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Clinical and Functional Predictors of Prolonged Hospitalization in STEMI Patients Following Percutaneous Coronary Intervention

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Abstract

Background: ST-segment elevation myocardial infarction (STEMI) patients undergoing percutaneous coronary intervention (PCI) typically require 3 to 5 days of hospitalization. Prolonged length of stay (LOS) significantly impacts healthcare quality, family burden, and resource allocation. This study aimed to identify clinical predictors and explore the effect of pre-discharge functional capacity on prolonged hospitalization in STEMI-PCI patients in Thailand.

Methods: A retrospective observational cohort study was conducted using the Acute Coronary Syndrome registry at the Queen Sirikit Heart Center (June 2021–June 2023). The analysis included 536 STEMI-PCI survivors, categorized into standard LOS (≤ 5 days; n = 379) and prolonged LOS (> 5 days; n = 157) groups. Independent predictors were determined using multiple logistic regression.

Results: The prolonged LOS cohort was significantly older, had a higher proportion of females, presented with greater clinical severity, and experienced more in-hospital complications. Following multivariate adjustment, initial Killip class IV emerged as the strongest independent predictor of prolonged hospitalization (Adjusted OR = 4.73; 95% CI: 2.56–8.74, $p < 0.001$). Mechanical complications demonstrated a borderline trend for extended stays ($p = 0.053$). Conversely, higher physical activity capacity, as indicated by higher estimated pre-discharge METs, was significantly associated with a shorter duration of hospitalization.

Conclusion: Initial hemodynamic compromise, notably Killip class IV, is the primary driver of prolonged hospitalization in STEMI patients following PCI. Higher pre-discharge functional capacity correlates with shorter stays, underscoring the vital role of cardiopulmonary reserve and early rehabilitation strategies in optimizing patient recovery.

Keywords: *STEMI; percutaneous coronary intervention; length of stay; Killip class; functional capacity, Role of Cath Lab and CCU Nursing*

INTRODUCTION

ST-Segment Elevation Myocardial Infarction (STEMI) is a major healthcare challenge. It is one of the most severe and fatal types of coronary artery disease (CAD) [1]. Patient outcomes are affected by many factors, including pre-existing noncommunicable diseases (NCDs), a lack of physical activity, and how severe the symptoms are at admission [2,3].

These clinical and lifestyle factors directly affect how long a patient needs to stay in the hospital, known as the length of stay (LOS). Usually, STEMI patients stay in the hospital for about four days after receiving percutaneous coronary intervention (PCI) [4,5,6]. However, prolonged stays are still common. LOS is an important indicator of healthcare quality because it affects patient recovery, family burden, and total hospital costs [7]. Past studies show that a longer LOS is linked to high cardiovascular risk, the patient's condition before arriving at the hospital, and complications during the PCI procedure [5]. Taking good care of these complex patients requires strong teamwork from multidisciplinary teams.

This includes acute monitoring by nurses and early physical rehabilitation strategies [8].

Finding out what causes a long LOS is very important to help hospitals manage beds, staff, and budgets better. In Thailand, published evidence on prolonged length of stay has largely examined patients with non–ST-segment elevation acute coronary syndrome (NSTE-ACS/NSTEMI), including studies evaluating predictors of hospital LOS and prolonged emergency department LOS in this population [9,10].

Therefore, this study aims to identify the clinical risk factors and complications (both before and during the hospital stay) that cause a prolonged LOS in STEMI patients treated with PCI. In addition, this study explores how physical activity levels, measured by metabolic equivalents (METs), affect the hospitalization time. By focusing on a cardiac center in the Esan region of Thailand.

METHOD

Study Design and Data Sources

This research was conducted as a retrospective observational cohort study. Data were retrieved from the Acute Coronary Syndrome (ACS) registry at the Queen Sirikit Heart Center of the Northeast (QSHC) spanning from June 2021 to June 2023. The study protocol was approved by the Center for Ethics in Human Research at Khon Kaen University (no. HE661487) and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Study Population

