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Physical activity, inactivity and sleep in older patients with coronary artery disease following percutaneous coronary intervention: A longitudinal, observational study

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Conflicts of interest

None declared.

Abstract

Background: Physical activity presents an important cornerstone in the management and care of coronary artery disease patients following percutaneous coronary intervention (PCI) and research in older patients continues to be overlooked. This study evaluated differences in physical activity, inactivity and sleep of coronary artery disease patients following PCI for acute coronary syndrome consisting of ST-segment elevation myocardial infarction (STEMI) and non STEMI (NSTEMI) and elective admission of stable angina patients over 12 months.

Methods: This was an observational, longitudinal study. Fifty-eight patients were recruited (STEMI, n=20, NSTEMI, n=18 and stable angina, n=20) and completed 7-day monitoring (physical activity, inactivity and sleep) using wrist-worn tri-axial accelerometers (GENEActiv, ActivInsights Ltd, UK) upon discharge from a tertiary centre and repeated measurements at 3 months (n=43), 6 months (n=40) and 12 months (n=33).

Results: Following PCI, CAD patient's showed a general trend of increasing light and moderate-vigorous physical activity over the 12 month follow-up. Time in inactivity remained high but decreased over time. Sleep duration and sleep efficiency remained consistent. NSTEMI patients spent less time asleep, more time inactive and less time in light and moderate-vigorous physical activity in comparison to STEMI and stable angina patients. Differences between the groups over time were minimal.

Conclusions: These findings suggest that older patients with CAD spend long periods in inactivity but the increasing trend of both light and moderate-vigorous physical activity over time presents a positive change in behaviour in the year following PCI.

Introduction

The global burden of cardiovascular diseases has resulted in an estimated 17.8 million fatalities in 2017 with ischaemic heart disease (IHD) accounting for 8.93 million deaths, which is a 22.3% increase from the previous decade [1]. Across varying geographic and income categories, IHD remains the leading cause of mortality [2]. This is coupled with an ever increasing ageing population with the proportion of individuals aged ≥65 years increasing from 6.1% to 8.8% from 1990 to 2017 [3]. These population-level characteristics present important trends for clinicians and public health specialists that can aid direction from global to sub-national levels [4].

In the UK, 45% of men and 59% of women aged 75 years and above self-reported as being inactive [5]. Regular participation in physical activity regardless of age, gender and race has many cardioprotective effects [6]. In contrast, time spent sedentary behaviour (>10 hours/day) is associated with greater risk of cardiovascular diseases [7]. The harmful effects of high sitting time (>8 hours per day) are diminished when individuals engage in moderate-vigorous physical activity for 60-75 minutes per day with an inverse relationship found with cardiovascular disease mortality [8]. Our ageing population generally demonstrate reduced physical activity levels [9, 10], which increases the risk of cardiovascular diseases [11].

Older adults with coronary artery disease (CAD) continue to be underrepresented in clinical research [12, 13]. The prevalence of older patients presenting for percutaneous coronary intervention (PCI) following acute coronary syndrome (ACS) continues to rise [14, 15]. We have previously shown in older patients (≥75 years) at discharge following PCI procedure for ACS that time spent sedentary is higher and time engaged in physical activity of a light intensity or greater is lower in comparison to elective PCI in stable angina patients [16]. In a recent meta-analysis of ten randomised controlled trials, patients with CAD who exercised following PCI resulted in improved left ventricular ejection fraction, decreased incidence of cardiac death, myocardial infarction, coronary angioplasty, angina pectoris and restenosis compared to controls [17]. Likewise, cardiac rehabilitation in elderly patients after ACS has resulted in significant improvements in functional capacity and physical performance [18]. However, the longitudinal patterns of physical activity, sedentary behaviours and sleep in older patients (≥75 years) following PCI is scarce. The purpose of the present study was to evaluate the physical activity levels, inactivity and sleep patterns of older patients with CAD following PCI, longitudinally over 12 months.

