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Association Of Anxiety And Executive Function With Attendance And Fitness Improvement In Cardiac Rehabilitation

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ASSOCIATION OF ANXIETY AND EXECUTIVE FUNCTION WITH ATTENDANCE AND FITNESS IMPROVEMENT IN CARDIAC REHABILITATION

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ABSTRACT

Psychological factors such as anxiety and executive function (EF) may impact patient health outcomes from cardiac rehabilitation (CR). High anxiety and low executive function could reduce attendance or impede fitness improvements yielded from CR. Other research on exercise performance suggests, in certain circumstances, moderate levels of anxiety can be beneficial towards fitness gains. The current study evaluated the associations of anxiety and EF with attendance and fitness improvement in CR through retrospective analyses of two datasets from studies conducted at the University of Vermont Medical Center CR program. One sample contained a representative sample of CR patients, and the other, lower-SES patients. No relationships between anxiety or EF and attendance or fitness improvement were detected in the representative sample of patients. However, higher anxiety and lower executive function were associated with diminished fitness improvement among lower-SES patients. Moderate anxiety levels were not found to be beneficial for fitness improvement. Maximizing patient attendance and fitness improvement in CR is integral to long-term survival rates. Lower-SES patients are already at higher risk for earlier dropout, nonattendance, and more severe psychological impairments. Even when lower-SES patients do attend, it appears that the benefits they gain may be impeded by elevated levels of anxiety or executive dysfunction. Lower-SES patients should be the focus of efforts to treat anxiety and support executive function deficits within CR.

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CHAPTER 1: INTRODUCTION

1.1. Cardiovascular and Heart Disease

Cardiovascular disease (CVD) affects 49.2% of adults older than 20 years of age, is responsible for over 800,000 deaths a year, and results in over 350 billion dollars in medical expenditure annually (Benjamin et al., 2019). Coronary artery disease (CAD), a subcategory of CVD, contributed to over 635,000 of those deaths in 2016 alone (Benjamin et al., 2019; Farmakis et al., 2016). Some causes and risk factors for CAD are uncontrollable, such as family history, older age, or being male. Fortunately, many risk factors are modifiable—blood pressure, blood cholesterol levels, smoking, obesity, poor diet, and sedentary lifestyle— and are targetable through secondary prevention (Fairfield et al., 2018; Hajar, 2017).

CAD attributable mortality rates are decreasing due to improvement in medical care; however, the prevalence of CAD is increasing, due to behavioral trends towards poorer health such as decreases in physical activity (Benjamin et al., 2019). Primary and secondary preventative measures for CAD must adapt to the progressively behavioral causes of heart disease (Balady et al., 2007). Toward this goal, the psychological factors that drive health behaviors in patients with CAD need to be better understood.

1.2. Cardiac Rehabilitation

For patients who have already experienced an adverse cardiac event such as a myocardial infarction (MI) or surgical interventions such as coronary artery bypass surgery or valve repairs/replacement, the most efficacious approach to reduce future morbidity and mortality is to attend Phase II Cardiac Rehabilitation (CR). Phase II CR is an outpatient secondary prevention program that targets modifiable risk factors of cardiac disease. CR is an evidence-based treatment regime that has received the highest level of recommendation (Class 1A) from the American Heart Association due to overwhelming evidence of its efficacy (Anderson et al., 2016). For instance, CR has been found to reduce the likelihood of subsequent CAD attributable mortality by 26% at one-year post-event (Anderson et al., 2016; Kwan & Balady, 2012; Oldridge et al., 2019). These benefits are conferred through individualized, progressive exercise regimes and efforts to reduce other risk factors by promoting medication adherence, dietary change, and smoking cessation.

1.3. Psychological Factors

Many psychological factors are strongly associated with the performance of health-related behaviors (Zänkert et al., 2019; Conner 2008). Budding research in CR suggests that factors such as depression impact fitness improvement within, and attendance at, CR (Rao et al., 2020; Kubzansky et al., 2005). Certain psychological facets, such as depression, have been widely studied in CR contexts, while other factors are less well studied (Hare et al., 2014).

Preliminary evidence implicates lower EF and higher anxiety with lower rates of attendance to CR. Research in nonmedical samples has also found a negative association between both factors and performance levels on exercise tasks (Kakos et al., 2010; Farris et al., 2019; Jeng & Braun, 1997; Vlaeyen & Linton, 2000). Prior research has established pathways through which anxiety and EF impact the initiation and performance of health behaviors, but these pathways have not been thoroughly explored in CR patients. However, it is possible to extrapolate from extant literature. Within the context of CR, high anxiety may induce fear of precipitating a cardiac event through exercise, which may inhibit attendance or performance (Kakos et al., 2010; Farris et al., 2019). Executive function issues may also reduce patients' perceived benefits of CR, increase perceived costs, and impair patients' abilities to organize and plan health behaviors. (Gaalema et al., 2019b; Jeng & Braun, 1997; Vlaeyen & Linton, 2000). These factors in combination may have especially potent effects on patients' success within CR.

1.3.1. Anxiety

Anxiety is a trait or state emotion, characterized by high levels of arousal, feelings of dread, fear, worry, overreaction, and somatic discomfort (Rosenhan et al., 1989). Fears of precipitating a cardiac event through exercise have been reported in patients with high levels of anxiety and are hypothesized to result in exercising at lower intensities or even discontinuing CR entirely (Farris et al., 2019). Further, heightened levels of somatic discomfort and low confidence in succeeding in lifestyle changes may result in low motivation to continue exercise regimes (Horwitz & McCaffrey, 2008).

It is no surprise then that high anxiety is a consistent predictor of health outcomes for CAD patients. Patients with higher levels of anxiety are less likely to initially attend CR (Rao et al., 2020), more likely to drop out (Kubzansky et al., 2005), and have higher morbidity and mortality rates by 4 years post coronary artery and valve surgeries (Székely et al., 2007). Unfortunately, high levels of anxiety are also especially common in cardiac patients, affecting up to 28% of patients entering CR in some samples (Rao, 2020). Table 1 summarizes findings and limitations of literature on anxiety in CR and related fields.

Table 1

Relevant Findings on Anxiety

Study	Population	Findings	Limitations
Rao et al., 2020	Patients Entering CR (N = 5908)	11% higher dropout rate for those with moderate or worse levels of anxiety compared to patients with lower levels.	Did not assess fitness improvement. Anxiety levels were dichotomous.
McGrady et al., 2009	Patients referred to CR (N = 380)	Higher scores on the Beck Anxiety Inventory were associated with noncompletion. Anxiety attributable noncompletion is highest at the earliest stages of CR.	Did not assess fitness improvement. Linear model only.
Farris et al., 2019	Cardiac (N = 69) and Pulmonary Rehabilitation (N = 48) patients; CR and PR Practitioners (N = 16)	Anxiety resulted in greater fears and avoidance of exercise. 62% of practitioners reported that they would decrease exercise intensity in response to increased exercise related fear.	Did not assess fitness improvement, linear assessment of anxiety.

Brewer 2010	Sports Injury Rehabilitation (N = 26)	Anxiety is negatively associated with performance in new rehabilitation activities and using the injured body part.	Non-CR sample, linear model of anxiety.

Relationships between anxiety and fitness improvement have not been studied in CR. However, research in sports injury rehabilitation has found that higher anxiety impairs performance and subsequent recovery in new rehabilitation activities (Brewer, 2007). In this study, fear of exercising on an injured body-part —analogous to inducing stress on cardiovascular systems— was hypothesized as the primary mechanism for reduced performance. This may impact the intensity patients are encouraged to exercise at, as over 60% of practitioners reported in one study that they would reduce necessary exercise intensity in response to patient fears (Farris et al., 2019).

Anxiety may also reduce fitness benefits yielded during CR by affecting exercise performed outside of exercise sessions. Patients are encouraged to exercise at home, in addition to the exercise they do at the program. Strong associations have been found between anxiety and avoidance of exercise within CR patients, which extends to leisure time physical activity (Bélair et al., 2018). It is possible that anxiety influences both adherence to at-home exercise recommendations and lower performance during CR sessions, reducing improvements in cardiorespiratory fitness across the duration of CR.

1.3.2. Executive Function

Executive functions are a series of top-down cognitive systems and skills that regulate goal-directed behavior (Diamond, 2012). Flexible thinking, working memory, and inhibition are included in most conceptualizations of EF and are integral towards implementing healthy lifestyle changes (Allan et al., 2016; Gutierrez-Colina et al., 2020; Cushman et al., 2021). Those with executive function deficits may struggle to implement long-term dietary and exercise plans, fail to inhibit responses to enticing but unhealthy foods or smoking, and discount the value of distal health outcomes (Gutierrez-Colina et al., 2020; Cushman et al., 2021; Williams et al., 2017; Graham, 2004, pp. 125-145; Meltzer & Krishnan, 2007, pp. 77-105; Wyckoff et al 2017; William et al., 2017; McAuley et al., 2011; Mueller et al., 2009).

Executive function deficits are quite common amongst patients in CR. This may be due to both acute effects associated with the cardiac event (e.g., interruptions in blood flow or effects of surgery related anesthesia) or more chronic issues that are associated with general declines of the cardiovascular system (Salzwedel et al., 2017; Eggermont et al., 2012). Research has also shown directly that deficits in some facets of EF result in lower attendance and adherence to CR (Gaalema et al., 2021). Limited research has also implicated other facets (lower flexible thinking skills) with lower fitness improvement by the end of CR (Kakos et al., 2010). However, this study did not directly control for attendance. Table 2 shows the available prior literature on EF in CR, findings, and limitations.