Participants were selected based on the following inclusion criteria: (1) age ≥ 18 years, (2) a confirmed diagnosis of ST-segment elevation myocardial infarction (STEMI), (3) treatment exclusively via percutaneous coronary intervention (PCI), and (4) a minimum hospital admission duration of one day. STEMI was operationally defined in accordance with the QSHC ACS registry criteria, requiring characteristic ischemic symptoms accompanied by new ST-segment elevation at the J-point in at least two contiguous leads (typically ≥1 mm, with specific age and sex criteria for leads V2-V3) and a subsequent rise in cardiac biomarkers (e.g., high-sensitivity cardiac troponin). Furthermore, all included patients underwent a combination of primary and rescue PCI as their index reperfusion strategy. To focus on the recovery trajectory and resource utilization of patients who successfully completed their acute care, the analysis was restricted to hospital survivors. Consequently, to mitigate potential immortal time bias and competing risks associated with mortality, exclusion criteria included: (1) patients who died during the PCI procedure, (2) patients treated with coronary artery bypass grafting (CABG), and (3) patients who died during the index hospitalization prior to discharge. This approach frames the outcome specifically as the length of stay among STEMI-PCI survivors.

Outcome and Variable Definitions

LOS was defined as the total number of calendar days from the date of hospital admission to the date of discharge, encompassing both the intensive care (CCU) and general ward stays. The primary outcome was prolonged LOS, where patients were dichotomized into two groups: standard LOS (≤ 5 days) and prolonged LOS (> 5 days). The 5-day threshold was established based on established prior studies indicating that uncomplicated STEMI patients undergoing percutaneous coronary intervention (PCI) typically require a hospital stay of 3 to 5 days, whereas stays exceeding 5 days are generally associated with a higher burden of complications or the need for advanced monitoring [4,6].

Clinical data extracted for analysis included initial Killip class, comorbidities, prior cardiovascular procedures, number of coronary lesions, and in-hospital complications. Given the critical role of cardiopulmonary capacity in recovery, physical activity levels were estimated using Metabolic Equivalents (METs). The estimated METs were assessed prior to hospital discharge using the 2024 Compendium of Physical Activities [11].

Statistical analysis

Data distribution was assessed for normality. Continuous variables are presented as mean ± standard deviation (SD) or median with interquartile range (IQR) as appropriate, while categorical variables are expressed as frequencies and percentages. Group comparisons for clinical characteristics, complications, and rehabilitation factors between the ≤5 days and > 5 days LOS groups were performed using the Mann-Whitney U test for continuous data and the Chi-square test or Fisher's exact test for categorical data.

To identify independent risk factors associated with prolonged LOS, a multiple logistic regression analysis was conducted. Variables demonstrating a significant unadjusted association in the univariate analysis (p-value < 0.05) or those deemed clinically relevant were entered into the multivariate model. Missing data, specifically within the rehabilitation factors (e.g., estimated METs), were addressed using complete case analysis. Results from the regression analysis are reported as adjusted odds ratios (OR) with corresponding 95% confidence intervals (CI). All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 28.0 (IBM Corp., Armonk, NY, USA), with statistical significance set at a two-tailed P-value of < 0.05.

RESULTS

Study Population

From June 2021 to June 2023, a total of 1,361 individuals were registered in the QSHC ACS registry. After excluding patients referred to other hospitals (n = 14) and those without an ACS diagnosis (n = 46), 1,301 ACS patients remained. The cohort was then categorized into NSTEMI (n = 639) and STEMI (n = 662) groups. Focusing solely on the STEMI cohort, 126 patients were further excluded (119 received CABG or alternative treatments, and 7 died during PCI). The final analysis included 536 STEMI patients treated exclusively with PCI. Based on their length of stay (LOS), patients were dichotomized into a standard LOS group (≤ 5 days; n = 379) and a prolonged LOS group (> 5 days; n = 157) (Figure 1).

Baseline Characteristics and In-hospital Complications

The median LOS for the entire cohort was 4 days (interquartile range [IQR], 3–6 days). When categorized based on the 5-day threshold, patients were divided into a standard LOS group (≤ 5 days; n = 379) and a prolonged LOS group (> 5 days; n = 157). The clinical and demographic characteristics of the patients are summarized in Table 1. The prolonged LOS group was significantly older (mean age 66.80 vs. 64.34 years, $p = 0.030$) and had a higher proportion of female patients compared to the standard LOS group. Furthermore, patients with a hospital stay exceeding 5 days presented with greater clinical severity, characterized by higher initial Killip classes (particularly Killip IV), higher rates of multivessel disease (DVD and TVD), and a greater burden of comorbidities including hypertension, diabetes, prior heart failure, and cerebrovascular disease (all $p < 0.05$). In-hospital complications—notably heart failure, cardiogenic shock, acute renal failure, and mechanical complications—were also significantly more prevalent in the prolonged LOS cohort. Conversely, patients with shorter hospital stays demonstrated higher physical activity capacities, as indicated by higher estimated METs ($p < 0.001$).

