3±0.2	0.195
SF-36: Role emotional	-	-	0.2±0.2	0.423	2.5±1.4	0.078	-0.3±0.2	0.175
SF-36: Mental health	-	-	0.2±0.2	0.353	2.2±1.0	<b>0.037</b>	0.0±0.1	0.911
SF-36: Physical composite score	-	-	0.1±0.2	0.828	3.1±1.3	<b>0.022</b>	0.0±0.1	0.973
SF-36: Mental composite score	-	-	0.2±0.2	0.382	2.1±1.3	0.108	-0.2±0.2	0.348

p-values given in bold are statistically significant. SF-36: Medical Outcomes Study Short-Form 36; B: non-standardised coefficient; se: standard error.

cohort. Similar results have been reported in patients with acute exacerbations of COPD following hospitalisation, where time spent in moderate physical activity did not improve between week 1 and week 6 following discharge from hospital [31]. Although information on MCID does not exist for patients with PPE, increases in daily number of steps (+2041 steps) were above the MCID of 600–1000 steps observed in patients with COPD [22]. We observed that moderate-to-vigorous physical activity time was well below that observed in older adults ( $\sim 3 \text{ min}\cdot\text{day}^{-1}$  versus  $26\text{--}52 \text{ min}\cdot\text{day}^{-1}$  [32, 33]) and those levels reported in patients following hospitalisations for acute exacerbations of COPD ( $32\text{--}35 \text{ min}\cdot\text{day}^{-1}$ ) [31], and ultimately well below recommended levels of physical activity ( $150 \text{ min}\cdot\text{week}^{-1}$ ) [34]. Not surprisingly, we found that QoL scores, specifically the SF-36 PCS, was low at discharge from the hospital, with values substantially below normative values in older adults without the disease (46 to 49 points [35–37]). Despite improvements above the MCID of 5 points in SF-36 PCS, values remained below normative values [35–37] at 30 days.

The causes of the insufficient moderate-to-vigorous physical activity in patients with PPE are likely multi-factorial. Slow recovery from respiratory limitations (*e.g.* hypoxaemia) because of the pneumonia and PPE [38], chest pain from the infection or drainage interventions [8], deconditioning from long hospitalisation [39], low mood and exacerbations of underlying cardiopulmonary comorbidities may all contribute [40]. Potentially, we also speculate that psychological elements, such as the misconception of a need for bedrest and/or fear of “over-doing” activities after a major illness, may be important.

The clinical impact of the physical activity profile is an interesting and important area to explore in patients with parapneumonic effusion. We found that low levels of moderate-to-vigorous rather than light physical activity correlated with low QoL scores. Our finding concurs with previous studies in adults [41, 42] that indicates a significant correlation between higher moderate-to-vigorous physical activity and better QoL scores. It is expected that hospitalised patients will present lower levels of physical activity and increase their levels following discharge from hospital [43], although not substantially ( $\sim 8\%$ ) as we observed in our cohort. Engaging in moderate-to-vigorous physical activity rather than light physical activity is still important to overcome hospitalisation’s detrimental effects [44] given several benefits in cardiometabolic health [45–47], independent living [48] and cognition [49], leading to an enhanced QoL. This is an interesting finding in patients with PPE as it supports that interventions targeting physical activity levels could enhance QoL in patients with PPE. However, additional intervention studies are required to determine if this relationship is causal.

Our hypothesis-generating modelling suggested an interesting scenario – that reallocating  $\sim 16 \text{ min}\cdot\text{day}^{-1}$  of sedentary time to moderate-to-vigorous physical activity could be associated with meaningful improvements in QoL. While these data indicate a relationship, it does not imply causation of poor QoL. Nonetheless, other studies have successfully reallocated 10 to 30 min of sedentary time to moderate-to-vigorous activity and improved physical function performance, metabolic and cardiovascular health outcomes in a variety of clinical populations (*e.g.* cancer and stroke) [45–47]. Whether such intervention is feasible and will benefit PPE patients deserves further investigations.

A previous meta-analysis comprising more than one million participants showed that regular physical activity was associated with a  $\sim 20\%$  reduced risk of pneumonia and  $\sim 35\%$  reduced risk of pneumonia-related mortality [50]. However, changing physical activity behaviour is challenging. Strategies comprising time-efficient workouts (*i.e.* short bouts of physical activity) may be more tolerable for patients with several comorbidities or following discharge from hospital. Even several bouts of  $< 1 \text{ min}$  of moderate-to-vigorous exercise were found to be feasible, well-tolerated and time-efficient to break prolonged sedentary activities and improve cardiorespiratory fitness and metabolic health in healthy adults [51, 52]. Vigorous-intensity physical activity (or vigorous intermittent lifestyle physical activity) [53], such as suggesting the patient taking the stairs on a normal day, may offer a promising opportunity to increase moderate-to-vigorous physical activity in this group of patients.

Our study has limitations. First, PPE patients present with different underlying causes (*i.e.* bacterial, viral, fungal), clinical presentation (*i.e.* age, immune status, symptoms) and radiographic findings (*i.e.* small localised versus large multilobulated), and our findings require confirmation in larger cohorts. Second, our observational data preclude determining the causality of physical activity behaviours on measures of QoL, which will require an intervention study. Third, we utilised the SF-36, a set of generic quality-of-life measures, rather than a disease-specific questionnaire. Although specific QoL questionnaires do not exist for pleural effusion, the SF-36 has been utilised in previous pneumonia studies [54, 55] and may be valuable to capture aspects of QoL in this population. Fourth, our data were limited to patients’ activity



behaviour at 30 days post-discharge. The long-term follow-up of physical activity levels and QoL in this population will be informative to design future intervention strategies for promoting exercise.

In summary, this is the first report on poor physical activity levels and QoL scores in pneumonia patients with pleural effusion, and the abnormalities persisting following discharge from the hospital. From this research we provide a platform for urgent investigation of this important but neglected aspect of post-pneumonia care. Uncovering the drivers for the poor physical activity levels to design therapeutic interventions to increase especially moderate-to-vigorous activities warrants further research.

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This study is registered at [www.anzctr.org.au](http://www.anzctr.org.au) with identifier number ACTRN12618000947202. Data used will be made available upon reasonable request to the corresponding author.

The study was approved by the Human Research and Ethics Committee of Sir Charles Gairdner and Osborne Park Health Care Group (RGS840).

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