Table 2

Relevant Findings on Executive Function

Study	Population	Findings	Limitations
Gaalema et al., 2019b (N = 112)	Medicaid Patients in a randomized control trial for contingency management (N = 112)	Impulsivity and lower cognitive flexibility significantly predicted lower adherence. Higher delayed discounting resulted in more benefits from CM.	Did not assess fitness improvement
Kakos et al., 2010	Cardiac Rehabilitation Patients (N = 44)	Lower cognitive flexibility was associated significantly with lower METs improvement over CR	Did not control for attendance

1.4. Interrelationship Between Anxiety and Executive Function on Attendance and Fitness Improvement

EF and anxiety may have cumulative effects on patient motivation to attend CR. Motivation to engage in health behaviors is derived from a web of cognitive assessments made by patients (Xu, 2009). These may include the perceived benefits of CR, the health consequences of not attending, fear of inducing a cardiac event from exercise, discomfort during exercise, and the patient's self-efficacy for improving their own health (Xu, 2009). A CR patient with a combination of higher anxiety and lower EF would experience negative effects across all these assessments and should consequently have lower motivation to attend and thus be less likely to attend (Rao et al., 2020; Farris et al., 2019; Gaalema et al., 2019a; Kakos et al., 2010).

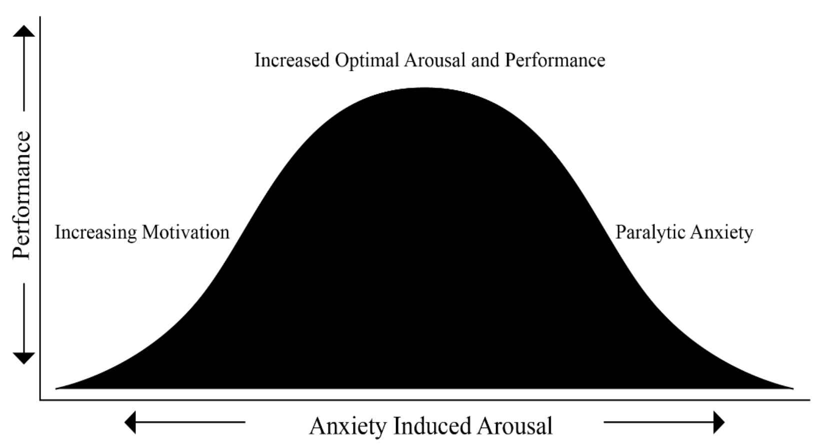
This hypothetical patient would also be more sensitive to discomfort during exercise, more frightened of inducing a cardiac event, and less confident in their ability to commit to CR due to anxiety (Farris et al., 2019; Deci et al., 1999). They would also discount both the consequences of not attending and the health benefits from attending due to lower EF (Gaalema et al., 2019a; Nigg, 2016; Krueger et al., 2011). Accordingly, the effects of executive function deficits and anxiety within CR should be examined concurrently, as their effects could be cumulative.

1.4.1. Potential Curvilinear Effects of Anxiety

It is important to consider the shape of associations between predictors and health outcomes. When anxiety is assessed in CR it has so far only been modeled as a binary or linear predictor, but other forms should be considered. For example, in education and sports psychology, anxiety levels often form a bell-curve with initiation and performance of academic or exercise tasks (Ford, 2017). Figure 1. summarizes the findings of several bell-curve models, where low amounts of anxiety are not

Figure 1:

Yerkes-Dodson Anxiety-Performance Curve



motivating, and excessive amounts of anxiety can be inhibitory, but moderate levels of anxiety-induced arousal produce peak performance and the highest likelihood of initiating healthy behavior. The inverted-U pattern has been found to predict initiation and performance in a wide range of tasks, including public speaking, academic performance, competitive sports performance, and injury rehabilitation outcomes (Ford, 2017, Brewer et al., 2002).

It is assumed that as anxiety levels increase in CR patients, attendance and positive health outcomes decrease. It has been well demonstrated that very high levels of anxiety induce fear and avoidance, reducing attendance (Rao et al., 2020; Székely et al., 2007). However, low levels of anxiety may be indicative of a lack of concern about diagnosis and may not be sufficiently motivating for patients to participate in CR. Moderate levels of anxiety could predict higher levels of attendance and performance given these findings (Ford, 2017; Martens et al., 1990; Wiese Bjornstal et al., 1998). Currently, the capacity for moderate levels of anxiety to improve attendance and performance in CR has not been assessed.

1.5. Anxiety, Executive Function, and Socioeconomic Status in Cardiac Rehabilitation

Lower-SES patients are an underserved population in CR with higher-risk profiles that warrant special consideration for additional support. These patients experience higher rates and worse severity of cardiac risk factors, have higher levels of anxiety, lower levels of EF, and often struggle to attend CR, all of which manifest in poorer prognoses (Gaalema et al., 2017a; Gaalema et al, 2017b; Mwinyi et al., 2017; Murphy et al., 1991). Due to the higher prevalence of anxiety and EF challenges alongside sobering statistics on attendance and health outcomes, the relationship between anxiety and EF on attendance or fitness outcomes may be especially potent in lower-SES patients.

1.5.1 Novel Explorations of Anxiety and Executive Function in CR

This study assesses three major gaps in extant literature. First, no study has examined the relationships between anxiety or EF on CR attendance or fitness improvement between samples of lower-SES and representative SES patients. Second, no study has yet examined associations between EF and anxiety with fitness improvements while controlling for attendance. And third, no study to date has modeled anxiety as a potential curvilinear predictor of attendance or fitness improvement.

CHAPTER 2: METHODS

2.1. Aims

There were two aims in this study. The primary aim was to demonstrate an association between anxiety and executive function with CR attendance. The secondary aim was an exploratory analysis to examine how fitness improvements yielded during CR vary with these factors. These aims were examined in both a lower-SES and a more representative sample of CR patients and led to the following hypotheses:

2.1.1. Attendance Hypotheses

1. Lower executive function will predict lower attendance.
2. Higher anxiety will predict fewer sessions attended. An inverse U-shaped relationship is hypothesized between the two variables, where those with low and high levels of anxiety will have lower attendance than those with moderate levels of anxiety.

2.1.2. Fitness Hypotheses

1. Lower executive function will predict less fitness improvement.
2. Higher anxiety will predict less fitness improvement. An inverse U-shaped relationship between the two is hypothesized, where those with low and high levels of anxiety will have less improvement than those with moderate levels of anxiety.

2.2. Data Sources

Data for analyses were taken from both *Predictors of Recovery from a Cardiac Event* (main outcomes reported in Khadanga et al., 2021) and *Financial Incentives to*

Improve Cardiac Rehabilitation Participation among Lower Socioeconomic Status Patients (main outcomes reported in Gaalema et al., 2019b). For the latter study, only data from patients who did not receive the intervention (i.e., the control group) were included for analyses of attendance. The full dataset was utilized for analyses of fitness improvement. Both studies are described below.

2.2.1 Khadanga Study

The purpose of the Khadanga study was to explore the medical and psychosocial predictors of CR participation and adherence. The study population included people hospitalized at the University of Vermont Medical Center (UVMMC) hospital for a cardiac diagnosis that made them eligible for CR (myocardial infarction, coronary bypass surgery, coronary stent placement, chronic heart failure) and lived within the catchment area for the UVMMC CR program.

Subjects were approached while they were in-patient and asked a series of demographic questions and completed assessments of psychosocial factors. These included measures of anxiety, depression, social support, and executive function. All patients were allowed to participate in the UVMMC CR program. 148 patients attended CR, and those who completed their course of CR (12-36 sessions depending on insurance or physician recommendations) repeated their fitness assessment upon exiting the program.

2.2.2 Gaalema Study

The primary objective of this study was to determine whether providing financial incentives increased participation in, and continued attendance at, CR within a sample of lower-SES patients. Secondary objectives were to determine if differences in attendance affected health or quality of life outcomes.

The Gaalema study was a parallel condition, randomized controlled trial. Patients were eligible if they had a CR-eligible diagnosis (myocardial infarction, coronary bypass surgery, coronary stent placement, chronic heart failure with reduced ejection fraction <35%) had not successfully completed CR in the past, had Medicaid or similar state-supported insurance, and resided in the catchment area for the UVMMC CR program with no plans to move within the year.

Patients were recruited while in-patient or from an outpatient cardiac clinic. All patients were referred to the UVMMC CR program and were assessed prior to participation in CR and 4 months after their initial assessment. Assessments consisted of an exercise tolerance test, detailed sociodemographic questions, medical history, and an executive function and cognitive battery.

Participants randomized to the contingency management intervention received incentives, in the form of cash, for completion of CR sessions, which was defined as completing the exercise and other activities scheduled for that session. The final sample consisted of 140 participants, 10 participants that served as pilot subjects (all in the intervention arm) and 130 who were randomized 1:1 to usual care or to contingency management.

2.3. Measures

2.3.1. Main Predictors

Executive Function (BRIEF-A)

The Behavior Rating Inventory of Executive Function (BRIEF-A) is a 75-item questionnaire measuring two indices of EF: behavioral regulation, and metacognition (Grieve et al., 2014). We utilized a global composite summary score of EF, where higher scores indicate more problems with EF, normalized as T-scores against a national sample (Derogatis, 1993). A T-score of ≥ 65 can be considered impaired (Derogatis, 1993). BRIEF-A T summary scores were collected as part of both the Khadanga and Gaalema studies. Scores were treated as continuous.

