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Prehabilitation Prior to CABG

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ABSTRACT

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Background and Purpose: Globally, coronary artery disease (CAD) affects 126.5 million adults. To decrease mortality, coronary artery bypass graft (CABG) surgeries are often performed. CABGs have inherent risks such as financial burden, physical complication, and emotional stress. Cardiac rehabilitation programs help decrease complications postoperatively. However, few interventions are performed preoperatively. Prehabilitation (prehab) programs have been created to address this gap in other types of surgeries. Prehab is the purposeful implementation of physical activity before a procedure to improve perioperative outcomes. Prehab prior to CABG has not been well studied previously. Furthermore, it is unknown if families should support a sedentary or active lifestyle for CABG patients prior to surgery. Therefore, the purpose of this systematic review was to investigate the effects of preoperative physical activity on outcomes for CABG patients.

Methods: Following PRISMA guidelines, 635 articles were identified, screened, and assessed. Databases included: Embase, MEDLINE, CINAHL, Cochrane Library, and SportDISCUS. Articles were assessed using Kmet et al.'s criteria for both qualitative and quantitative studies. In total, 13 articles were included in the systematic review.

Results: Physical activity at least twenty-four hours prior to CABG decreases postoperative complications, hospital length of stay, atrial fibrillation occurrence, rehospitalization, and mortality rates. Physical activity prior to CABG can impact psychosocial wellbeing by improving anxiety, creating a broader support system, and increasing quality of life. Preoperative physical activity also has the potential to increase physical ability both preoperatively and postoperatively. Lastly, the literature suggests that prior physical activity increases enrollment in post CABG CR programs.

Conclusions and Implications: We recommend early implementation of physical activity in patients at risk for or diagnosed with CAD to improve outcomes in the event CABG becomes necessary. These outcomes suggest families should support CABG patients in being physically active through structured, such as prehab, and unstructured methods.

Keywords: CABG, coronary artery bypass graft, prehabilitation, physical activity, physiotherapy, physical therapy, preoperative, presurgical

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Introduction

Coronary artery disease (CAD) is a prevalent type of heart disease, affecting approximately 126.5 million adults globally. Each year, an estimated 8.9 million people die from CAD (Viranni et al., 2020). One common intervention to help decrease the rate of mortality of those with CAD is coronary artery bypass graft surgery (CABG).

With such a high incidence of CAD and CABG internationally, the impact is also astounding. For example, in 2014, the cumulative cost of CAD in the United States was over $218 billion, with CABGs contributing an average cost of $151,800 per patient (Viranni et al., 2020; Glacamino et al., 2015). Along with the financial burden of CAD and CAGBs, the physical and emotional complications are also problematic. Patients receiving a CABG may experience cardiovascular complications, up to 40%; pulmonary complications, up to 90%; neurologic complications, up to 4%; and others (Aroesty, 2020; Leal-Noval et al., 2000; Carter et al., 2020). Depression is also a very common complication associated with CABG—it is more than twice as likely to occur in CABG patients than in any other group experiencing a medical condition (Whooley, 2006).

With such high financial, physical, and psychological costs of CABG, effective interventions must be sought out. One potential intervention is physical activity (PA). PA has the possibility of providing similar results as CABG for CAD patients due to the increased blood flow and oxygen it provides to the heart. Research has demonstrated that with proper amounts, PA improves the contractility and coronary artery dilating ability, reduces oxygen demand of the heart, forms collateral artery formation, and decreases coronary artery arteriosclerosis (Yadav, 2011). In addition, PA improves depression and anxiety, decreases emotional distress, and enhances positive emotions (Chan et al., 2019).

Despite PA offsetting many CAD effects, CABG may still be warranted. In such circumstances, PA prior to CABG may improve surgical outcomes and long-term success. PA improves vasculature, which provides healthier vessels for CABG harvest. With more robust vessels used in the surgery, PA could improve the longevity of or delay the need for CABG. This could result in reduced total lifetime procedures needed, health care costs, and complications. Historically, PA has been performed in tandem to CABG, most commonly through post-surgical cardiac rehabilitation (rehab). However, exercise could be beneficial before surgery. An emerging area of research has investigated the benefits of PA prior to surgery, commonly called prehabilitation (prehab).

Prehab is the purposeful implementation of PA before a procedure or surgery in the hopes of improving outcomes perioperatively. Researchers have implemented and studied prehab in many types of surgeries such as cardiothoracic, abdominal, orthopedic, and oncologic. Reviews of these studies of prehab show reduced hospital length of stay, reduced pulmonary complications, and improvement in general surgical outcomes (Garcia et al., 2016; Valkenet et al., 2011). However, no systematic review has been done examining the impact of prehab specifically on CABG surgeries. Therefore, the purpose of this systematic review is to investigate the effect of preoperative PA (structured or unstructured) on perioperative outcomes for CABG patients.

Methods

Search Strategy

This systematic review followed the PRIMSA guidelines with a two-step verification process to identify apropos articles. With the help of an expert librarian in nursing literature, the two authors created a searching framework employing these search terms: "physical activity" or exercis* or "physical therapy" or physiotherapy; preoperat* or "pre operat*" or prehab* or presurg* or "pre surg*"; and "coronary artery bypass". In order to find potential articles, these search terms were run through these databases: Embase, MEDLINE, CINAHL, Cochrane Library, and SportDISCUS. All databases were searched from inception to August 2019. In addition to identifying pertinent articles in the databases, articles were found through searching reference lists of relevant articles. The authors rejected posters and abstracts of conference presentations yielded in the search. All article citations and abstracts were exported to a spreadsheet where manual deduping took place.