Methods

Study design, setting and patients

In this prospective, longitudinal, observational study, a total of 65 consecutive patients aged 75 years and older were recruited from a tertiary centre at the Freeman Hospital, Newcastle upon Tyne, UK after admission for coronary angiography with a view to revascularisation. The Freeman hospital receives patients referred from six district hospitals covering a population of 2 million with an annual percutaneous coronary intervention (PCI) procedure volume of ~3000 cases (60-65% ACS cases). The inclusion criteria were patients aged ≥75 years presenting with acute coronary syndrome (ACS), consisting of ST-segment elevation myocardial infarction (STEMI) or non STEMI (NSTEMI) or elective admissions for stable angina. Patients were excluded from the study if physical condition would limit rehabilitation or mobility such as stroke, myopathy, neuropathy, other major organ failure such as renal or hepatic failure or those with co-existing malignancy with life expectancy <1 year. Patients were identified by a consultant interventional cardiologist and nominated members of the research team. Patients were given an information sheet explaining the study and were given the opportunity to ask questions prior to providing written informed consent. The study protocol was approved by the National Health Service, National Research Authority (County Durham and Tees Valley Research and Ethics Committee). All clinical investigations were conducted according to the principles expressed in the Declaration of Helsinki.

Study protocol and measurements

Patient’s age (years) was recorded as a decimal value. Standing height (to the nearest 0.1cm) and body weight (to the nearest 0.1kg) were measured using the SECA stadiometer and scales (North East Weighing & Calibration Ltd.). Body mass index (BMI) was calculated using the equation: BMI=body mass (kg)÷stature^2(m^2). In addition, the research team collected patient clinical baseline characteristics, baseline blood tests and co-morbidities.

Wrist-worn accelerometers (GENEActiv, Activinsights Ltd, United Kingdom) were used to monitor 7-day habitual physical activity, sedentary behaviour and sleep in patients following PCI for either STEMI, NSTEMI or stable angina following discharge from the tertiary centre. This measurement was repeated at 3, 6 and 12 months. The accelerometer set up and download procedures for this study have been described previously [16]. To be included in the analysis, patients were required to have worn the monitor for at least three of the seven monitoring days, which included at least one weekend day.

From the 65 patients meeting the inclusion criteria for the study, a total of 58 baseline datasets were included in the final analysis with three patients excluded due monitor removal (n=3, STEMI), two patients dropped out as they did not like wearing the monitor (n=1, STEMI; n=1, NSTEMI) and two patients were deceased prior to discharge from the tertiary centre (n=1, STEMI; n=1, NSTEMI). After completion of monitoring, patients returned the accelerometer to the tertiary centre by post. For the 3, 6 and 12 month data collections, the research team contacted the patient prior to sending the accelerometer in the post. The patient was asked to wear the accelerometer for 7-days and return it to the tertiary centre by post.

Accelerometer data was processed in R (www.cran.r-project.org) using R-package GGIR (Version 2.7.0) [19-21]. We have previously described the processing of the accelerometry data [16]. In brief, signals were inspected and corrected for calibration error [22] and only days with at least 16 hours of valid data were retained for further analysis. The average magnitude of wrist acceleration per 5 second epoch was calculated with metric ENMO as previously described (1m*g* = 0.001 x gravitational acceleration) [23]. Monitor non-wear was detected as described previously [23] and replaced by the average accelerometer data on similar time points on different days of the measurement [24, 25]. The following acceleration categories were calculated: Inactivity (<40 mg), light physical activity (40-100 mg) and moderate physical activity (>100 mg), vigorous physical activity (>400 mg) [26, 27]. Estimated total sleep duration (minutes) and sleep efficiency (%) were calculated and the analysis has been described elsewhere [28].

Statistical analysis

Linear mixed-effect models were used to assess the change in activity levels over time, whilst also accounting for the variation between participants as a random effect. All models were created in Stan computational framework [29] accessed with the brms package [30] in the R statistical software [31], which can accommodate the known changes in participant numbers across the study period. Models were assessed using the 95% credible intervals (CI) of each parameter estimate. If a parameter (beta) estimates CI does not contain zero, then we assume that given the observed data, the effect has a 95% change of falling within this range, and as such there is a temporal effect on the parameter.