Anxiety (ASEBA ASR, OASR)

The Achenbach System of Empirically Based Assessment's Adult Self Report (ASEBA, ASR) is a 127-item self-report measure of adaptive function. The ASEBA measures several problem areas, with one subsection (6 items) designed to assess anxiety based on DSM-5 criteria. Two versions of the ASEBA were used as appropriate, the Adult Self Report (ASR) for adults 18-59 and the Older Adult Self Report (OASR) for adults 60+. T-normalized scores from the anxiety subscale were used in analyses of anxiety on fitness benefits and attendance. The ASEBA was administered in the Gaalema study at the intake assessment and were used as the measure for anxiety in analyses using data from this sample.

General Anxiety Disorder-7 (GAD-7)

The GAD-7 is a seven-item measure of anxiety based on the DSM-5 classifications of general anxiety disorder. Items are scored from zero to three resulting in a score range of 0 to 21, with higher scores indicating more severe anxiety. GAD-7 scores were considered continuous. These scores were collected in the Khadanga study during the inpatient visit and were used as the measure of anxiety for data in that sample.

2.3.2. Outcome Variables

Cardiac Rehabilitation Attendance

Outpatient, Phase II Cardiac Rehabilitation consists of monitored exercise sessions, symptom monitoring and counseling on secondary prevention behaviors. Insurance typically covers up to 36 sessions completed over the course of four months. Patients in the Gaalema study sample who were randomized to CM were excluded in analyses of attendance. For analyses of fitness improvement, only patients who have attended at least one session were included. Attendance was treated as a continuous variable in all analyses. The number of sessions completed was extracted from the clinical records for both studies.

Peak Metabolic Efficiency of Tasks scores at Exit (Exit METspeak)

Peak METS (METspeak) was used as the measure of fitness in this study, as measures of METS were available for more patients in both studies than other fitness measures. METspeak was assessed through symptom-limited treadmill exercise tolerance tests (ETT) prior to entry and upon 4 months after entry into CR. METspeak was defined as the workload performed on the last completed stage of ETT. For analyses of fitness improvement, METspeak at exit was used, controlling for METspeak at entry. In the Gaalema study data, exit METspeak scores were acquired for patients whenever possible, regardless of whether they had dropped out of CR. Most data on exit METspeak in the Khadanga study was from patients who completed CR, and thus this sample had a higher number of CR sessions attended than in the Gaalema study.

2.3.3. Potential Covariates

Baseline METspeak

To assess improvement in fitness, baseline fitness scores must be accounted for. METspeak was taken prior to entry to CR and were treated identically to four-month METspeak, with the exception that it was introduced into models as a covariate.

Age

Increased age has been associated with declining executive function. Fitness also declines as age increases (Wecker et al., 2005). Thus, age was assessed as a continuous covariate and was included in analyses where it shared significant correlations with primary predictors and outcomes.

Contingency Management Treatment Condition

Evidence from Gaalema et al., 2019a shows that contingency management may alleviate differences in attendance between individuals with lower and higher levels of EF. For this reason, patients in the contingency management condition were not included in analyses of attendance. However, these individuals were included in analyses of fitness improvement, and in these analyses, treatment condition was included as a potential covariate.

Attendance

Fitness improves with the number of sessions patients attend (Lavie et al., 2009). Consequently, analyses of fitness improvement included attendance as a continuous variable as a potential covariate.

Sex

Sex has been found to affect fitness improvement during CR, with women showing lower increases in METspeak from baseline to exit from CR (Keteyian et al., 2017). Women are also less likely to enroll in CR and may complete fewer sessions (Halm et al., 1999). Accordingly, sex was included in an initial correlation matrix between potential covariates and primary predictors and was included in analyses where it is significantly related to primary predictors and outcomes.

Diagnosis

Whether a patient has received a surgical or nonsurgical diagnosis influences their likelihood of attending CR and adhering to CR (Resurrección et al., 2019). Therefore, diagnosis of surgical or nonsurgical intervention was included in initial correlation matrices and was included in analyses where it was significantly associated with primary predictors and outcomes.

Smoking Status at Entry

Those who smoke are less likely to attend CR and are more likely to drop out of CR (Gaalema et al., 2015; 2020). Those who smoke also have lower measures of fitness and smoking can impede improvements in CVD risk profiles that are seen from exercise (Asthana et al., 2012; Riley et al., 2018). Smoking status was included in initial correlation matrices with primary predictors and outcomes and was included as a covariate when it significantly correlated with primary predictors and outcomes.

2.4. Analyses

The analyses in this study were retrospective and followed recommendations for identification of covariates in exploratory analyses (phases of analyses shown in Table 3), where potential covariates were identified through initial correlation matrices and t-tests. Covariates that shared significant relationships with primary predictor and outcome variables were added to the first block of hierarchical regression models. Main independent variables were added in the subsequent blocks. All analyses used listwise deletion and followed recommendations from Aiken & West, 1991.

Table 3

Phase Implementation of Hierarchical Regressions

Phase	Stat. Goal	Selected Analyses	Assessment
Correlation Matrix	Assign sig. covariates to analyses	All	Pearson correlation; T-tests; Sig. ≤ 0.05
Regression Block 1	Model of covariates	All	NA
Regression Block 2	Assess sig. of primary predictors	EF; Anxiety	β; Δ F; Sig. ≤ 0.05
Regression Block 3	Assess sig. of curvilinear anxiety parameter	Anxiety^2	β; Δ F; Sig. ≤ 0.05 Assessment of PP-plots

Data for analyses of EF and anxiety on attendance included all patients except those randomized to the CM treatment condition in the Gaalema sample; Gaalema N = 57; Khadanga N = 315.

For exploratory analyses of fitness improvement, a subsample that included only those who completed > 0 sessions was taken from both studies (Gaalema N = 103; Khadanga N = 148). Patients in the Khadanga study who had exit scores (and thus can be included in analyses of fitness improvement) generally completed their ETT upon completing CR, and thus had all completed a high number of sessions.

2.4.1. Analyses for Aim 1: Attendance

Effects of Anxiety on Attendance

Attendance was regressed on potentially significant covariates —sex, diagnosis, age, smoking status— in the first block. Anxiety scores were entered into the second block as a linear variable and were assessed at this point. Anxiety was transformed into a quadratic parameter, (i.e., $-\text{Anxiety}^2$) and this transformation was entered into the third block. Improvements in model fit, parameter statistics, and visual assessment of PP plots were used to assess the significance of the curvilinear predictor. This analysis was performed in both the general CR-eligible sample (Khadanga) and in a subsample of lower-SES patients (Gaalema) who did not receive a CM intervention.

Effects of Executive Function on Attendance

Attendance was regressed on potentially significant covariates —sex, diagnosis, age, smoking status, and contingency management condition — in the first block. EF scores were entered into the second block to assess the variability contributed to attendance by executive function above covariates. This analysis was performed in both the general CR-eligible sample (Khadanga) and the lower-SES sample (Gaalema) excluding patients randomized to the CM condition.

2.4.2. Analyses for Aim 2: Fitness Improvement

Effects of Anxiety on Fitness Improvement

Exit METspeak was regressed on potentially significant covariates —sex, diagnosis, age, smoking status, contingency management condition, METspeak at baseline, and attendance— in the first block. Anxiety scores were entered into the second block as a linear variable and were assessed at this point. Anxiety was transformed into a quadratic variable (i.e., anxiety^2), and this transformation was entered into the third block. Improvements in model fit, parameter significance, and visual assessment of PP plots were used to assess the significance of the curvilinear predictor. This analysis was performed in both the general CR-eligible sample (Khadanga) and the full lower-SES sample (Gaalema), in those who completed at least one session of CR.

Effects of EF on Fitness Improvement

Exit METspeak was regressed on potentially significant covariates —sex, diagnosis, age, smoking status, baseline METspeak, and contingency management conditions— in the first block. EF scores were entered into the second block to assess the variability contributed to fitness improvement by executive function above covariates. This analysis was performed in both the general CR-eligible sample (Khadanga) and the full lower-SES sample (Gaalema), in those who completed at least one session of CR.

CHAPTER 3: RESULTS

3.1. Demographics

Table 4

Descriptive Statistics of Continuous Variables Between Samples

Variable		Mean	±SD	Range	N
Age	Rep	68.3	11.65	58.0	337
	Lower-SES	57.1	10.20	57.0	130
Entrance METspeak	Rep	5.86	2.52	14.14	161
	Lower-SES	5.20	2.68	15.0	109
Exit METspeak	Rep	7.37	2.91	16.62	170
	Lower-SES	6.51	3.30	12.5	90
Sessions	Rep	19	6.29	19	168
	Lower-SES				
	(Financial incentives)	18.6	15.79	36	130
	Lower-SES (No intervention)	14.7	14.82	36	65
Anxiety	Rep (GAD-7)	4.47	4.76	21	331
	Lower-SES (ASR)	59.4	8.28	30	111
BRIEF-A	Rep	42.0	10.05	53	302
	Lower-SES	55.9	11.75	52	106

Characteristics of the two samples can be seen in Tables 4 (continuous variables) and 5 (categorical variables). As expected, given prior research, the two samples differed on several characteristics. Compared to the representative sample, patients in the lower-SES sample were much younger (57 vs 68 yrs), had lower

METspeak scores at entrance (5.2 vs 5.9) and at exit (6.5 vs 7.4), and lower-SES patients not randomized to the CM condition attended fewer sessions than those in the representative sample (14.7 vs 19). Lower-SES patients were also nearly four times more likely to smoke (11% vs 42%) and were less likely to have had a surgical diagnosis (17% vs 47%). Roughly two-thirds of both samples were male, and among those who had both an entrance and exit fitness score, there were no differences in magnitude of fitness improvement (1.51 METspeak for both samples).