Inclusion and Exclusion Criteria

Inclusion criteria consisted of the following: (1) CAGB procedure, (2) an intervention took place prior to CABG, (3) the intervention was PA —cardiorespiratory exercise, weights, stretching, (4) the results measured must show relation to the PA practiced prior to CABG, and (5) available in English. Articles were excluded if the intervention was (1) solely respiratory exercises, (2) if the procedure was not an isolated CABG, or (3) the PA was for testing/measurement purposes, such as a stress test.

Study Selection and Methodological Quality

After removal of duplicates, the two authors reviewed all articles by title and abstract to determine relevancy to this systematic review. Using the inclusion and exclusion criteria, full text reviews were conducted on potentially suitable articles. Any disagreements between authors were resolved through discussion and resulted in consensus.

The quality of articles was assessed utilizing Kmet et al.'s (2004) checklists for quantitative and qualitative studies. Each article determined as eligible after a full text review (n=15) was scored by both authors independently. The authors compared scores and reached consensus through discussion. Acceptable scores were defined as >70%.

Data Extraction and Synthesis of Results

Once eligible articles were identified, each article was reviewed multiple times to determine themes of findings. A spreadsheet was then created to categorize findings. The data was summarized by the second author, reviewed and added upon by the first author, and then discussed by both to determine mutual understanding.

Results

Study Identification

The database searches yielded 631 results. Four articles were found through the reference list of germane articles, totaling 634 articles. After the removal of duplicates, 566 articles remained. Thirty articles persisted after a screening of titles and abstracts, in addition to the four articles from references in relevant articles. A full text review was conducted on the remaining 34 articles, with 19 articles removed for not meeting criteria. Finally, the remaining 15 articles were scored for quality, resulting in 13 articles included in this systematic review. See Figure 1 for more in depth information.

Methodological Quality

Both authors independently scored each of the 15 articles. The scores ranged from 27% to 100%. The authors determined articles with a score of 70% or above had adequate methodological quality and would be included in the systematic review. Thirteen articles remained after imposing the acceptance score of ≥ 70%. Disagreements on article scoring were resolved through discussion.

Study Characteristics

A full description of the characteristics of the different studies is featured in Table 1. Comprising the 13 included articles were four descriptive studies, three randomized control trials, four pilot studies, one prospective cohort study, and one quasi-experimental study. The studies came from eight different countries, with Brazil and Canada each contributing three. Two of the studies were conducted in the UK. The United States of America, Australia, Italy, Norway and Taiwan each contributed one. The dates of publication of the articles range from 2000-2019. The majority of the participants in the studies were male, and the average age was ≥ 70 years old.

Protocols

Every study measured PA prior to CABG. Eight of the studies implemented structured PA as the intervention (Arthur et al., 2000; Herdy et al., 2008; Ku et al., 2002; Mooney et al., 2006; Rosenfeldt et al., 2001; Sawatzky et al., 2014; Smenes et al., 2018; Waite et al., 2017). Structured PA was prescribed by a medical professional and often included the types of exercises to do, the number of days per week to exercise, the amount of time to exercise each day, and the goal energy expenditure to reach with each exercise. The length of time the intervention occurred varied from one day to months, with the location of the exercises taking place at home or at a facility.

The five remaining studies investigated unstructured PA utilizing questionnaires to gauge participants' activity levels, usually over the previous twelve months (Cook et al., 2001;

Giaccardi et al., 2007; Kehler et al., 2019; Nery & Barbisan, 2010; Nery et al., 2007). Based on questionnaire responses, most studies categorized participants as either physically active or sedentary, or other similar terminology.

General Findings

After conducting a thorough review of the 13 studies, five themes emerged. The themes were postoperative complications, cost savings of prehab, psychosocial health, physical ability, and enrollment in a post-CABG rehabilitation program. Significant findings were defined as having p value of < 0.05.

Results of Individual Studies

Postoperative Complications

Twelve studies commented on postoperative complications and sequelae. Complications included general postoperative complications, length of stay, occurrence of atrial fibrillation (AF), and/or rehospitalization and mortality rates.

General Postoperative Complications

In four of the reviewed studies, researchers found that those who practiced preoperative PA had significantly less general postoperative complications (Cook et al., 2001; Herdy et al., 2008; Nery & Barbisan, 2010; Nery et al., 2007). Cook et al. (2001), Nery & Barbisan (2010), and Nery et al. (2007) reported that those with a sedentary lifestyle were at an increased overall risk of postoperative complications, such as myocardial infarction, need for angioplasty, need for another CABG, AF, and readmission. In the study performed by Nery & Barbisan (2010), the authors reported a 78% decrease in the occurrence of major cardiac events post-CABG, which included death, myocardial infarction, and cardiac reoperation. Prehab also demonstrated a relationship to decreased pulmonary complications: decreased incidences of pneumonia, fewer pleural effusions, and less cases of atelectasis (Herdy et al., 2008).

Other studies found mixed findings regarding general complications. The studies carried out by Arthur et al. (2000) and Sawatzky et al. (2014) stated no significant difference in occurrence of general post-CABG complications. Smenes et al. (2018) found that PA performed within 24 hours of CABG increased apoptotic markers and decreased mitochondrial respiration.

Length of Stay

Ten studies reported on length of stay and found that preoperative PA had either a positive or neutral impact. Six of these studies found an inverse relationship between pre-surgery PA and length of hospital stay (Arthur et al., 2000; Cook et al., 2001; Herdy et al., 2008; Nery & Barbisan, 2010; Nery et al., 2007; Waite et al., 2017). Four studies reported no significant difference in length of hospital stay between physically active and not physically active participants (Kehler et al., 2019; Ku et al., 2002; Rosenfeldt et al., 2011; Sawatzky et al., 2014). Rosenfeldt et al. (2014), Kehler (2019) et al., and Ku et al. (2002) reported shorter hospital length of stay in the physically active groups, but the difference was not significant. Participants in Sawatzky et al.'s (2014) study had an equal hospital length of stay regardless of which group they belonged.