Results

Patient baseline demographic characteristics are presented in Table 1. The mean (±SD) age for all patients was 79 (±4) years old with 31% of the sample female. NSTEMI patients were older (81±6 years old) than both STEMI (78±2 years old) and stable angina patients (78±3 years old). A longer time from presentation to PCI was found for NSTEMI patients compared to STEMI patients (107±97 vs. 1±1 hours, respectively). However, time from PCI to discharge was longer for STEMI patients compared to both NSTEMI and stable angina patients. Figure 1 provides a flowchart of recruitment and 3, 6 and 12 month follow up for the study. Attrition was 38% and 5% of patients were deceased during the 12 month trial.

There were a total of 174 observations across the four time points, covering a total of 58 participants (58 data points at baseline, 43 at three months, 40 at six months and 33 at 12 months). Table 2 presents summary statistics (mean ± SD) for physical activity, inactivity, sleep duration, time spent awake at night and sleep efficiency across the four time points.

Table 3 summarises the outputs of linear mixed-effect models investigating temporal trends in sleep duration, sleep efficiency, time awake during the night, inactivity during the day and the four levels of physical activity. There was a general trend of increasing light, moderate and vigorous physical activity through time. These increases in activity duration were reflected in a reduction in inactivity over the time period. The 95% credible intervals around these estimates suggest these increases could be considered statistically robust. There was no clear change in sleep duration, time awake during the night or sleep efficiency over the study period.

Table 4 presents summary statistics (mean ± SD) for physical activity, inactivity, sleep duration, time spent awake at night and sleep efficiency across the four time points for each subgroup (STEMI, NSTEMI and stable angina). Table 5 summarises the outputs of linear mixed-effect models investigating temporal trends in sleep duration, sleep efficiency, time awake during the night, inactivity during the day and four levels of physical activity.

NSTEMI patients spent less time sleeping, more time awake at night and spent longer periods in inactivity compared to the other two subgroups. In comparison, STEMI and stable angina patients spent more time in light, moderate and vigorous intensity physical activity. However, when looking at differences in activity subcomponents and sleep over time, there was no temporal effect within the subgroups, possibly due to the small sample size of each group.

Discussion

The purpose of this study was to provide longitudinal observations of older CAD patient's physical activity, inactivity and sleep behaviours over 12 months following PCI procedure. The main findings demonstrated that in this population, light and moderate-vigorous physical activity increased over the 12 months of observations whereas inactivity decreased and sleep duration and sleep efficiency remained consistent. The subgroup analyses revealed that NSTEMI patients spent less time sleeping and more time awake at night but more time in inactivity during the day in comparison to STEMI and stable angina patients. In comparison, STEMI and stable angina patients were more active during the day in comparison to NSTEMI patients.

This was an observational study with no intervention. The findings demonstrate that older patients with CAD showed a trend to increase their physical activity levels and lower their inactivity over a 12 month period following PCI. In the first year post myocardial infarction, it has been reported increased physical activity is associated with reduced mortality [32]. However, inactivity remained high throughout the monitoring periods for the current study ranging from 12-13 hours/day. NSTEMI patients spent nearly 14 hours/day in inactivity behaviours at baseline. Older adults spend 65-80% of their waking day in sedentary behaviour [33] but our findings suggest longer periods were spent in inactivity for our cohort. Following myocardial infarction, patients who continue to spend prolonged periods in sedentary behaviour (4-8 hours/day) present a 62% higher mortality than those who spend <4 hours/day sedentary [34, 35]. The detrimental effects of prolonged sitting on health outcomes (cardiovascular disease and all-cause mortality) are already known but thresholds for sedentary behaviour in clinical populations such as older CAD patients remains unclear [6, 36].

In this current study, moderate-vigorous physical activity increased by approximately 10 minutes/day from baseline to 3 months and remained at this increased level at 12 month follow-up. Likewise, inactivity time was reduced by nearly 50 minutes from baseline to 3 months and remained at this decreased level at 6 months. It has been found that following acute coronary syndrome, patients are able to produce improvements in moderate-vigorous physical activity during cardiac rehabilitation and lower sedentary time was reported with these changes remaining at 1-year follow-up [37]. Long-term changes and adherence at 2-years post ACS have been reported in walking capacity and cardiorespiratory fitness in older patients following both centre-based sessions and home-based exercise prescription [38].