Table 5

Descriptive Statistics of Categorical Variables Between Samples

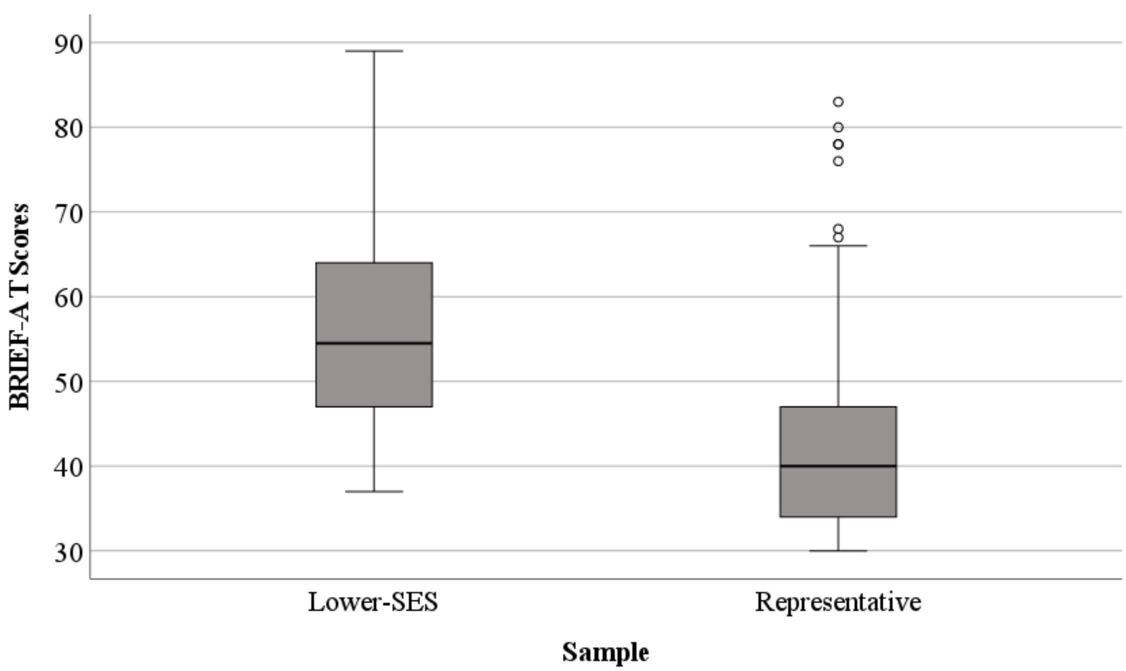
Variable	N (%)	
	Representative	Lower-SES
Sex		
Male	225 (66.8)	81 (62.3)
Female	112 (33.2)	49 (37.7)
Diagnosis		
Surgical	157 (46.6)	108 (83.1)
Nonsurgical	180 (53.4)	22 (16.9)
Smoking Status		
Current Smoker	37 (11.0)	55 (42.3)
Non/Former Smoker	299 (89.0)	75 (57.7)
Anxiety		
Normal	211 (63.7)	62 (55.9)
Mild+ or Problematic	120 (36.3)	49 (44.1)
BRIEF-A		
Normal	291 (96.4)	82 (76.4)
Executive function deficits	11 (3.6)	25 (23.6)

When looking at the cognitive variables, patients in the lower-SES sample had higher average scores of executive function deficits (55.5 vs 42.0; Figure 2). The two samples utilized separate measures of anxiety and thus could not be directly compared. However, higher levels of anxiety were detected by both measures than would be expected from the 18-28% established by prior literature (Rao, 2020), as 36% of patients in the representative sample were identified with at least mild anxiety by the GAD-7 and 44% had problematic anxiety scores in the lower-SES sample by the ASR/OASR anxiety

Figure 2:

Boxplots of BRIEF-A Scores by Sample

subscale. Variables were checked for skew and kurtosis, but no distribution warranted an adjustment in analyses.



3.2. Establishing Covariates

3.2.1. Representative Sample

Correlation matrices were drawn between predictors, outcomes, and potential covariates in both samples. In the representative sample, our primary outcome, sessions attended, only shared significant correlations with age, where older patients attended more sessions (r = 0.19, $p<.01$). Our secondary outcome, METspeak at exit, shared a significant positive association with METspeak at entrance (r = 0.77, $p<.01$), and a negative association with age (r = -0.37, $p<.01$) and female sex (Male M = 3.57, Female M = 2.14, $p<.05$). BRIEF-A scores were only significantly associated with GAD-7 scores, where higher anxiety was correlated with worse executive deficits (r = 0.40, $p<.01$). Anxiety scores also increased with age (r = 0.16, $p<.01$) and were higher in patients who smoked (Smoker M = 6.49, Nonsmoker = 4.23, $p<.01$). Older age was also associated with being female (Male M = 67, Female M = 71, $p<.01$) and older adults were more likely to be nonsmokers (Smoker M = 59, Nonsmoker M = 69, p<.01). A higher proportion of Males smoked (Male = 13%, Females = 6%, Chi2 = 3.88 $p<.05$), and smoking was associated with having a surgical intervention (Surgical = 7%, Nonsurgical = 15%, $p<.05$).

These matrices resulted in the inclusion of age and smoking status in the analysis of attendance by anxiety levels in the representative sample. Only age was included as a covariate in the analysis of attendance by level of EF. The analysis of fitness improvement by anxiety levels in the same sample included age, METspeak at entrance, sessions attended, and smoking status. The fitness improvement analysis by EF levels in this sample included age, METspeak at entrance, and sessions attended.

3.2.2. Lower-SES Sample

Similar correlation matrices were drawn for the lower-SES sample. Our primary outcome, sessions attended, was significantly associated with smoking status, where smokers attended fewer sessions (Smokers M = 7.6, Nonsmoker M = 20.0, $p<.01$). Only smoking status was included as a covariate for assessments of anxiety and EF on attendance.

Fitness analyses in the lower-SES sample included all patients, not only those who were in the non-incentive condition. Thus, new matrices were drawn for the new sample. METspeak at exit was significantly associated with higher entrance fitness (r = 0.81, $p<.01$), lower ASR/OASR scores (r = -0.23, $p<.05$), lower age (r = -0.41, $p<.01$), male sex (Male M = 7.06, Female M = 5.59, $p<.05$), and having a surgical diagnosis (Surgical = 6.28, Nonsurgical = 5.03, $p<.05$). Higher BRIEF-A scores were significantly associated with higher ASR/OASR scores (r = 0.54, $p<.01$) and younger age (r = -0.20, $p<.01$). Higher ASR/OASR scores were also associated with being female (Female M = 62, Male M = 58, $p<.05$).

Older patients attended more sessions (r = 0.23, $p<.01$), and were less likely to smoke (Smoker M = 53, Nonsmoker = 60, $p<.01$). The contingency management condition (receiving an incentive) only shared a significant relationship with sessions attended (r = 0.42, $p<.01$), which was not a primary outcome for analyses including the full lower-SES sample. Thus, sessions attended, fitness at entry, sex, age, and diagnosis were included in both the analyses of anxiety and EF on fitness outcomes.

3.3. Analyses in the Representative Sample

3.3.1. Anxiety and Attendance

Attendance was regressed on smoking status, age, and GAD-7 scores to determine whether anxiety impacted attendance in the representative sample (Table 6). Although the model itself was significant ($F(3,171) = 3.12$, $p < .05$), no significant association was found between GAD-7 scores and attendance in the representative sample ($b = -0.18$, $t(173) = -0.84$, p = NS; $\Delta R^2 = 0.004$, $\Delta F(1,171) = 0.71$, p = NS). Age was positively associated with attendance ($b = 0.22$, $t(173) = 2.27$, $p < .05$), and smoking status was not ($b = -4.11$, $t(173) = -1.03$, p = NS). Curvilinearly transformed anxiety T scores did not contribute significant variation to the model ($\Delta F(1,170) = 0.23$, $p < .05$, $\Delta R^2 = 0.001$).

Table 6

Anxiety as a Predictor of Attendance in the Representative Sample

Predictor	Coefficient	S.E.	t	P
Constant	7.83	6.78	1.16	0.25
GAD-7	-0.18	0.21	-0.84	0.4
Age	0.22	0.10	2.27	0.02*
[a]Smoking Status	-4.11	4.00	-1.03	0.31

Current Smoker = 0, nonsmoker = 1

3.3.2. Executive Function and Attendance

Attendance was then regressed on age and BRIEF-A T scores in the representative sample to assess whether executive function was associated with attendance (Table 7). The model was significant, ($F(2, 160) = 3.27$, $p < .05$), however executive function was not significantly related to attendance, ($b = -0.10$, $t(161) = -1.06$, p = NS; $\Delta R2 = 0.007$, $\Delta F(1,160) = 1.13$, p = NS). Only age was significantly associated with attendance, where older patients attended more sessions ($b = 0.21$, $t(161) = 2.26$, $p < .05$).

Table 7

Executive Function as a Predictor of Attendance in the Representative Sample

Predictor	Coefficient	S.E.	t	P
Constant	11.08	7.93	1.40	0.16
Age	0.21	0.10	2.26	0.03*
BRIEF-A	-0.10	0.10	-1.06	0.29

3.3.3. Anxiety and Fitness Improvement

METspeak at exit was regressed on METspeak at entrance, sessions attended, smoking status, age, and GAD-7 scores to determine whether anxiety impacted fitness improvement (Table 8). The model reached significance ($F(5,63) = 24.35$, $p < .01$), though no significant association was found between GAD-7 scores and exit METspeak ($b = 0.06$, $t(67) = 1.15$, p = NS; ΔR2 = .007, $\Delta F(1,63) = 1.31$, p = NS). METspeak at entry was significantly and positively associated with METspeak at exit ($b = 1.00$, $t(67) = 7.74$, $p < .01$) and age shared a negative relationship with exit METspeak ($b = -0.07$, $t(67) = -2.86$, $p < .01$). Neither the number of sessions attended ($b = 0.02$, $t(67) = 0.92$, p = NS), or smoking status were related with exit fitness ($b = -1.06$, $t(67) = -1.11$, p = NS). The addition of a quadratic anxiety term did not account for significant variability above the linear model ($\Delta F(1,62) = 0.80$, $p = NS$, $\Delta R^2 < .001$).