Included in five of the studies' results was the impact of increased PA on time spent in the ICU (Arthur et al., 2000; Herdy et al., 2008; Kehler et al., 2019; Ku et al., 2002; Sawatzky et al., 2014;). Of these five studies, one study found that prehab significantly decreased time until order for discharge from the ICU. (Arthur et al., 2000). The remaining studies found either a non-significant trend towards decreased ICU length of stay or no difference (Herdy et al., 2008; Kehler et al., 2019; Ku et al., 2002; Sawatzky et al., 2014).

Occurrence of AF

Regarding occurrence of AF, two studies found decreased occurrences in those who practiced preoperative PA (Giaccardi et al., 2011; Herdy et al., 2008). Arthur et al. (2000), Rosenfeldt et al. (2011), and Sawatzky et al. (2014) found that preoperative PA does not provide a significant difference in the occurrence of AF.

Rehospitalization and Mortality Rates

Kehler et al. (2019), Nery et al. (2017), and Nery & Barbisan (2010) reported significant decrease in rehospitalization and/or mortality rates when measured compositely with another finding. The study performed by Kehler et al. (2019) found that individuals physically active prior to CABG experienced fewer mortality and rehospitalization rates when measured compositely. Nery et al. (2007) reported a composite finding of decreased complications postoperatively, which included decreased readmissions in the physically active group. In the study by Nery & Barbisan (2010), the data demonstrated decreased mortality rates in the active group when compositely measured with acute myocardial infarction incidences. Another study found no significant difference in mortality rates between physically active and sedentary groups (Arthur et al., 2000).

Cost Savings

One study reported on cost savings of prehab (Arthur et al., 2000). The authors found that prehab was more cost effective than traditional cardiac rehab programs performed exclusively post CABG. Based on the average cost of care of a CABG patient in Canada, prehab has the potential of saving $133 per patient per day. This study did not state if this finding was significant.

Psychosocial Wellbeing

Three studies stated improved quality of life and psychosocial health in relation to PA performed pre-CABG (Rosenfledt et al., 2011; Mooney et al., 2006; Ku et al., 2002). The study conducted by Mooney et al. (2006) found qualitative differences in the treatment group, demonstrating increased motivation and increased support from others in the study, nurses, and those who previously had the surgery. Rosenfeldt et al. (2011) found that mental quality of life significantly improved six weeks postoperatively in the intervention group while mental quality of life scores remained the same in the control group. Ku et al. (2002) reported that those in the experimental group experienced significantly decreased anxiety levels at both one day preoperatively and at discharge.

Two studies described no difference between the physically active group and the sedentary group regarding quality of life and mental health perioperatively (Sawatzky et al., 2014; Arthur et al., 2000). One of the studies stated that both groups experienced improved quality of life scores, improved depression scores, and decreased fear after the CABG, with no significant difference between the groups (Sawatzky et al., 2014). The other study found that both the treatment group and the control group demonstrated similar anxiety scores prior to CABG and that the anxiety scores remained nearly unchanged for both groups immediately postoperatively, though six months postoperatively the treatment group felt they had more support (Arthur et al., 2000).

Increased Physical Ability

In Mooney et al.'s (2006) qualitative study, patients reported increased confidence in ability to perform PA and increased motivation to exercise after participating in the preoperative intervention. Sawatzky et al. (2014) and Waite et al. (2017) showed those in the studies' intervention group could walk farther and faster post-intervention. In Waite et al.'s (2017) study, the physically active group also experienced improved Short Physical Performance Battery Protocol and decreased clinical frailty. During the waiting period in Arthur et al.'s study (2000), both the intervention group and the control group experienced decreased physical functioning scores, with the intervention group showing significantly less decline. In addition, the study reported increased physical composite summary score and physical aspects of role functioning among the intervention group while in the waiting period.

Enrollment in Post CABG Rehabilitation

Three studies reported on enrollment in a post CABG cardiac rehab program, showing increased enrollment in those who were physically active prior to CABG (Waite et al., 2017; Arthur et al., 2000; Sawatzky et al., 2014). In Sawatzky et al.'s study (2014) 43% of the standard care patients and 100% of the prehab patients enrolled in a postoperative rehab. Arthur et al. (2000) found 57% of the control group chose to enroll in a rehab program while 70% of the prehab group enrolled, though the authors did not comment on the significance of this finding. Another study found that 82% of the participants enrolled in post-CABG rehab, though the study did not specify if this was a significant finding (Waite et al., 2017).

Discussion

Preoperative PA is beneficial and offers a protective effect against postoperative complications if done 24 hours prior to surgery. The data collected for this systematic review suggests that preoperative PA is associated with increased physical ability, improved psychosocial health, increased enrollment in post CABG rehab, and decreased hospital length of stay. These findings are similar to those found in other prehab studies (Asoh & Tsuji, 1981;

Donkers et al., 2010; Hulzebos et al., 2012; Mina et al., 2014; Olsen & Ansen, 2014; Rooks et al., 2006; Timmerman et al., 2011; Valkenet et al., 2011).

One reason for the beneficial findings of preoperative PA could be due to physiological adaptations that occur from exercise, namely cardiovascular and pulmonary changes. At the vascular level, PA rebalances NO production and inactivation, which results in healthier endothelium, improved cardiac circulation, and healthier vessels available for CABG harvest (Hambrecht et al., 2000; Hornig et al., 1996). More robust vessels used in CABG restores blood flow to the heart and decreases the necessity of future CABG. PA also increases collateral coronary artery formation, increased contractility, and increased electrical stability of the heart, thus improving the heart's ability to withstand the stress of CABG (Yadav, 2011). Prehab prior to other types of surgeries found improved pulmonary function and increased respiratory muscle endurance in those who participated in prehab (Dronkers et al., 2010; Garcia et al., 2016). With improved respiratory muscle endurance and function, a patient would have greater ability to move air through the lungs, decreasing the risk of atelectasis, pneumonia, and pleural effusion.