Predictors of Prolonged Length of Stay

To identify independent predictors of prolonged LOS, factors demonstrating significant associations in the univariate analysis were entered into a multiple logistic regression model (Table 3). After adjusting for potential confounders, initial Killip class IV (Adjusted OR = 4.73; 95% CI: 2.56–8.74, $p < 0.001$) remained the strongest independent predictor of an extended hospital stay. Notably, while triple vessel disease (Adjusted OR = 1.93; 95% CI: 0.92–4.05, $p = 0.081$) and in-hospital heart failure (Adjusted OR = 1.79; 95% CI: 0.84–3.80, $p = 0.128$) were strongly associated with prolonged LOS in the unadjusted analysis, they did not reach statistical significance in the multivariate model. Mechanical complications demonstrated a borderline trend toward prolonged hospitalization (Adjusted OR = 10.19; 95% CI: 0.96–107.33, $p = 0.053$).

DISCUSSION

The findings of this study provide a robust clinical framework for understanding the variables that drive hospital resource intensity and patient outcomes for STEMI patients undergoing PCI in QSHC Thailand. Our analysis identifies several high-risk predictors, most notably in-hospital mechanical complications (OR: 12.43; p=0.020). This result aligns with international literature, which classifies complications such as papillary muscle rupture or ventricular septal defects as catastrophic sequelae of myocardial necrosis that typically lead to cardiogenic shock and carry in-hospital mortality rates approaching 50% [12].

Hemodynamic status at admission remains a potent predictor of recovery trajectory. In our cohort, Killip Class IV was a significant predictor of adverse outcomes (OR: 4.73; p<0.001), reflecting the high intensity of care required for cardiogenic shock management, including mechanical circulatory support and continuous nursing surveillance [13]. Additionally, Triple-Vessel Disease (TVD) (OR: 1.93; p=0.081) and In-hospital Heart Failure (OR: 1.79; p=0.128) were found to significantly extend hospital stays. These findings are consistent with the Thai PCI Registry, where high lesion complexity (56.9% Type C lesions) remains a primary driver of resource consumption despite high procedural success rates (95.2%) [14].

The association between male sex and a lower risk of adverse outcomes (OR: 0.47; p=0.018) compared to females highlights a significant demographic disparity. Previous studies suggest that female patients are more likely to present with atypical symptoms, which frequently leads to delayed recognition and diagnosis [15,16]. Specifically, approximately 90% of females presenting with atypical symptoms experience significant delays in door-to-balloon (DTB) time. This delay is a critical concern, as arrival-to-balloon times exceeding 30 minutes are independently associated with higher one-year mortality.

The Specialized Role of Cath Lab and CCU Nursing

The insights gained from this study have significant implications for patient care strategies and resource allocation within cardiac centers, particularly in regions like Esan, Thailand. By identifying patients at higher risk for prolonged hospital stays based on their initial clinical presentation and comorbid conditions, healthcare providers can implement more

personalized and proactive care plans. Especially, during in hospital Cath lab and CCU nurses play a pivotal and complementary role in reducing door-to-balloon (DTB) time and total length of stay (LOS) in ACS patients undergoing PCI. In the cath lab, nurses are responsible for pre-procedural patient preparation, continuous hemodynamic monitoring, immediate reporting of ECG and vital sign changes to the interventional cardiologist, and prompt medication administration [17]. Effective pre-hospital ECG triage combined with early cath lab activation significantly reduces DTB time, and delayed cath lab arrival-to-balloon time exceeding 30 minutes has been independently associated with higher one-year mortality [18,19]. Nurses must also be equipped to respond rapidly to life-threatening complications such as ventricular fibrillation, cardiac tamponade, and coronary artery perforation, and to ensure accurate post-procedural documentation for high-quality handover to the CCU team, as communication breakdown remains a leading cause of preventable medical errors [20,21]. Within the CCU, nurses reduce LOS through five key functions: continuous ECG and hemodynamic surveillance using Early Warning Score systems for earlier complication detection [22]; strict adherence to DAPT and anticoagulation protocols as outlined in current evidence-based guidelines to reduce stent thrombosis and readmission [23]; implementation of Early Ambulation Protocol following transracial PCI, which allows immediate mobilization, reduces bed rest time, and significantly shortens LOS without increasing complication rates [24]; structured patient education using teach-back methods initiated at admission, which has been shown to significantly reduce overall readmission rates in cardiac patients [25]; and coordination of multidisciplinary discharge planning, whereby a dedicated discharge coordinator reduces LOS and improves early discharge rates while maintaining patient safety [26].