Table 8

Anxiety as a Predictor of Exit Fitness in the Representative Sample

Predictor	Coefficient	S.E.	t	P
Constant	4.89	2.19	2.23	0.03*
Age	-0.07	0.02	-2.86	0.01**
Sessions	0.02	0.02	0.92	0.36
Entrance METspeak	1.00	0.13	7.74	0.00**
[a]Smoking Status	-1.06	0.96	-1.11	0.27
GAD-7	0.06	0.05	1.15	0.26

Current Smoker = 0, nonsmoker = 1

3.3.4. Executive Function and Fitness Improvement

METspeak at exit was regressed on BRIEF-A T scores, METspeak at entrance, sessions attended, and age to determine whether anxiety impacted fitness improvement (Table 9). The model was significant (F(4,60) = 27.10 , $p < .01$), but no significant association was found between BRIEF-A T scores and exit METspeak (b = -0.02 , t(63) = -0.85, p = NS; ΔR2 = .004, ΔF(1,60) = 0.40, p = NS). METspeak at entry was positively associated with METspeak at exit (b = 1.05, t(63) = 9.42, $p < .01$), and age shared a negative relationship with exit METspeak (b = -0.07, t(67) = -2.93, $p < .01$). The number of sessions attended (b = 0.03, t(63) = 1.40, p = NS) was not significantly associated with exit METspeak scores.

Table 9

Executive Function as a Predictor of Exit Fitness in the Representative Sample

Predictor	Coefficient	S.E.	t	P
Constant	5.20	2.22	2.35	0.02*
Age	-0.07	0.02	-2.93	0.01*
Sessions	0.03	0.02	1.40	0.17
Entrance METspeak	1.05	0.13	8.42	0.00*
BRIEF-A	-0.02	0.02	-0.85	0.40

3.4. Analyses in the Lower SES Sample

3.4.1. Anxiety and Attendance

Attendance was regressed on smoking status and ASR/OASR anxiety T scores in the control group for the lower-SES sample (Table 10). The model accounted for a significant proportion of variation in attendance ($F(2,54) = 4.10$, $p < .05$, $R^2 = 0.13$). No significant association was found between ASR/OASR anxiety T scores and attendance ($b = -0.20$, $t(55) = -0.90$, p = NS; $\Delta R2 = .013$, $\Delta F(1,54) = 0.81$, p = NS). Those who smoke attended 9.6 fewer sessions when anxiety T scores were accounted for than nonsmokers, ($b = 9.62$ $t(55) = 2.45$, $p < .05$). Although a linear relationship did not appear for anxiety, an exploratory analysis of the curvilinear relationship was performed. Quadratic transformed ASR/OASR T scores did not contribute significant variation to the model ($\Delta F\ (1,53) = 0.69$, p = *N.S.*, $\Delta R^2 = 0.01$).

Table 10

Anxiety as a Predictor of Attendance in the Lower-SES Sample

Predictor	Coefficient	S.E.	t	P
Constant	22.92	14.46	1.59	0.12*
ASR/OASR	-0.20	0.23	-0.90	-0.90
[a]Smoking Status	9.62	3.92	2.45	0.02*

Current Smoker = 0, nonsmoker = 1, does not include participants in the current contingency management condition

3.4.2. Executive Function and Attendance

Attendance was regressed on BRIEF-A T scores and smoking status in the control group of the lower-SES sample (Table 11). The model was significant (F(2, 52) = 3.56, $p < .05$), but when the predictors were examined individually executive function was not significantly related to attendance, (b = -0.15, t(53) = -0.92, p = NS). Only smoking status was significant, where smokers attended 9.6 fewer sessions than nonsmokers after accounting for executive function (b = 9.64 t(53) = 2.45, $p < .05$).

Table 11

Executive Function as a Predictor of Attendance in the Lower-SES Sample

Predictor	Coefficient	S.E.	t	P
Constant	18.55	9.46	1.96	0.06
[a]Smoking Status	9.64	3.94	2.45	0.02*
BRIEF-A	-0.15	0.16	-0.92	0.36

Current Smoker = 0, nonsmoker = 1, does not include participants in the current contingency management condition

3.4.3. Anxiety and Fitness Improvement

METspeak at exit was regressed on METspeak at entrance, sessions attended, contingency management condition, diagnosis type, sex, age, and ASR/OASR T scores (Table 12). The model was significant (F(7,81) = 35.29, $p < .01$, $R^2 = 0.75$), and ASR/OASR anxiety T scores were negatively related to exit fitness (b = -.05, t(81) = -2.1, $p < .05$). METspeak at baseline positively predicted METspeak at exit (b = 0.87, t(81) = 11.9, $p < .01$), as did the number of sessions attended (b = 0.06, t(81) = 4.45, $p < .01$).

Age was negatively associated with METspeak at exit (b = -0.06, t(81) = -2.39, $p < .05$). Sex (b = -0.66, t(81) = 1.63, p = NS), contingency management condition (b = -0.56, t(81) = -1.45, p = NS), and diagnosis (b = -0.26, t(81) = -0.52, p = NS), were not significantly associated with exit METspeak.

Table 12

Anxiety as a Predictor of Exit Fitness in the Lower-SES Sample

Predictor	Coefficient	S.E.	t	P
Constant	7.48	2.27	3.30	.00*
Sessions	0.06	0.014	4.45	.00*
[a]Contingency Management	-0.56	0.401	-1.45	.15
Entrance METspeak	0.87	0.073	11.92	.00*
[b]Sex	-0.65	0.404	-1.62	.10
Age	-0.06	0.023	-2.39	.02*
[c]Diagnosis	-0.26	0.501	-.53	.61
ASR/OASR	-0.05	0.022	-2.08	.04
-ASR/OASR^2	0.00	0.00	-0.81	0.42

Control = 0, Incentive = 1
Male = 0, Female = 1
Nonsurgical Diagnosis = 0, Surgical Diagnosis = 1

3.4.4. Executive Function and Fitness Improvement

METspeak at exit was regressed on BRIEF-A T scores, METspeak at entrance, contingency management condition, sessions attended, sex, age, and diagnosis to determine whether anxiety impacted fitness improvement (Table 13). The model was significant ($F(7,77) = 36.65$, $p < .01$). BRIEF-A T-scores were negatively associated with METspeak at exit (b = -0.03, t(77) = -2.16, $p < .05$) as was age (b = -0.07, t(81) = -

3.10, $p < .01$). Sessions attended was positively related to METspeak at exit (b = 0.05, t(81) = 3.99, $p < .01$), and males improved fitness scores more than females (b = -0.81, t(81) = -2.04, $p < .05$). Neither contingency management condition (b = -0.26, t(81) = -0.67, p = NS), nor diagnosis were significantly related with exit fitness (b = -2.4, t(81) = -0.48, p = NS).

Table 13

Executive Function as a Predictor of Exit Fitness in the Lower-SES Sample

Predictor	Coefficient	S.E.	t	P
Constant	7.79	2.08	3.74	0.00*
Sessions attended	0.05	0.01	3.99	0.00*
[a]Contingency Management condition	-0.26	0.39	-0.67	0.51
Entrance METspeak	0.84	0.07	11.80	0.00*
[b]Sex	-0.81	0.40	-2.04	0.04*
Age	-0.07	0.02	-3.10	0.00*
[c]Diagnosis	-0.24	0.49	-0.48	0.63
BRIEF-A	-0.03	0.02	-2.16	0.03*

[a]Control = 0, Incentive = 1
[b]Male = 0, Female = 1
[c]Nonsurgical Diagnosis = 0, Surgical Diagnosis = 1

CHAPTER 4: DISCUSSION

4.1. Summary

When looking at the baseline characteristics of these samples, the lower-SES and the more representative sample clearly differed. The lower-SES sample had characteristics consistent with a higher-risk profile, as would be expected given prior literature. Compared to the representative sample, lower-SES patients were on average 13 years younger, had lower fitness scores, were nearly four times more likely to smoke and were less likely to have a surgical diagnosis. Executive function deficits were more common in the lower-SES sample and anxiety may have been more prevalent as well.

Overall, analyses showed that patient attendance was not predicted by level of anxiety or executive function in either sample. However, both higher anxiety and lower EF were associated with diminished fitness improvements amongst lower-SES patients. These relationships were strong, even whilst controlling for sessions attended, age, and smoking status. The relationship between anxiety and fitness improvement was more consistent with a linear model than an inverse-U shaped pattern.

4.2. Null Results on Attendance

Prior literature indicated that both higher levels of anxiety and lower executive function would be associated with reduced attendance. Our results contrast with this small but consistent field of findings, and this may be due to high baseline rates of attendance in both samples. Patients in the representative sample attended over 19 sessions on average and although session attendance was lower in the lower-SES sample, patients still attended an average of almost 15 sessions. Ceiling effects may have been present for a considerable number of patients who had completed, or nearly completed, CR. Future research should examine these relationships among samples with more variability in number of sessions completed. Very low rates of executive deficits were also identified in the representative sample, which may have served to further reduce power for those analyses.