Exercise positively impacts psychosocial health—ameliorating depression and anxiety, increasing positive mood, and decreasing feelings of distress. These findings are especially pertinent to those receiving CABG because these patients are doubly at risk for depression compared to other groups (Blumenthal et al., 2003; Whooley et al., 2006). Depression has a significant negative impact on post CABG recovery, such as increased: length of stay, graft and wound site infections, pain, rehospitalizations, risk of future cardiac events, and rates of mortality (Barth et al., 2004; Blumenthal et al., 2003; Doering et al., 2005). Therefore, PA has a role in improving psychosocial health and decreasing complications perioperatively.

In addition, this systematic review found increased enrollment in postoperative cardiac rehab in preoperative physically active groups. Recent research demonstrates that those with decreased social support systems have decreased enrollment rates in cardiac rehab (Williamson et al., 2018). As Mooney et al. (2006) found, CABG patients in the physically active group experienced increased social support, perhaps contributing the increased participation in cardiac rehab in the physically active group.

Difference in Findings

Some articles found preoperative PA beneficial in its impact on postoperative complications while other studies did not. Another mixed finding was length of stay, with some studies showing decreased length of stay while other studies found no significant difference. Notable, however though, is no study showed increased length of stay in the physically active group. These differences in findings could partially be attributed to the different physical activities implemented in the protocols, the different individuals in each study, as well as the differences in the rate of compliance to the protocols. Another potential contributing factor regarding length of stay is diverse criteria for discharge, which is dependent on the facility. With such differences in the protocols, methods of research, and adherence, some differences in findings are expected.

Cost Savings

After a CABG, most patients recover in the intensive care unit (ICU) where they are mechanically ventilated for a time. According to a 2005 study, the cost of stay in the ICU while mechanically ventilated is approximately $450/hour on the first day (Dasta et al., 2005). All studies which reported ICU length of stay found that physically active individuals had decreased time in the ICU (Arthur et al., 2000; Herdy et al., 2008; Sawatzky et al., 2014; Ku et al., 2002;

Kehler et al., 2019). Based on the data from Dasta et al. (2005) and the articles in this review, physically active patients would have decreased cost overall.

Another important aspect to consider when examining the cost savings of preoperative PA is the benefits that come from increased participation in post CABG cardiac rehab. One such benefit may include increased functional independence, decreasing the need for home health and physical therapy post cardiac rehab; likewise, increased endothelial health could result in decreased risk of another CABG, which potentially may lower the cost of CABG in the long term.

Comparison of Protocols

Structured vs. Unstructured

The studies examined in this systematic review either implemented a structured protocol or unstructured protocol, with both demonstrating positive effects. The findings concerning the themes of cost savings, psychosocial wellbeing, physical ability, and increased enrollment in cardiac rehab appear to favor structured protocols. One potential reason that structured protocols impacted psychosocial wellbeing is how quickly PA can improve mood, as little as 10 days (Craft & Perna, 2004). Similarly, as Mooney et al. (2006) found, prehab increases patients' perceived social support, often from those met through prehab. Improved psychosocial wellbeing in structured protocols could also be attributed to the platform it provided the patients: increased time with health professionals, lending to more opportunities to ask questions about the upcoming CABG, ameliorating the participants' anxiety.

Each study that reported on cost savings, physical ability, and cardiac rehab implemented structured protocols and found a positive correlation between prehab and the individual finding. It cannot be stated that structured protocols led to more beneficial outcomes because there were no unstructured protocols that measured cost savings, physical ability, or enrollment in cardiac rehab.

Length of Prehab

Not only is it important to determine if structured or unstructured protocols produce the most beneficial results, it is also important to know if the length of time of the intervention makes a difference. Most of the unstructured protocols measured PA of the prior year, though some did not state the timeframe measured, making it difficult to compare the differences. The structured protocols ranged from one day to 12 weeks. Structured interventions lasting ≥ four weeks produced the majority of positive outcomes relating to prehab. This may be due to the finding that endothelial changes incurred from exercise occur as early as four weeks (Hambrecht et al. 2000). Another explanation could be related to Smenes et al.'s (2018) findings: exercise preconditioning in the 24 hours prior to CABG can lead to damage, which imposes increased stress on the heart prior to surgery. The heart is then in a weakened state prior to CABG and may not have time to recover before enduring another stressful event.

Suggestion for Implementation

The findings of this systematic review suggest that engaging in PA for at least one year prior to CABG had the greatest impact on decreasing postoperative complications. Conversely, the psychosocial benefit of prehab favored protocols implemented closer to CABG. Due to the differing benefits of long-term and short-term PA and the impossibility of habitual PA in all patients requiring a CABG, it is necessary to determine what is the best preoperative PA protocol to provide both psychosocial and physiological benefits.

Since protocols that were implemented ≥ four weeks rendered more benefit than shorter ones, it is recommended that prehab begin at least four weeks preoperatively. It would be advantageous to create a prehab program that is structured, increasing adherence to the intervention, and thus increasing the likelihood that the patient will experience the benefits of preoperative PA. A structured program also increases patients' resources and support, which could be a contributor to increased psychosocial wellbeing. The structured program could be done in the patient's home or at a facility, where a health team member is present to oversee the exercises, occurring at least two days a week and lasting 60 minutes (Arthur et al., 2000; Waite et al., 2017; Rosendfeldt et al., 2011; Sawatzky et al., 2014). It is imperative that before the PA is initiated, patients undergo screening to measure their maximum physical expenditure limit to ensure safety during the intervention. In following safety measures, it is also recommended that patients receive or are educated about a means of measuring physical expenditure during activity, so they do not surpass their limit of safety. It is necessary though to stop all structured physical activities 24 hours prior to CABG to prevent cardiac mitochondrial damage.