Cardiac rehabilitation continues to be underutilised in older populations but plays an important role in the rehabilitation from cardiovascular procedures [39] as well as lower hospitalisations, improved symptoms [40] and lower mortality [41]. In a recent systematic review and meta-analysis, moderate evidence supports that an association exists between attendance at cardiac rehabilitation and increases in physical activity regardless of monitoring method (subjective or objective) with more positive findings reported when high doses of cardiac rehabilitation were delivered [42]. Interestingly, differences have been reported between countries in patient's physical activity levels and sedentary behaviour at the commencement of cardiac rehabilitation following PCI with patients from Sweden being significantly more active and less sedentary than Australian counterparts at this stage of recovery [43]. We did not record details of patients who attended cardiac rehabilitation and cannot rule out the importance and benefit of this in increasing physical activity levels in this population over the 12 month study.

This study has many strengths, which include the longitudinal, objective measurement of physical activity, inactivity and sleep in three CAD population groups over 12 months. Older CAD patients continue to be underrepresented in clinical research so these findings provide clinicians with trends of activity in these groups over time. However, this study is not without limitations and these include the small sample size, which makes the findings difficult to generalise. We did not report attendance at cardiac rehabilitation and we cannot rule out the increase in physical activity in the findings for 3 and 6 months may have been skewed by attendance at these classes.

Conclusions

In conclusion, older patients with CAD continued to spend large amounts of time in inactive behaviours in the year following PCI procedure. Behaviours remained stable and a trend for an increase in light and moderate-vigorous physical activity was recorded suggesting that older patients with CAD are able to moderate their behaviour. Future studies should target the periods of large inactivity in older patients and observe and talk to patients about when are the most appropriate periods for increasing physical activity during their daily lives.

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Table 1. Demographics of the coronary artery disease patients following percutaneous coronary intervention

	All	STEMI	NSTEMI	SA
Age (years)	79±4	78±2	81±6	78±3
<80 years old (%)	64	70	44	75
>80 years old (%)	36	30	56	25
Sex, n (% female)	58 (31)	20 (25)	18 (39)	20 (30)
Standing height (cm)	168±9	169±9	168±10	167±9
Body weight (kg)	75±14	77±15	74±11	74±15
Body mass index (kg/m2)	27±4	27±5	26±4	26±4
Time from presentation to PCI (hours)	-	1±1	107±97	N/A
Time from PCI to discharge (hours)	34±20	49±12	35±22	18±13

Abbreviations: STEMI ST-segment elevation myocardial infarction, NSTEMI non-ST-segment elevation myocardial infarction, SA, stable angina.

Table 2. Accelerometry outputs for the longitudinal observations of physical activity, inactivity and sleep in coronary artery disease patients

	Baseline	3 months	6 months	12 months
Sleep duration (minutes/day)	420 (110.4)	440.4 (73.7)	428.2 (100.1)	410.7 (92.8)
Sleep efficiency	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)	0.8 (0.1)
Night time minutes awake (minutes/day)	87 (36.1)	88.1 (36.6)	93.7 (51.5)	94.1 (58.5)
Inactivity (minutes/day)	780.3 (108.2)	732.7 (104.2)	728.5 (121.7)	742.2 (117.5)
Light physical activity (minutes/day)	123.1 (55.4)	139.5 (64)	149.3 (64.7)	152.2 (66.8)
Moderate physical activity (minutes/day)	29.3 (23.3)	38.4 (29.7)	40.1 (30.6)	39.8 (30.9)
Vigorous physical activity (minutes/day)	0.5 (0.9)	0.9 (1.2)	0.7 (0.9)	0.9 (1.6)
Moderate-vigorous physical activity (minutes/day)	29.8 (23.7)	39.3 (30.5)	40.8 (31.3)	40.7 (31.8)

Table 3. Linear Mixed-Effect Model summary statistics for all participants over time. Intercept and parameter coefficients are presented with 95% credible intervals, alongside the standard deviation of the random effect.

