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Diet and Exercise Interventions Following Coronary Artery Bypass Graft Surgery: A Review and Call to Action

Garrett N. Coyan
University of Kansas Medical Center

Katherine M. Reeder
University of Kansas Medical Center, katherine.reeder@sdstate.edu

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Diet and exercise interventions following coronary artery bypass graft surgery: a review and call to action

Garrett N. Coyan, MSc, **K. M. Reeder, PhD, RN**, and **James L. Vacek, MD, MSc**
University of Kansas Medical Center, Kansas City, KS. 66160

Abstract

Coronary artery bypass graft surgery (CABG) has been used for the treatment of coronary artery disease (CAD) for nearly 50 years, and has been performed for millions of people worldwide. However, little is known about the impact of lifestyle changes, including diet and exercise, on long-term outcomes in patients who have had CABG surgery. While clinical practice guidelines on post-CABG surgery management have been available for nearly 2 decades, evidence regarding secondary prevention behavioral interventions, lifestyle modifications, and self-management to slow progressive worsening of CAD, reduce cardiac hospitalizations, and prevent the need for reoperation is virtually absent from the literature. Diet and exercise are modifiable factors that impact secondary CAD risk.

This article reviews the relevant recent literature on long-term diet and exercise outcomes in patients who have had CABG surgery. The limited available literature showed positive impacts of exercise on psychosocial well-being and physical fitness. Current evidence indicates diet and exercise interventions are effective in the short-term, but intervention effects fade over time. Potential age and gender differences were found across the reviewed studies; however, further research is needed with more rigorous designs to replicate and confirm findings as well as to define optimal management regimens and cost-effective prevention strategies.

Introduction

Coronary artery bypass graft (CABG) surgery is a reliable treatment option for patients with coronary artery disease (CAD) not amenable to medical management or percutaneous intervention.[1] In 2010, an estimated 219,000 CABG surgeries were performed in the United States, alone.[2] As more patients undergo this surgical procedure, and short-term outcomes continue to improve, we will be faced with a large cohort of long-term survivors of CABG. Consensus guidelines to limit CAD progression and maintain positive outcomes of CABG are urgently needed for this substantial patient population.[3] While national guidelines for optimizing medical management of post-operative CABG surgical patients have been published, most of the evidence on post-CABG surgery management focuses on medication adherence and tobacco cessation.[3,4]

Corresponding Author; James L. Vacek, MD, MSc jlvacek@kumc.edu.

Sparse evidence exists regarding long-term (greater than 1 year) impact of diet and exercise lifestyle changes on outcomes of patients who underwent CABG surgery.[5,6,7] Most often diet and exercise, if included in studies, have been measured as secondary endpoints.[8] Poor diet and lack of exercise are known risk factors for subsequent development and worsening of CAD after CABG surgery, and recent studies suggest that lack of proper diet and exercise remain to be important risk factors specifically in patients who are post-CABG.[9,10] In light of this, little is known about the long-term impact of diet and exercise interventions after CABG surgery.[11] This review of the recent literature was conducted to synthesize extant research, highlight gaps in knowledge, and identify further research warranted on diet and exercise after CABG surgery. We believe that summarizing the small amount of evidence available will demonstrate the need for a renewed vigor in researching optimal management paradigms for the post-CABG patient in terms of diet and exercise intervention. With the changes in how we deliver health care in the United States and abroad, developing evidence-based guidelines for this population is of the upmost importance.

Materials and Methods

A literature search was conducted using four electronic databases: Medline (accessed via Pubmed), Cochrane Database of Systematic Reviews, Cochrane Central Register of Clinical Trials, and CINAHL. We used the search terms “CABG” and “Coronary Artery Bypass Surgery” in conjunction with “Diet”, “Nutrition”, “Exercise”, and “Physical Activity” to identify pertinent articles through the included electronic resources. English language articles published between 1995 and 2013 were obtained and evaluated for relevance to the topic using stated criteria. References cited in those articles were also culled for additional studies.