Implications for Nurses and Nurse Practitioners

With their intimate knowledge of the intricacies involved in creating change that will impact patient care, nurses provide invaluable contributions to creating changes in healthcare systems (Hickey & Giardino, 2019). Concerning the implementation of prehab in CABG patients, nurses have a potential leading role. Working with the unit or clinic manager, nurses can create a prehab protocol for their institution based on the most current literature. For this new protocol to gain traction, the nurse must disseminate the current evidence regarding the benefits of prehab, why the institution is implementing it in the pre-CABG patients, and construct a multidisciplinary team to potentiate prehab program success.

Nurse practitioners (NP) also have a role to play. In the primary care setting, the NP is often the first point of contact for patients with CAD. At the time of diagnosis of CAD, the NP can start a conversation about the risk of CAD and the potential need of a CABG. During this discussion, it would be prudent for the primary care NP to give the patient the most up to date information about how to best care for CAD and decrease risks of CABG, which includes prehab. It may be appropriate at this time to encourage the patient to start engaging in PA at least twice per week in the event CABG is needed in the future. A NP specializing in cardiology can also create an impact by prescribing a prehab protocol based on the most current research to CAD patients needing a CABG.

Limitations

It is important to be cognizant of the limitations of this study when interpreting the results. Firstly, only published articles written in English were included; therefore, information from unpublished material and articles in other languages were omitted. Secondly, the heterogeneity of the studies limits the ability to make comparisons. Thirdly, the types of studies included could limit the validity of the findings since both pilot and descriptive studies were admitted. Fourthly, the average age of the participants in the included studies was 70 or higher, making it difficult to generalize to younger populations who need a CABG. Lastly, some findings were measured compositely, making it difficult to assess the significance of the finding.

Further research is needed to determine the most beneficial protocol: length of time prehab is implemented, times per week participants engage in prehab, type of PA that is best (cardiorespiratory, strength training, balancing, etc.), monitored vs unmonitored, home vs facility, and so on. More research utilizing randomized control trials is needed to investigate the full breadth of preoperative PA’s impact. The information rendered from such studies would make it possible to create a standardized prehab protocol to recommend.

Conclusion

CAD affects many people and often requires CABG. While CABG fixes things in the moment, it does not alter behaviors that cause CAD. With the knowledge of the impact CABG has on patients and the increasing knowledge of the benefits of exercise, the purpose of this systematic review was to determine the impact of PA performed prior to CABG. Based on the review of the literature, it appears there is some benefit of prehab on postoperative complications, psychosocial wellbeing, cost savings, increased physical ability, and enrollment in post CABG cardiac rehab. Further research is needed to determine the full impact of prehab and to determine the most effective protocol.