Parameter	Intercept	Beta Coefficient	Random Effect (SD)
Sleep duration (minutes/day)	419.46 (392.86:447.59)	-0.15 (-1.93:1.6)	43.74
Sleep efficiency (%)	0.82 (0.8:0.84)	-0.00005 (-0.002:0.002)	0.04
Time awake at night (minutes/day)	89.24 (78.69:99.59)	0.22 (-0.98:1.43)	32.47
Inactivity (minutes/day)	760.82 (732.87:788.99)	-2.39 (-4.77:-0.1)	63.00
Light physical activity (minutes/day)	133.94 (119.87:149.1)	1.86 (0.51:3.33)	34.42
Moderate physical activity (minutes/day)	34.49 (27.87:41.18)	0.64 (0.13:1.16)	13.19
Vigorous physical activity (minutes/day)	0.55 (0.29:0.8)	0.03 (0:0.05)	0.68
Moderate-vigorous physical activity (minutes/day)	34.99 (27.86:41.83)	0.66 (0.13:1.18)	13.50

Table 4. Accelerometry outputs for the longitudinal observations of physical activity, inactivity and sleep in STEMI, NSTEMI and stable angina patients

	STEMI	NSTEMI	Stable angina
Baseline			
Sleep duration (minutes/day)	423.5 (100.5)	391.6 (128.7)	441.9 (101.6)
Sleep efficiency (%)	0.8 (0.07)	0.8 (0.1)	0.9 (0.05)
Time awake at night (minutes/day)	88.7 (33.9)	94.2 (40.4)	78.9 (34.3)
Inactivity (minutes/day)	792.1 (94.1)	826.1 (114.9)	727.2 (96.6)
Light physical activity (minutes/day)	109.1 (43)	105.6 (50.1)	152.8 (60.8)
Moderate physical activity (minutes/day)	25.7 (16.1)	21.9 (18.2)	39.7 (29.8)
Vigorous physical activity (minutes/day)	0.3 (0.3)	0.5 (1.2)	0.5 (1.1)
Moderate-vigorous physical activity (minutes/day)	26.0 (16.3)	22.4 (18.8)	40.2 (30.5)
3 months			
Sleep duration (minutes/day)	424.7 (104.7)	410.1 (108.4)	467.3 (69.8)
Sleep efficiency (%)	0.8 (0.08)	0.8 (0.1)	0.9 (0.05)
Time awake at night (minutes/day)	82 (38.9)	113.2 (68.1)	82.7 (28.3)
Inactivity (minutes/day)	728.5 (107.5)	748 (136.5)	693.6 (127)
Light physical activity (minutes/day)	154.1 (62)	140.7 (65.4)	154.7 (74.6)

Moderate physical activity (minutes/day)	50.2 (33.2)	28.9 (22.7)	39.8 (33.3)
Vigorous physical activity (minutes/day)	1 (1)	0.3 (0.3)	0.8 (1.4)
Moderate-vigorous physical activity (minutes/day)	51.2 (34.1)	29.2 (22.8)	40.6 (34.5)
6 months			
Sleep duration (minutes/day)	439 (98.4)	374.8 (80.1)	418.7 (89.4)
Sleep efficiency (%)	0.8 (0.07)	0.8 (0.1)	0.9 (0.04)
Time awake at night (minutes/day)	76.9 (35.8)	133 (77)	68 (17)
Inactivity (minutes/day)	731.5 (117.4)	777.6 (125.4)	713 (100.5)
Light physical activity (minutes/day)	145.3 (60.6)	129.1 (54.1)	190.1 (73.7)
Moderate physical activity (minutes/day)	46.5 (35.4)	25.1 (16.2)	48.7 (32.9)
Vigorous physical activity (minutes/day)	0.8 (0.8)	0.4 (0.5)	1.5 (2.7)
Moderate-vigorous physical activity (minutes/day)	47.4 (36.1)	25.5 (16.5)	50.2 (34.5)
12 months			
Sleep duration (minutes/day)	450.5 (88.6)	423.7 (46.4)	447.7 (80.2)
Sleep efficiency (%)	0.8 (0.06)	0.8 (0.08)	0.8 (0.04)
Time awake at night (minutes/day)	91 (35.7)	89.8 (50.4)	82.2 (23)