Regional Disparities and Policy Implications

In the Isan region, resource allocation remains a challenge. The 7th health service area (Khon Kaen and surrounding provinces) reports a low timely treatment rate of 15.22%, largely due to the fact that 89% of hospitals lack a cardiac catheterization room. Moreover, disparities between healthcare funding schemes (GS vs. UC/SS) suggest that equity in access to high-cost devices like Drug-Eluting Stents (DES) must be prioritized to improve regional mortality rates.

Ethical Issues

This study was approved by the Center for Ethics in Human Research, Khon Kaen University (approval no. HE661487) and conducted in accordance with the Declaration of Helsinki. Informed consent was waived given the retrospective registry-based design.

Conflict of Interest

The authors declare no competing interests.

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CONCLUSION

Prolonged hospitalization (> 5 days) in STEMI patients undergoing percutaneous coronary intervention (PCI) is primarily driven by the severity of the initial hemodynamic compromise, with Killip class IV emerging as the strongest independent predictor. Additional contributing factors include in-hospital mechanical complications, TVD, and delayed presentations, particularly among female patients. Conversely, higher pre-discharge functional capacity, as indicated by estimated METs, is significantly associated with shorter hospital stays, underscoring the critical role of cardiopulmonary reserve and the integration of early rehabilitation strategies.

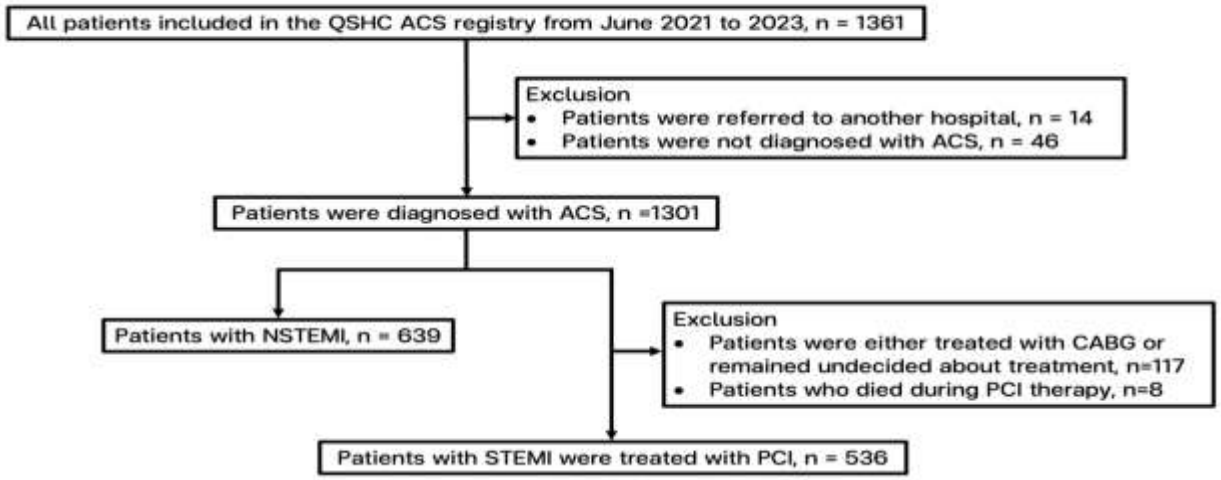

Figure 1. Patient inclusion flow chart

Table 1. Baseline demographic, clinical, and procedural characteristics of STEMI patients undergoing PCI, stratified by length of stay