4.3. Fitness Improvement

Both anxiety and executive function predicted amount of fitness improvement in the lower-SES sample but not in the more representative sample. Lower-SES patients had higher baseline rates of anxiety and lower levels of executive function and fitness than representative patients, which could have made effects easier to detect. Conversely, rates of clinically relevant executive deficits may have been too low in the representative sample to adequately power an analysis (N(%) = 11(8)). Whilst we hypothesized these relationships to also occur in the representative sample, it was expected for the effect sizes to be greater among lower-SES patients.

Many barriers to fitness improvement (e.g., lack of access to healthy foods, safe places to exercise, resources to attend CR, or friend/family support for smoking cessation) are overrepresented in lower-SES populations, and higher levels of anxiety and executive function deficits may make these barriers harder to surmount (Gaalema et al., 2017b; Vilchinsky et al., 2018; Shanmugasegaram et al., 2013). Among lower-SES patients, lower EF or higher anxiety may detrimentally affect fitness improvement through at least two potentially modifiable pathways: lower adherence to at home recommendations, and worse performance during CR exercise sessions (Sandercock et al., 2013; Abu-Haniyeh et al., 2018; Casillas et al., 2016; Khushhal et al., 2019).

4.3.2. Adherence to At-Home Recommendations

To reap optimal cardiovascular benefits, patients must adhere to at-home recommendations. These include meeting physical activity recommendations, implementing heart healthy diets, abstaining from smoking, reducing stress, and adhering to medications (Franklin et al., 2013). Healthy lifestyle changes are notoriously difficult to make and issues with facets of EF such as planning, problem solving, organizing, and cognitive flexibility can impair patients' abilities to adhere to these recommendations (Gaalema et al., 2017b; Allan et al., 2016; Gaalema et al., 2021). High levels of anxiety have also been found to impair health-related behavior change and, unfortunately, patients often self-medicate anxiety with unhealthy behaviors such as disordered eating or smoking (Bandura, 1988; Xu, 2009). It is likely that problems with both psychological factors reduce adherence to at-home recommendations.

4.3.3. Performance During CR

Patients' performance during exercise sessions is linked with their fitness improvement, as exercising at appropriate levels of intensity is necessary for clinically meaningful improvements in cardiovascular health (Franklin et al., 2013; Hansen et al., 2021). Anxiety has been shown to affect performance across a wide variety of tasks, including exercise performance (Ford, 2017). Higher levels of anxiety may increase patients' somatic sensitivity to discomfort during exercise, reduce their confidence in improving their fitness, or increase fear of inducing a cardiac event. Any of these factors could result in earlier discontinuation or reductions of exercise intensity (Farris et al., 2019).

Executive function deficits may also be associated with lower fitness improvement through reductions in performance. Considering that many patients, especially those of lower-SES, enter CR deconditioned and with scant exercise histories, it is likely that CR sessions may be physically unpleasant or even painful (Menezes et al., 2012; Keessen et al., 2020). Patients with lower EF are more sensitive to such discomfort and are also being more likely to discount the long-term benefits of exercise (McAuley, 2011). It would not be surprising if lower EF patients discontinued exercise early or performed at a lower intensity when confronted with an unpleasant task with few perceived benefits.

4.4. Null Results for Curvilinear Effects

Anxiety may predict behavior directly, where higher anxiety predicts lower performance, or as an inverse U-shaped relationship, where moderate levels of anxiety are associated with optimal performance. In these analyses, the direct relationship was a better predictor of fitness improvement. This observation may occur for several reasons. First, inverse-U shaped patterns between anxiety and performance occur when tasks are challenging, anxiety is task specific (state-based), and levels of self-efficacy are at least moderate (Ford, 2017). It is unlikely that patients do not find exercise in CR challenging, as it is scaled to maximal safe intensity. However, the task may simply be too uncomfortable to far any amount of anxiety to modify performance positively. These findings match with prior literature, as negative linear relationships between anxiety and performance are detected when stressors breach a threshold of discomfort or injuriousness, and become ‘distracting’ (Ford, 2017).

Rather than the measures utilized in our study, state-based measures of anxiety may have been more capable of capturing potential curvilinear effects. The ASR/OASR and the GAD-7 are measures of generalized/trait-based anxiety and cannot distinguish state from trait-based anxiety. Finally, patients exercise-specific self-efficacy may be very low, which is probable, considering the deconditioned state of many patients when they enter CR (Menezes et al., 2012; Keessen et al., 2020). When individuals are not confident in the probability of success in tasks, and thus have low self-efficacy, curvilinear effects often disappear, and stressors only serve to diminish performance (Ford, 2017).

4.5. Clinical Relevance and Future Research

In the full lower-SES sample, an increase of a single T-score in anxiety was associated with a decrease of -0.05 improvement in METspeak. BRIEF-A T scores had a similar effect size, $\beta = -0.03$. This is concerning, as an increase of a single MET by the end of CR has been associated with a 28% decrease in all-cause mortality in heart failure patients. Patients with very high anxiety or very low EF may receive only a fraction of that benefit. Unfortunately, a substantial portion of the lower-SES patients had scores who exceeded clinically concerning cutoffs (31%, 63+ ASR/OASR, 24% 65+ BRIEF-A) (Franklin et al., 2013).

To put these findings in perspective, a fully attending patient with an ASR/OASR T score of 63 would be expected to lose out on 0.65 METspeak in improvement compared to a patient with an expected mean ASR/OASR score (T = 50). Similarly, a patient with a BRIEF-A T score of 65 would be expected to lose 0.45 METs in improvement compared to a patient with an expected mean BRIEF-A score (T = 50).

Ultimately, the findings in this study can inform patient treatment. Therapies such as interoceptive exposure therapies have shown success in reducing state-based anxiety experienced during panic attacks and may be effective in reducing exercise related anxiety (Craske et al., 1997; Boettcher & Barlow, 2019; Keessen et al., 2020). This therapy has the added benefit of ease of administration, often taking less than five minutes, and requires minimal training (Lee et al., 2006). Motivational interviewing, which is frequently utilized in medicine and uses highly adaptable modules, may be able to improve motivation to implement healthy behavior change in patients with lower EF (Naroee et al., 2020; Pietrabissa et al., 2015; Rubak, 2005).

Accordingly, results from this study suggest several areas for future research. Research should be conducted to identify how anxiety and executive function deficits confer disadvantages in fitness improvements to CR patients. Once the mechanisms responsible have been identified, appropriate therapies and interventions can be selected to ameliorate lower fitness improvement in these patients. We have proposed two possible, potentially modifiable, pathways through which these relationships may exist, where lower adherence to at-home recommendations and lower performance during exercise sessions may lead to less fitness improvement.

A combination approach would be an effective route of study to parse out these possibilities. Measures of diet, physical activity, and medication adherence could be obtained alongside measures of performance during exercise sessions. An ambulatory assessment of patients' behaviors at home could utilize self-report diet logs and pedometers, while METspeak or Borg scale assessments could be taken during exercise sessions to monitor performance. We are currently exploring pedometer tracking and the use of Borg RPE scales in lower-SES patients. Follow up research from this thesis is being discussed that could examine the effects of motivational interviewing and interoceptive exposure therapies on fitness improvement.

Overall, examinations of anxiety and EF revealed few effects in a representative SES sample of patients. However, lower-SES patients who struggled with executive deficits, or high levels of anxiety, received fewer fitness benefits from CR. These effects persisted after controlling for prominent confounds. These relationships continue to highlight the burdens borne by lower-SES patients following a cardiac event. Alongside evidence that this population has lower rates of CR attendance, higher rates of cardiac event incidence, and higher risk profiles (e.g., smoking, obesity, lower physical activity), results from this study suggest that improvements during CR are being impeded by anxiety and executive function deficits. CR programs should seek to provide extra support for lower-SES patients, and future research is needed to identify what types of interventions may reduce fitness improvement differences beyond simply improving attendance.

CHAPTER 5: References

Abu-Haniyeh, A., Shah, N. P., Wu, Y., Cho, L., & Ahmed, H. M. (2018). Predictors of cardiorespiratory fitness improvement in phase II cardiac rehabilitation. *Clinical cardiology*, 41(12), 1563–1569.

Aiken, L. S., & West, S. G. (1991). Multiple regression: Testing and interpreting interactions. Newbury Park, CA: Sage Publications.

Allan, J.L., McMinn, D., & Daly, M. (2016). A Bidirectional Relationship between Executive Function and Health Behavior: Evidence, Implications, and Future Directions. *Frontiers in neuroscience*, 10, 386.

Anderson, L., Thompson, D. R., Oldridge, N., Zwisler, A. D., Rees, K., Martin, N., & Taylor, R. S. (2016). Exercise-based cardiac rehabilitation for coronary heart disease. *The Cochrane database of systematic reviews*, 2016(1), CD001800.

Asthana, A., Piper, M.E., McBride, P.E., Ward, A., Fiore, M.C., Baker, T.B., Stein, J.H., 2012. Long-term effects of smoking and smoking cessation on exercise stress testing: three-year outcomes from a randomized clinical trial. Am. Heart J. 163 (1), 81–87.

Balady, G. J., Williams, M. A., Ades, P. A., Bittner, V., Comoss, P., Foody, J. M., Franklin, B., Sanderson, B., Southard, D., American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee, the Council on Clinical Cardiology, American Heart Association Council on Cardiovascular Nursing, American Heart Association Council on Epidemiology and Prevention, American Heart Association Council on Nutrition, Physical Activity, and Metabolism, & American Association of Cardiovascular and Pulmonary Rehabilitation (2007). Core components of cardiac rehabilitation/secondary prevention programs: 2007 update: a scientific statement from the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee, the Council on Clinical Cardiology; the Councils on Cardiovascular Nursing, Epidemiology and Prevention, and Nutrition, Physical Activity, and Metabolism; and the American Association of Cardiovascular and Pulmonary Rehabilitation. *Circulation,* 115(20), 2675–2682.