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Appendix

***Figure 1.* PRISMA Flow Chart**

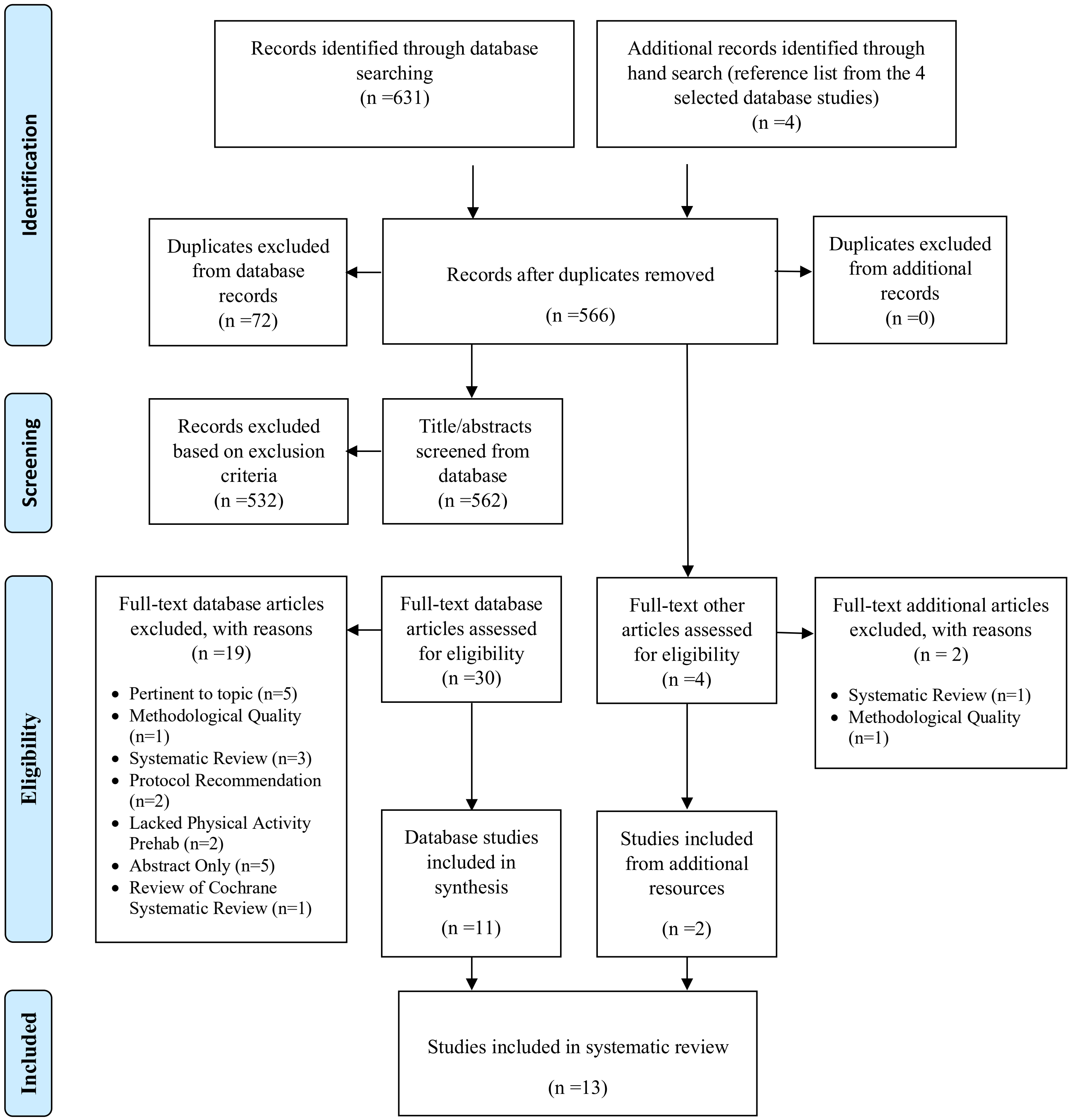

***Table 1*. Study Characteristics Table**

Citation	Aim	Protocol	What was measured?	Adherence	Participants *N* (male/female) OR *N* I: *N* (male/female) C: *N*(male/female)	Attrition Rate	Age range (age ± SD)
Arthur et al., 2000 (Brazil)	To determine if exercise training, education, and social support impacts physical and psychological readiness for CABG and decreases HLOS	Structured: Supervised prescribed exercise training twice/week for 90 min. Education and reinforcement provided monthly via nurse-initiated phone calls. Mean length of intervention was 8.3 weeks.	• ICU Length of Stay • HLOS • General health related QOL: SF-36 • Support: Support Evaluation List • Anxiety: Spielberg State-Trait Anxiety • Inventory Health Services Utilization Questionnaire	• Mean number of classes attended: 14 • Mean exposure time: 8.3 weeks • All received educational intervention at baseline and 1-week pre-surgery • All received one home phone call	249 (3 dropped out after randomization) I: 123 (108/15) C: 123 (102/21)	I: 90/123 retained C: 78/123 retained	I: 61.8 ± 8.4 C: 63.8 ± 7.8
Cook et al., 2001 (United States)	To measure physical fitness condition of patients receiving CABG and the effects on postoperative outcomes	Unstructured: Preoperatively, participants completed VSAQ, grip strength and skin-fold thickness were measured. Participants were stratified as low risk or high risk based on STSNCSD prediction of operative mortality. No time frame stated.	• HLOS • Postoperative Complications • Mortality	100%	200 (147/53)	100% retention	>70 yo
Giaccardi et al., 2011 (Italy)	To investigate if moderate-intensity physical activity in the year prior to CABG influences the incidence of AF postoperatively	Unstructured: Postoperatively, participants completed the Harvard Alumni Questionnaire to assess physical activity of the previous year. Based on results, level of physical activity was classified as light, moderate, or intense.	• Incidence of AF in post-acute rehabilitation	100%	158 (90/68)	100% retention	Interquartile age range: 71-78 years
Herdy et al., 2008 (Brazil)	To evaluate the effects of in-hospital cardiopulmonary rehabilitation performed before and after CABG on postoperative outcomes	Structured: Participants were admitted to the hospital five days prior to CABG. Patients participated in phase I cardiac rehabilitation from admission to discharge.	• ICU Length of Stay • HLOS • Pulmonary complications • AF • A-flutter • Time to extubation	Not reported	56 (40/16)	Not reported	~60 yo
Kehler et al., 2019 (Canada)	To examine the relationship between preoperative physical activity and depression on HLOS and re-hospitalization and mortality rates.	Unstructured: Prior to surgery, participants completed the International Physical Activity Questionnaire and the PHQ-9 to determine level of physical activity and depressive symptoms. Time frame measured not stated.	• HLOS • Rehospitalization and mortality rates one year postoperatively	100%	405 (284/121)	100% retention	Range: 58-76
Ku et al., 2002 (Taiwan)	To investigate if phase I cardiac rehabilitation effects CABG patients' anxiety levels during hospitalization	Structured: Experimental group received a manual with information regarding cardiac phase I exercises. The patient was admitted to the hospital prior to CABG in order to start cardiac tphase I program. Preoperatively, the researcher spent 15 min daily with participants to answer questions, discuss exercises completed that day, give suggestions on progressive exercises and additional exercises for next day. Length of intervention ranged from one-ten days.	• Anxiety: State Anxiety Inventory	Not reported	60 I: 30 (26/4) C: 30 (24/6)	100% retention	I: 68.5 ± 7.2 C: 69.0 ± 8.1