Variables	Total Cohort (N = 536)	LOS ≤ 5 days (n = 379)	LOS > 5 days (n = 157)	P-value
Demographic and Anthropometric Characteristics				
Age, years	65.06 ± 11.95	64.34 ± 11.84	66.80 ± 12.09	0.030
Gender, n (%)				0.002
- Male	387 (72.2)	288 (76.0)	99 (63.1)	
- Female	149 (27.8)	91 (24.0)	58 (36.9)	
Body Mass Index (kg/m²)				0.860
- < 18.5	46 (8.8)	35 (9.5)	11 (7.1)	
- 18.5 – 22.9	217 (41.5)	151 (41.1)	66 (42.3)	
- 23.0 – 24.9	93 (17.8)	66 (18.0)	27 (17.3)	
- ≥ 25.0	167 (31.9)	115 (31.3)	52 (33.3)	
Current smoking (%)	84 (17.8)	65 (19.5)	19 (13.9)	0.150
Initial Clinical Presentation				
Initial Killip class				< 0.001
- Class I (%)	340 (67.2)	276 (77.5)	64 (42.7)	
- Class II (%)	25 (4.9)	16 (4.5)	9 (6.0)	
- Class III (%)	8 (1.6)	5 (1.4)	3 (2.0)	
- Class IV (%)	133 (26.3)	59 (16.6)	74 (49.3)	
Comorbidities				
Hypertension (%)	212 (40.0)	134 (35.8)	78 (50.0)	0.002
Diabetes Mellitus (%)	165 (31.2)	105 (28.2)	60 (38.5)	0.020
Dyslipidemia (%)	82 (15.6)	53 (14.3)	29 (18.7)	0.200
Prior myocardial infarction (%)	369 (69.8)	266 (71.1)	103 (66.5)	0.280
Prior PCI (%)	356 (67.2)	257 (68.7)	99 (63.5)	0.240
Prior CABG (%)	4 (0.8)	2 (0.5)	2 (1.3)	0.580
Prior heart failure (%)	88 (16.7)	37 (9.9)	51 (32.9)	< 0.001
Cerebrovascular disease (%)	18 (3.4)	6 (1.6)	12 (7.7)	< 0.001
CKD Stage 3 (eGFR < 60 mL/min/1.73m²) (%)	41 (7.8)	24 (6.5)	17 (11.0)	0.070
COPD (%)	18 (3.4)	12 (3.3)	6 (3.9)	0.710
Procedural and Angiographic Characteristics				
PCI Procedures				0.750
- Elective (%)	29 (5.4)	19 (5.0)	10 (6.4)	
- Urgency (%)	49 (9.1)	36 (9.0)	13 (8.3)	
- Emergent (%)	458 (85.4)	324 (85.5)	134 (85.4)	
Number of coronary lesions				< 0.001
- Single Vessel Disease (%)	225 (42.0)	183 (48.3)	42 (26.8)	
- Double Vessel Disease (%)	158 (29.5)	109 (28.8)	49 (31.2)	
- Triple Vessel Disease (%)	153 (28.5)	87 (23.0)	66 (42.0)	
Left Main (LM) Disease (%)	68 (12.7)	37 (9.8)	31 (19.7)	0.002
In-hospital Complications				
Any complication (%)	237 (44.2)	132 (34.8)	105 (66.9)	< 0.001
- Cardiogenic shock (%)	169 (31.5)	94 (24.8)	75 (47.8)	< 0.001
- Heart failure (%)	160 (29.9)	82 (21.6)	78 (49.7)	< 0.001
- Arrhythmia (%)	84 (15.7)	49 (12.9)	35 (22.3)	0.007
- Acute renal failure (%)	20 (3.7)	7 (1.8)	13 (8.3)	< 0.001
- Bleeding (%)	16 (3.0)	8 (2.1)	8 (5.1)	0.060
- Cardiac arrest (%)	11 (2.1)	10 (2.6)	1 (0.6)	0.130
- Mechanical complication (%)	6 (1.1)	1 (0.3)	5 (3.2)	0.009
- Stroke (%)	5 (0.9)	2 (0.5)	3 (1.9)	0.150
- Tamponade (%)	4 (0.7)	1 (0.3)	3 (1.9)	0.070
Rehabilitation Factors				
AACVPR Risk Stratification				< 0.001

- Low	94 (26.4)	69 (32.5)	25 (17.4)	
- Moderate	45 (12.6)	34 (16.0)	11 (7.6)	
- High	217 (61.0)	109 (51.4)	108 (75.0)	
- Missing data	180	167	13	
Estimated METs				< 0.001
- 1 MET	4 (0.9)	3 (0.9)	1 (0.7)	
- 2 METs	29 (6.3)	17 (5.3)	12 (8.3)	
- 3 METs	368 (79.3)	273 (85.3)	95 (66.0)	
- 4 METs	11 (2.4)	11 (3.4)	0 (0.0)	
- 5 METs	1 (0.2)	0 (0.0)	1 (0.7)	
- Missing data (N/A)	51 (11.0)	16 (5.0)	35 (24.3)	