Inactivity (minutes/day)	723.4 (111)	769.5 (103.2)	705.6 (100.6)
Light physical activity (minutes/day)	132.1 (61.2)	125 (57.1)	162 (77.1)
Moderate physical activity (minutes/day)	41.7 (31.7)	31.3 (24.8)	42 (34.7)
Vigorous physical activity (minutes/day)	0.6 (0.6)	0.7 (0.9)	1.5 (1.8)
Moderate-vigorous physical activity (minutes/day)	42.3 (32.1)	32.0 (25.3)	43.5 (36.3)

Table 5. Linear Mixed-Effect Model summary statistics for each group over time. Intercept and parameter coefficients are presented with 95% credible intervals, alongside the standard deviation of the random effect.

Group	Parameter	Intercept	Beta Coefficient	Random Effect (SD)
STEMI	Sleep Duration (minutes/day)	426.01 (382.89:467.76)	0.26 (-3.25:3.69)	41.99
	Inactivity (minutes/day)	765.81 (722.65:811.64)	-2.53 (-7.10:1.94)	63.31
	Light Activity (minutes/day)	126.16 (103.05:147.98)	1.77 (-0.64:4.18)	35.32
	Moderate Activity (minutes/day)	36.02 (24.31:48.53)	0.66 (-0.50:1.78)	16.62
	Vigorous Activity (minutes/day)	0.59 (0.30:0.88)	0.01)-0.03:0.06)	0.67
	Moderate-Vigorous Activity (minutes/day)	36.76 (24.58:48.65)	0.66 (-0.47:1.81)	17.15
	Time Awake at Night (minutes/day)	85.10 (70.49:101.96)	-0.15 (-2.21:1.76)	28.74
	Sleep Efficiency (%)	0.83 (0.79:0.86)	0.002 (-0.001:0.004)	0.04
NSTEMI	Sleep Duration (minutes/day)	396.40 (342.05:451.62)	0.08 (-3.90:4.02)	50.76
	Inactivity (minutes/day)	797.91 (738.03:857.16)	-3.23 (-8.69:2.23)	73.98
	Light Activity (minutes/day)	117.98 (92.48:142.97)	2.23 (-0.65:5.34)	38.08
	Moderate Activity (minutes/day)	23.37 (14.45:32.53)	0.84 (0.05:1.69)	8.04

	Vigorous Activity (minutes/day)	0.46 (-0.09:0.97)	-0.04 (-0.20:0.14)	0.35
	Moderate-Vigorous Activity (minutes/day)	23.83 (14.90:33.49)	0.86 (0.05:1.73)	7.91
	Time Awake at Night (minutes/day)	105.05 (79.45:130.20)	0.11 (-3.05:3.44)	44.28
	Sleep Efficiency (%)	0.78 (0.72:0.83)	-0.00008 (-0.004:0.004)	0.06
Stable angina	Sleep Duration (minutes/day)	438.72 (395.91:480.55)	-1.01 (-4.30:2.28)	39.71
	Inactivity (minutes/day)	722.73 (679.75:763.83)	-2.25 (-6.60:1.98)	52.12
	Light Activity (minutes/day)	157.00 (128.50:186.40)	2.32 (-1.26:6.56)	26.78
	Moderate Activity (minutes/day)	41.41 (28.64:54.96)	0.68 (-0.53:1.97)	13.98
	Vigorous Activity (minutes/day)	0.65 (0.00:1.38)	0.05 (-0.02:0.12)	0.82
	Moderate-Vigorous Activity (minutes/day)	41.63 (27.34:56.60)	0.71 (-0.54:2.01)	14.18
	Time Awake at Night (minutes/day)	78.12 (63.50:92.23)	0.40 (-1.49:2.02)	19.50
	Sleep Efficiency (%)	0.85 (0.83:0.88)	-0.001 (-0.004:0.001)	0.03

Figure 1: Flow diagram of patient recruitment and 3, 6 and 12 month follow-up accelerometry monitoring in coronary artery disease patients following percutaneous coronary intervention