Citation	Aim	Protocol	What was measured?	Adherence	Participants *N* (male/female) OR *N* I: *N* (male/female) C: *N*(male/female)	Attrition Rate	Age range (age ± SD)
Mooney et al., 2006 (UK-Ireland)	To provide a qualitative description of CABG patients' experiences in preoperative cardiac rehabilitation	Structured: Intervention group completed 12 week program of weekly low- to moderate-intensity exercises (not specified), motivational interviewing, education, and relaxation training.	Qualitative themes identified: • Good to have support • Getting fitter • Overcoming fear • Knowing what to expect • Will I be cured, or not?	100%	8 (not given)	7/8 retained	Range: 54-74
Nery & Barbisan, 2010 (Canada)	To study the potential benefits of preoperative leisure-time physical activity regarding major cardiac events postoperatively	Unstructured: Participants completed Baecke Usual Physical Activity Questionnaire to measure level of leisure physical activity performed prior year. Those in group I performed physical activity at least three times a week for 30 min or more. Group II was comprised of those classified as sedentary	• HLOS • Death • AMI • Rates of reoperation	100%	202 I: 66 (51/15) C: 136 (83/53)	100% retention	I: 60 ± 10 C: 62 ± 10
Nery et al., 2007 (Brazil)	To determine the affect physical activity has on the prognosis of CABG patients	Unstructured: One-year post-CABG, patients completed a questionnaire regarding: demographic characteristics, habits related to physical activity pre (one year prior to CABG) and postoperatively, and clinical episodes post-CABG.	• Clinical Episodes Post-CABG • HLOS • Outcomes After CABG	100%	55 (32/23)	100% retention	I: 63 ± 11 C: 66+ 14
Rosenfeldt et al., 2011 (Australia)	To examine the feasibility of offering physical conditioning and stress reduction programs and to investigate the impact of these programs on quality of life, postoperative AF, and hospital length of stay	Structured: For the first two weeks, participants performed monitored physical activity two days/week for 60 min (20 min stretching, 40 min endurance-type training). After the first two weeks, participants were encouraged to walk 4 days/week for 30 min. During the first two weeks, participants also met with an OT to discuss ways to cope with life stressors.	• QOL: SF-36 • AF • HLOS	Not reported	117 I: 60 (47/13) C: 57 (40/17)	Not reported	I: range 59-68.5 C: range 58.0-77.0
Sawatsky et al., 2014 (Canada)	To evaluate the feasibility of a preoperative rehabilitation program for those awaiting CABG	Structured: Participants exercised twice weekly for 60 min for four weeks. The sessions consisted of aerobic exercises at 85% maximal O_2 consumption, stretches, and resistance training. They also attended 12 education classes regarding medication, exercise, stress, diet, and cardiovascular risk factor management.	• ICU Length of Stay • HLOS • Atelectasis • AF • Δ in 6MWT • Δ in 5-meter gait speed change	19± 7 exercise sessions over a mean exposure time of 8.2 ± 2.2 weeks	17 (14/3)	16/17 retained	Mean: 63 yo
Smenes et al, 2018 (Norway)	To determine if moderate intensity physical activity 24 hours prior to CABG reduces I/R injury incurred during surgery	Structured: Twenty-four hours prior to CABG participants performed 30 min of treadmill walking with the intensity increasing every 10 minutes.	• Mitochondrial respiration • Apoptotic markers • Troponin T, CK-MB, Pro-BNP	• All participants completed intervention • Blood samples not drawn: 4 in I group and 1 in C group (cardiac injury biomarkers)	20 I: 10 (9/1) C: 10 (10/0)	Not reported	I: 62.6 ± 8.5 Cl: 65 ± 7.6
Waite et al., 2017 (UK-England)	To examine if a home-based preoperative physical activity	Structured: Participants performed individualized exercise programs consisting of balance and strength training that was progressed as able. Exercises were completed three days/week in the weeks prior to CABG. Participants also received phone	• Clinical Frailty: Clinical Frailty Scale Anxiety: Hospital Anxiety and Depression Scale	• Completed exercises 3x/week in weeks prior to surgery: 90%	22 (does not provide)	15/22 patients attended surgical pre-assessment	Not reported

Citation	Aim	Protocol	What was measured?	Adherence	Participants *N* (male/female) OR *N* I: *N* (male/female) C: *N*(male/female)	Attrition Rate	Age range (age ± SD)
	program improves physical function and frailty in those awaiting CABG	consultation to offer encouragement. Intervention completed for at least six weeks.	• Depression: Hospital Anxiety and Depression Scale • Functional Capacity: Short Physical Performance Battery Protocol, Duke Activity Status Index, 6MWT • Anthropometrics: weight, BMI	• Went to pre-operative assessment clinic: 100% • Went to surgical pre-assessment appointment: 68.2%		appointment prior to surgery	

Abbreviations: CABG, coronary artery bypass graft; HLOS, hospital length of stay; ICU, intensive care unit; QOL: SF, quality of life: short form; I, intervention group; C, control group; VSAQ, veterans specific activity questionnaire; STSNCSD, The Society of Thoracic Surgeons National Cardiac Surgery Database; AF, atrial fibrillation; A-flutter, atrial flutter; AMI, acute myocardial infarction; OT, occupational therapy; Δ, change; 6MWT, 6 minute walk test; CK-MB, creatinine kinase myocardial band; Pro-BNP, pro-brain natriuretic peptide; BMI, body mass index.

***Table 2*. Themes Table**

Citation	Postoperative Complications	Cost Savings	Psychosocial	Physical Ability	Enrollment in Post-CABG Rehabilitation Program
Arthur et al., 2000	**General**: No significant difference **Rehospitalization/Mortality**: No significant difference **HLOS** • ↓ HLOS (p=0.001) PA: 5 (interquartile range of 5-6) N-PA: 6 (interquartile range of 5-7) • ↓ ICU stay (p=0.038) PA: 19.67 (interquartile range of 15.91-23.25) N-PA: 21.16 (interquartile range of 18.49-39.57)	↑ **Cost Savings**: Net cost savings of ~$133/patient/day	**Social Support:** No significant difference during waiting period, but increased in PA group 6 months postoperatively (p=0.002) **Anxiety:** No significant difference PA: 37 N-PA: 39	SF-36 Subscale (mean change from baseline ± SD) • ↑ physical composite score (p=0.04) PA: 1.55 ± 7.48 N-PA: -1.46 ± 7.81 • ↑ physical role (p=0.01) PA: 9.46 ± 34.39 N-PA: -2.06 ± 33.70 • ↓ physical functioning in both groups, N-PA group ↓ significantly more (p=0.01) PA: -1.17 ± 18.46 N-PA: -6.56± 20.12	**Enrollment Rate:** ↑ (no p-value given) PA: 70% N-PA: 57%
Cook et al., 2001	**General**: Those with lower fitness scores had higher incidence of postoperative complications. (p=0.017) (n (%)) 1: 11 (52.4%) 2: 14 (26.4%) 3: 16 (21.3%) 4: 16 (31.4%) **HLOS**: those with lower fitness scores had longer hospital stays (p=0.0001) (Mean ± SD) 1: 13.4 ± 15.9 2: 8.9 ± 11.7 3: 5.7 ± 2.1 4: 5.8 ± 2.5 • **↓ VASQ and ↑ BF%** = ↑Postop complications and ↑ HLOS	Not reported	Not reported	Not reported	Not reported
Giaccardi et al., 2011	**AF**: ↓ incidence of AF in higher fitness group (p<0.001) PA: 6 (8.1%) N-PA: 27 (32.1%)	Not reported	Not reported	Not reported	Not reported
Herdy et al., 2008	**General** • ↓ incidence of pneumonia (0.01) PA: 0 (0%) N-PA: 7 (26%) • ↓ incidence of pleural effusions (0.03) PA: 6 (20%) N-PA: 13 (48%)	Not reported	Not reported	Not reported	Not reported