Bandura (1988) Self-efficacy conception of anxiety, *Anxiety Research*, 1:2, 77-98,

Bélair, M. A., Kohen, D. E., Kingsbury, M., & Colman, I. (2018). Relationship between leisure time physical activity, sedentary behaviour and symptoms of depression and anxiety: evidence from a population-based sample of Canadian adolescents. *BMJ open*, 8(10), e021119.

Benjamin, E. J., Muntner, P., Alonso, A., Bittencourt, M. S., Callaway, C. W., Carson, A. P., Chamberlain, A. M., Chang, A. R., Cheng, S., Das, S. R., Delling, F. N., Djousse, L., Elkind, M., Ferguson, J. F., Fornage, M., Jordan, L. C., Khan, S. S., Kissela, B. M., Knutson, K. L., Kwan, T. W., … American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke

Statistics Subcommittee (2019). Heart Disease and Stroke Statistics-2019 Update: A Report from the American Heart Association. *Circulation*, 139(10), e56–e528.

Boettcher, H., & Barlow, D. H. (2019). The unique and conditional effects of interoceptive exposure in the treatment of anxiety: A functional analysis. *Behaviour research and therapy*, 117, 65–78.

Brewer BW, Andersen MB, Van Raalte JL. (2002) Psychological aspects of sport injury rehabilitation: toward a biopsychological approach. In: Mostofsky DI, Zaichkowsky LD, editors. *Medical Aspects of Sport and Exercise.* Morgantown, WV: Fitness Information Technology; 2002. pp. 41–54.

Brewer, B. W. (2007). *Psychology of sport injury rehabilitation*. In G. Tenenbaum & R. C. Eklund (Eds.), Handbook of sport psychology (p. 404–424). John Wiley & Sons, Inc.

Casillas, J. M., Gudjoncik, A., Gremeaux, V., Aulagne, J., Besson, D., & Laroche, D. (2017). Assessment tools for personalizing training intensity during cardiac rehabilitation: Literature review and practical proposals. *Annals of physical and rehabilitation medicine*, 60(1), 43–49.

Conner, M. (2008), Initiation and Maintenance of Health Behaviors. *Applied Psychology*, 57: 42-50.

Craske, M. G., Treanor, M., Conway, C. C., Zbozinek, T., & Vervliet, B. (2014). Maximizing exposure therapy: an inhibitory learning approach. Behaviour research and therapy, 58, 10–23.

Cushman, G. K., West, K. B., Davis, M., LaMotte, J., Eaton, C. K., Gutierrez-Colina, A. M., Suveg, C., & Blount, R. L. (2021). The role of executive function, healthcare management, and self-efficacy in college students' health-related quality of life. *Journal of American college health*: J of ACH, 1–9. Advance online publication.

Diamond A. (2013). Executive functions. *Annual review of psychology*, 64, 135–168.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological bulletin*, 125(6), 627–700.

Derogatis, L. R. (1993). *The Brief Symptom Inventory (BSI): Administration, scoring, and procedures manual–II* (3rd ed.) Minneapolis, MN: National Computer Systems

Eggermont, L. H., de Boer, K., Muller, M., Jaschke, A. C., Kamp, O., & Scherder, E. J. (2012). Cardiac disease and cognitive impairment: a systematic review. *Heart (British Cardiac Society)*, 98(18), 1334–1340.

Fairfield, K. M., Black, A. W., Lucas, F. L., Siewers, A. E., Cohen, M. C., Healey, C. T., . . . Wennberg, J. E. (2018). Behavioral risk factors and regional variation in cardiovascular health care and death. *American Journal of Preventive Medicine*, 54(3), 376-384.

Farmakis, D., Stafylas, P., Giamouzis, G., Maniadakis, N., & Parissis, J. (2016). The medical and socioeconomic burden of heart failure: A comparative delineation with cancer. *International journal of cardiology*, 203, 279–281.

Farris, S. G., Abrantes, A. M., Bond, D. S., Stabile, L. M., & Wu, W. (2019). Anxiety and fear of exercise in cardiopulmonary rehabilitation. *Journal of Cardiopulmonary Rehabilitation and Prevention*, 39(2).

Ford, J. L., Ildefonso, K., Jones, M. L., & Arvinen-Barrow, M. (2017). Sport-related anxiety: current insights. *Open access journal of sports medicine*, 8, 205–212.

Franklin, B. A., Lavie, C. J., Squires, R. W., & Milani, R. V. (2013). Exercise-based cardiac rehabilitation and improvements in cardiorespiratory fitness: implications regarding patient benefit. Mayo Clinic proceedings, 88(5), 431–437.

Gaalema, D. E., Higgins, S. T., Shepard, D. S., Suaya, J. A., Savage, P. D., & Ades, P. A. (2014). State-by-state variations in cardiac rehabilitation participation are associated with educational attainment, income, and program availability. *Journal of cardiopulmonary rehabilitation and prevention*, 34(4), 248–254.

Gaalema, D. E., Cutler, A. Y., Higgins, S. T., & Ades, P. A. (2015). Smoking and cardiac rehabilitation participation: associations with referral, attendance and adherence. Preventive medicine, 80, 67-74.[a]Gaalema, D. E., Dube, S., Potter, A., Elliott, R. J., Mahoney, K., Sigmon, S. C., Higgins, S. T., & Ades, P. A. (2019). The effect of executive function on adherence with a cardiac secondary prevention program and its interaction with an incentive-based intervention. *Preventive medicine*, 128, 105865.

[b]Gaalema, D.E., Elliott, R.J., Savage, P.D., et al., 2019. Financial incentives to increase cardiac rehabilitation participation among low-socioeconomic status patients: a randomized clinical trial. *JACC Heart Failure*. 7 (7), 537–546.

Gaalema, D. E., Bolívar, H. A., Khadanga, S., Priest, J. S., Higgins, S. T., & Ades, P. A. (2020). Current smoking as a marker of a high-risk behavioral profile after myocardial infarction. Preventive Medicine, 140, 106245.

Graham, S. (2004). *“I can, but do I want to?” Achievement Values in Ethnic Minority Motivation and Executive Function Children and Adolescents*. In G. Philogène (Ed.), Racial identity in context: The legacy of Kenneth B. Clark (pp. 125-145). Washington DC: American Psychological Association

Grieve, A., Webne-Behrman, L., Couillou, R., & Sieben-Schneider, J.A. (2014). Self-Report Assessment of Executive Function in College Students with Disabilities. *The Journal of Postsecondary Education and Disability*, 27, 19-32.

Gutierrez-Colina, A. M., Davis, M., Eaton, C. K., LaMotte, J., Cushman, G., Quast, L., Blount, R. L., & Suveg, C. (2020). The role of executive function in health self-management and the transition to adult health care among college students. *Journal of American college health*: J of ACH, 1–7. Advance online publication.

Hajar, R. (2017). Risk factors for coronary artery disease: Historical perspectives. *Heart Views, 18*(3), 109

Halm, M., Penque, S., Doll, N., & Beahrs, M. (1999). Women and cardiac rehabilitation: referral and compliance patterns. *The Journal of cardiovascular nursing,* 13(3), 83–92.

Hansen, D., Abreu, A., Ambrosetti, M., Cornelissen, V., Gevaert, A., Kemps, H., Laukkanen, J. A., Pedretti, R., Simonenko, M., Wilhelm, M., Davos, C. H., Doehner, W., Iliou, M. C., Kränkel, N., Völler, H., & Piepoli, M. (2021). Exercise intensity assessment and prescription in cardiovascular rehabilitation and beyond: why and how: a position statement from the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology. *European journal of preventive cardiology*, zwab007. Advance online publication.

Hare DL, Toukhsati SR, Johansson P, Jaarsma T. Depression and cardiovascular disease: a clinical review. Euro Heart J. 2014;35(21):1365-72.

Horwitz, J., & McCaffrey, R. (2008). Effects of a third party observer and anxiety on tests of Executive Function. *Archives of Clinical Neuropsychology*, 23(4), 409-417.

Jeng, C., & Braun, L. T. (1997). The influence of self-efficacy on exercise intensity, compliance rate and cardiac rehabilitation outcomes among coronary artery disease patients. *Progress in cardiovascular nursing*, 12(1), 13–24.

Kakos, L. S., Szabo, A. J., Gunstad, J., Stanek, K. M., Waechter, D., Hughes, J., Luyster, F., Josephson, R., & Rosneck, J. (2010). Reduced executive function is associated with poorer outcome in cardiac rehabilitation. *Preventive cardiology*, 13(3), 100–103.

Keessen, P., den Uijl, I., Visser, B., van den Berg-Emons, H., Latour, C., Sunamura, M., Jorstad, H. T., Ter Riet, G., Scholte Op Reimer, W., Kraaijgenhagen, R. A., & Ter Hoeve, N. (2020). Fear of movement in patients attending cardiac rehabilitation: A validation study. *Journal of rehabilitation medicine*, 52(2), jrm00021.

Keteyian, S. J., Kerrigan, D. J., Ehrman, J. K., & Brawner, C. A. (2017). Exercise Training Workloads Upon Exit from Cardiac Rehabilitation in Men and Women: The Henry Ford Hospital Experience. *Journal of cardiopulmonary rehabilitation and prevention,* 37(4), 257–261.

Khadanga, S., Savage, P. D., Gaalema, D. E., & Ades, P. A. (2021). Predictors of Cardiac Rehabilitation Participation: OPPORTUNITIES TO INCREASE ENROLLMENT. *Journal of cardiopulmonary rehabilitation and prevention*, 10.1097/HCR.0000000000000573.