Continuous data are presented as mean ± standard deviation (SD), and categorical data as n (%). AACVPR: American Association of Cardiovascular and Pulmonary Rehabilitation; CABG: Coronary Artery Bypass Grafting; CKD: Chronic Kidney Disease; COPD: Chronic Obstructive Pulmonary Disease; METs: Metabolic Equivalents; PCI: Percutaneous Coronary Intervention.

Table 2. Unadjusted and Adjusted Logistic Regression Analysis of Factors Associated with Prolonged Length of Stay (> 5 days) in STEMI Patients

Variables	Unadjusted OR (95% CI)*	P-value	Adjusted OR (95% CI)**	P-value
Demographics				
Age (per year increase)	1.01 (1.00 – 1.03)	0.030	1.01 (0.98 – 1.03)	0.348
Gender				
- Male	1.00 (Ref.)	-	1.00 (Ref.)	-
- Female	1.85 (1.24 – 2.76)	0.003	0.47 (0.25 – 0.88)	0.018
Initial Clinical Presentation				
Initial Killip class				
- Class I	1.00 (Ref.)	-	1.00 (Ref.)	-
- Class II	2.42 (1.02 – 5.73)	0.040	3.93 (1.15 – 13.45)	0.029
- Class III	2.58 (0.60 – 11.10)	0.200	1.79 (0.26 – 12.21)	0.552
- Class IV	5.40 (3.49 – 8.37)	< 0.001	4.73 (2.56 – 8.74)	< 0.001
Comorbidities				
Hypertension (Yes vs No)	1.79 (1.22 – 2.61)	0.003	1.21 (0.65 – 2.27)	0.543
Diabetes Mellitus (Yes vs No)	1.59 (1.07 – 2.36)	0.020	0.82 (0.39 – 1.69)	0.588
Cerebrovascular Disease	5.05 (1.86 – 13.72)	0.001	3.23 (0.68 – 15.19)	0.138
CKD Stage 3	1.78 (0.93 – 3.43)	0.080	1.29 (0.45 – 3.74)	0.630
Coronary Lesions				
Number of involved vessels				
- Single Vessel Disease (SVD)	1.00 (Ref.)	-	1.00 (Ref.)	-
- Double Vessel Disease (DVD)	1.95 (1.21 – 3.15)	0.006	1.62 (0.83 – 3.17)	0.156
- Triple Vessel Disease (TVD)	3.30 (2.07 – 5.25)	< 0.001	1.93 (0.92 – 4.05)	0.081
Left Main (LM) Disease	0.44 (0.26 – 0.73)	0.002	2.18 (0.93 – 5.08)	0.071
In-hospital Complications				
Heart failure	3.57 (2.40 – 5.31)	< 0.001	1.79 (0.84 – 3.80)	0.128
Cardiogenic shock	2.77 (1.87 – 4.09)	< 0.001	1.41 (0.66 – 3.17)	0.354
Bleeding	2.49 (0.91 – 6.75)	0.070	2.35 (0.24 – 23.14)	0.496
Arrhythmia	1.93 (1.19 – 3.12)	0.007	1.85 (0.83 – 4.15)	0.131
Mechanical complication	12.43 (1.44 – 107.31)	0.020	10.19 (0.96 – 107.33)	0.053
Physical Activity & Rehabilitation				
Estimated METs (per MET increase)	0.23 (0.03 – 1.86)	0.170	1.29 (0.99 – 1.69)]	0.054
AACVPR risk stratification				
- Low Risk	1.00 (Ref.)	-	1.00 (Ref.)	-
- Moderate Risk	0.89 (0.39 – 2.02)	0.780	0.74 (0.28 – 1.93)]	0.545
- High Risk	2.73 (1.61 – 4.64)	< 0.001	1.07 (0.53 – 2.17)]	0.847

** Unadjusted Odds Ratios were derived from simple logistic regression analysis.
*** Adjusted Odds Ratios were derived from a multiple logistic regression model. The model included all variables listed in the table. CI: Confidence Interval; CKD: Chronic Kidney Disease.

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