Citation	Postoperative Complications	Cost Savings	Psychosocial	Physical Ability	Enrollment in Post-CABG Rehabilitation Program
	• ↓ incidence of atelectasis (p=0.03) PA: 2 (7%) N-PA: 9 (33%) **HLOS:** • ↓ HLOS (p=0.01) (days ± SD) PA: 5.9 ± 1.1 N-PA: 10.3 ± 4.6 • No significant difference in ICU stay (p=0.3) (min± SD) PA: 2855 ± 638 N-PA: 3110 ± 1211 **AF**: ↓incidence of AF (p=0.03) PA: 3 (10%) N-PA: 10 (37%)				
Kehler et al., 2019	**Rehospitalization/Mortality**: ↓ incidence of rehospitalization and mortality (p=0.03) **HLOS** • No significant difference in HLOS (no p-value given) • No significant difference in ICU stay (no p-value given)	Not reported	Not reported	Not reported	Not reported
Ku et al., 2002	**HLOS** • No significant difference in HLOS (p=.228) PA: 10.6 days N-PA: 12 days • No significant difference in ICU stay (no p-value given) PA (range): 2-7 days N-PA (range): 2-10 days	Not reported	**Anxiety** • ↓ anxiety 1-day preop (p<0.001) PA: 33.7 ± 10.4 N-PA: 49.8 ± 14.9 • ↓ anxiety at discharge (p<0.001) PA: 28.6 ± 7 N-PA: 38.4 ± 9.1	Not reported	Not reported
Mooney et al., 2006	Not reported	Not reported	**Psychosocial** • ↑Motivation	↑ confidence, safety, and motivation to participate in PA	Not reported
Nery & Barbisan, 2010	**General:** ↓ incidence of MCE (death, AMI, cardiac reoperation) PA: 78% less likely for MCE **HLOS:** ↓ HLOS (p=0.018)	Not reported	Not reported	Not reported	Not reported
Nery et al., 2007	**General:** ↓ complications (p=0.04) (n (%)) PA: 8 (31%) N-PA: 17 (59%)	Not reported	Not reported	Not reported	Not reported

Citation	Postoperative Complications	Cost Savings	Psychosocial	Physical Ability	Enrollment in Post-CABG Rehabilitation Program
	HLOS: ↓ HLOS (p<0.03) (days ± SD) PA: 12 ± 5 N-PA: 15 ± 8				
Rosenfeldt et al., 2011	**AF:** No significant difference (p=0.71) (incidence %) PA: 36% N-PA: 33% **HLOS:** No significant difference (p=0.54) (days (range)) PA: 6 (5-8) N-PA: 6 (5-8)	Not reported	**Mental Quality of Life:** ↑ from baseline (p=0.03) PA (baseline): 43.3 ± 1.6 N-PA (baseline): 44.3 ± 1.3 PA (6 weeks postop): 45.4 ± 1.2 N-PA (6 weeks postop): 45.2 ± 1.6	Not reported	Not reported
Sawatsky et al., 2014	**General:** No significant difference in incidence of atelectasis (p=0.47) (n (%)) PA: 2 (25%) N-PA: 0 (0%) **AF:** No significant difference (p=0.31) PA: 2 (25%) N-PA: 4 (57%)	Not reported	**Quality of Life:** No significant difference between groups • All groups experienced: ↑ QOL; ↓ PHQ-9; ↑ exercise self-efficacy; ↓ total CAQ score, fear CAQ subscale, and avoidance CAQ subscale (p<0.05)	**Walking** • ↑ distance walked (p<0.05) (meters ± SD) PA: 487 ± 106 N-PA: 357 + 27 • ↑ walking speed (p<0.05) (5-meter gait speed in seconds ± SD) PA: 3.7 ± 0.9 N-PA: 4.7 ± 0.2	**Enrollment Rates** • ↑ Enrollment (p<0.05) PA: 8 (100%) N-PA: 3 (43%)
Smenes et al, 2018	**General:** ↑ cellular apoptosis and ↓ cellular functioning	Not reported	Not reported	Not reported	Not reported
Waite et al., 2017	**HLOS:** ↓ HLOS (p=0.03)	Not reported	Not reported	**Walking** • ↑ 6MWT speed: p<0.001 • ↑ 6MWT distance: p<0.001 **Functional Capacity** • ↑ SPPB: <0.001 **Frailty** • ↓ clinical frailty score: p<0.001	**Enrollment Rates:** 82% of participants enrolled

Abbreviations: HLOS, hospital length of stay; PA, physically active group; N-PA, not physically active group; ICU, intensive care unit; SF-36, short form-36; SD, standard deviation; VSAQ, veterans specific activity questionnaire; BF, body fat; AF, atrial fibrillation; MCE, major cardiac event; AMI, acute myocardial infarction; QOL, quality of life; PHQ-9, patient health questionnaire 9; CAQ, cardiac anxiety questionnaire; 6MWT, 6 minute walk test; SPPB, short physical performance battery