Khushhal, A., Nichols, S., Carroll, S., Abt, G., & Ingle, L. (2019). Insufficient exercise intensity for clinical benefit? Monitoring and quantification of a community-based phase III cardiac rehabilitation programme: A United Kingdom perspective. *PLOS ONE,* 14(6).

Krueger, C. E., Laluz, V., Rosen, H. J., Neuhaus, J. M., Miller, B. L., & Kramer, J. H. (2011). Double dissociation in the anatomy of socioemotional disinhibition and executive function in dementia. *Neuropsychology*, 25(2), 249–259.

Kubzansky, L. D., Davidson, K. W., & Rozanski, A. (2005). The clinical impact of negative psychological states: expanding the spectrum of risk for coronary artery disease. *Psychosomatic medicine*, 67 Suppl 1, S10–S14.

Kwan G, Balady GJ. Cardiac rehabilitation 2012: advancing the field through emerging science. *Circulation*. 2012 Feb 21;125(7):e369-73.

Lavie, C. J., Thomas, R. J., Squires, R. W., Allison, T. G., & Milani, R. V. (2009). Exercise training and cardiac rehabilitation in primary and secondary prevention of coronary heart disease. Mayo Clinic proceedings, 84(4), 373–383.

Lee, C. L., & Chang, W. D. (2013). The effects of cigarette smoking on aerobic and anaerobic capacity and heart rate variability among female university students. *International journal of women's health*, 5, 667–679.

Lee, K., Noda, Y., Nakano, Y., Ogawa, S., Kinoshita, Y., Funayama, T., & Furukawa, T. A. (2006). Interoceptive hypersensitivity and interoceptive exposure in patients with panic disorder: specificity and effectiveness. BMC psychiatry, 6, 32.

Luyster, F. S., Hughes, J. W., & Gunstad, J. (2009). Depression and anxiety symptoms are associated with reduced dietary adherence in heart failure patients treated with an implantable cardioverter defibrillator. *The Journal of cardiovascular nursing*, 24(1), 10–17.

Martens, R., Vealey, R. S., & Burton, D. (1990). *Competitive anxiety in sport.* Champaign, Ill: Human Kinetics Books.

McGrady, A., McGinnis, R., Badenhop, D., Bentle, M., & Rajput, M. (2009). Effects of depression and anxiety on adherence to cardiac rehabilitation. *Journal of cardiopulmonary rehabilitation and prevention,* 29(6), 358–364.

McAuley, E., Mullen, S. P., Szabo, A. N., White, S. M., Wójcicki, T. R., Mailey, E. L., Gothe, N. P., Olson, E. A., Voss, M., Erickson, K., Prakash, R., & Kramer, A. F. (2011). Self-regulatory processes and exercise adherence in older adults: executive function and self-efficacy effects. *American journal of preventive medicine*, 41(3), 284–290.

Meltzer, L. & Krishnan, K. (2007). *Executive function difficulties and learning disabilities: Understandings and misunderstandings*. In L. Meltzer (Ed.), Executive function: From theory to practice (pp. 77-105). New York: The Guildford Press.

Menezes, A. R., Lavie, C. J., Milani, R. V., Arena, R. A., & Church, T. S. (2012). Cardiac rehabilitation and exercise therapy in the elderly: Should we invest in the aged? *Journal of geriatric cardiology* : JGC, 9(1), 68–75.

Mueller, E. T., Landes, R. D., Kowal, B. P., Yi, R., Stitzer, M. L., Burnett, C. A., & Bickel, W. K. (2009). Delay of smoking gratification as a laboratory model of relapse: effects of incentives for not smoking, and relationship with measures of executive function. *Behavioural pharmacology*, 20(5-6), 461–473.

Murphy, J. M., Olivier, D. C., Monson, R. R., Sobol, A. M., Federman, E. B., & Leighton, A. H. (1991). Depression and anxiety in relation to social status. A prospective epidemiologic study. *Archives of general psychiatry*, 48(3), 223–229.

Mwinyi, J., Pisanu, C., Castelao, E., Stringhini, S., Preisig, M., & Schiöth, H. B. (2017). Anxiety Disorders are Associated with Low Socioeconomic Status in Women but Not in Men. *Women's health issues : official publication of the Jacobs Institute of Women's Health*, 27(3), 302–307.

Naroee, H., Rakhshkhorshid, M., Shakiba, M., & Navidian, A. (2020). The Effect of Motivational Interviewing on Self-Efficacy and Continuation of Exclusive Breastfeeding Rates: A Quasi-Experimental Study. Breastfeeding medicine : the official journal of the Academy of Breastfeeding Medicine, 15(8), 522–527.

Nigg, J. T. (2016). Annual research review: On the relations among self-regulation, self-control, executive function, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. Journal of Child Psychology and Psychiatry, 58(4), 361-383.

Oldridge, N., Pakosh, M., & Grace, S. L. (2019). A systematic review of recent cardiac rehabilitation meta-analyses in patients with coronary heart disease or heart failure. *Future Cardiology*, 15(3), 227-249.

Pack, Q. R., Johnson, L. L., Barr, L. M., Daniels, S. R., Wolter, A. D., Squires, R. W., Perez-Terzic, C. M., & Thomas, R. J. (2013). Improving cardiac rehabilitation attendance and completion through quality improvement activities and a motivational program. *Journal of cardiopulmonary rehabilitation and prevention*, 33(3), 153–159.

Rao, A., Zecchin, R., Newton, P. J., Phillips, J. L., DiGiacomo, M., Denniss, A. R., & Hickman, L. D. (2020). The prevalence and impact of depression and anxiety in cardiac rehabilitation: A longitudinal cohort study. *European journal of preventive cardiology*, 27(5), 478–489.

Resurrección, D. M., Moreno-Peral, P., Gómez-Herranz, M., Rubio-Valera, M., Pastor, L., Caldas de Almeida, J. M., & Motrico, E. (2019). Factors associated with non-participation in and dropout from cardiac rehabilitation programmes: a systematic review of prospective cohort studies. *European journal of cardiovascular nursing: journal of the Working Group on Cardiovascular Nursing of the European Society of Cardiology*, 18(1), 38–47.

Riley, H., Headley, S., Winter, C., Mazur, S., Gaalema, D. E., Goff, S., Lindenauer, P. K., & Pack, Q. R. (2018). Effect of Smoking Status on Exercise Perception and Intentions for Cardiac Rehabilitation Enrollment Among Patients Hospitalized with an Acute Cardiac Condition. *Journal of cardiopulmonary rehabilitation and prevention*, 38(5), 286–290.

Rosenhan, D. L., & Seligman, M. E. P. (1989). *Abnormal psychology*. New York: W.W. Norton.

Rubak, S., Sandbaek, A., Lauritzen, T., & Christensen, B. (2005). Motivational interviewing: a systematic review and meta-analysis. *The British journal of general practice : the journal of the Royal College of General Practitioners*, 55(513), 305–312.

Salzwedel A, Heidler MD, Haubold K, Schikora M, Reibis R, Wegscheider K, Jobges M, Voller H. Prevalence of mild cognitive impairment in employable patients after acute coronary event in cardiac rehabilitation. *Vascular Health and Risk Management*. 2017;13:55-60.

Sandercock, G., Hurtado, V., & Cardoso, F. (2013). Changes in cardiorespiratory fitness in cardiac rehabilitation patients: A meta-analysis. *International Journal of Cardiology*, 167(3), 894-902.

Shanmugasegaram, S., Oh, P., Reid, R. D., McCumber, T., & Grace, S. L. (2013). Cardiac rehabilitation barriers by rurality and socioeconomic status: a cross-sectional study. International journal for equity in health, 12, 72.

Székely, A., Balog, P., Benkö, E., Breuer, T., Székely, J., Kertai, M. D., Horkay, F., Kopp, M. S., & Thayer, J. F. (2007). Anxiety predicts mortality and morbidity after coronary artery and valve surgery--a 4-year follow-up study. *Psychosomatic medicine*, 69(7), 625–631.

Vilchinsky, N., Reges, O., Leibowitz, M., Khaskia, A., Mosseri, M., & Kark, J. D. (2018). Symptoms of Depression and Anxiety as Barriers to Participation in Cardiac Rehabilitation Programs Among Arab and Jewish Patients in Israel. *Journal of cardiopulmonary rehabilitation and prevention*, 38(3), 163–169.

Vlaeyen, J., & Linton, S. J. (2000). Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. *Pain*, *85*(3), 317–332.

Wecker, N. S., Kramer, J. H., Hallam, B. J., & Delis, D. C. (2005). Mental flexibility: age effects on switching. *Neuropsychology*, 19(3), 345–352.

Wiese-bjornstal, D. M., Smith, A. M., Shaffer, S. M., & Morrey, M. A. (1998). An integrated model of response to sport injury: Psychological and sociological dynamics. *Journal of Applied Sport Psychology*, 10(1), 46–69.

Williams, P. G., Tinajero, R., & Suchy, Y. (2017). Executive function and health. *Oxford Handbooks Online*.

Wyckoff, E. P., Evans, B. C., Manasse, S. M., Butryn, M. L., & Forman, E. M. (2017). Executive function and dietary intake: Neurocognitive correlates of fruit, vegetable, and saturated fat intake in adults with obesity. *Appetite*, 111, 79–85.

Xu, Xiaoyan, "Health motivation in health behavior: Its theory and application" (2009). UNLV Theses, Dissertations, Professional Papers, and Capstones. 42.

Zänkert, S., Bellingrath, S., Wüst, S., & Kudielka, B. M. (2019). HPA axis responses to psychological challenge linking stress and disease: What do we know on sources of intra- and interindividual variability? *Psychoneuroendocrinology*, 105, 86–97.