The goal of our particular search was to identify long-term outcomes in CABG patients. We defined long-term outcomes as having at least one year of follow-up included in the study, consistent with previous reviews on exercise outcomes in patients with coronary artery disease.[12] Short-term is used to describe follow-up time periods of less than 12 months in this review. Since it was known in advance that few studies existed looking at diet and exercise long-term in CABG patients, it was decided that cohort studies, case-control studies, and cross-sectional study designs would be included, in addition to randomized clinical trials. For this reason, a meta-analysis was not planned, as we expected to find varying endpoints in our search.

Titles and abstracts were reviewed based on results of the queries described above. Complete articles were obtained and reviewed if the abstracts listed CABG patients in the study population, reported at least one year of follow-up, and evaluated diet and/or exercise in some regard. Articles were selected for final inclusion into the review if they met the following detailed criteria: 1) Patients included in the study underwent CABG surgery (if mixed cohort study, at least 50% of the patients must have received CABG, and subgroup analysis must be included); 2) Long-term (at least 12 months) of follow-up must be reported, even if the exercise or diet intervention lasted less than one year; 3) Articles must have used diet and/or exercise as the independent variable in the research question and analysis; 4) Outcomes included (broadly) functional status, psychosocial status, symptom status,

exercise capacity, and adverse cardiac events; 5) English language; 6) Published between January 1995 and May 2013. Outcome measures were left intentionally broad due to the small number of available studies. All types of study designs are represented in the final review.

Summary

Based on *a priori* inclusion criteria, a total of 9 articles were determined relevant to include in this review (Figure 1). Of the nine published studies, 1 study addressed long-term diet outcomes, 5 investigations examined the impact of long-term exercise, and 3 studies examined the impact of both diet and exercise interventions on long-term post-CABG outcomes (Table 1). There were 2 randomized clinical trials, and 7 observational (non-intervention or cohort) studies found addressing long-term outcomes in post-CABG patients. As expected, reporting of various outcomes was inconsistent across studies, precluding meta-analysis feasibility.

Diet Alone

Surprisingly, few studies specifically examining the effects of dietary interventions in the post-CABG surgery population have been published. A small cohort study on dietary habits, including pre- and post-operative dietary advice was conducted with 15 men who had CABG surgery.[13] During the 1-year follow-up period, investigators found total fat, saturated fat, and dietary cholesterol significantly increased from preoperative total fat, saturated fat, and dietary cholesterol daily intake reports (21%, 36%, and 51%, respectively, $p<.05$), which is quite remarkable considering that the patients had just undergone a major surgical procedure. Although the sample was small, findings indicate the need for long-term monitoring of self-management components, such as diet by both clinicians and patients. Further research is needed that examines long-term diet self-management in large samples of both men and women who have had CABG surgery. Dietary modifications are essentially risk free and relatively inexpensive secondary preventive strategies compared to pharmacologic therapies, and deserve further investigation and implementation if found to be effective.

Exercise Alone

Short-term outcomes of cardiac rehabilitation (CR) have been studied extensively in the CABG patient population; however, few studies on long-term outcomes of exercise beyond initial CR programs were found. One such study providing long-term outcome data on exercise was the Minnesota arm of the Post-CABG Biobehavioral Study.[14] Investigators analyzed data which focused on the effect of exercise on functional outcomes, symptoms, and quality of life in patients 5 – 6 years after CABG surgery.[15,16] This study was an observational, non-intervention study of patients' long-term exercise habits after CABG. Of the original 200 participants, 184 surviving patients (105 men and 79 women) were contacted for the study, with 163 participating in the study. In this secondary analysis study, a multivariate model controlling for age, sex, severity of angina, shortness of breath, and fatigue showed that higher levels of exercise were associated with increased functional status, as measured by the validated Functional Status Questionnaire (FSQ), $p<.01$.[15]

In this study, regular exercise, including low to moderate levels of exercise, was associated with improved functional status. This suggests that even low levels of exercise in patients who have had CABG surgery may benefit functional status, which is important for preventing progressive worsening of CAD, maintaining independence and avoiding hospitalizations. Significant differences between men and women were also found. Women who did not exercise more than 2 times a week had significantly lower physical and social functional status outcomes than women who exercised more than 2 times each week, $p<.01$. This same group of non-exercising women had statistically lower physical and social functional status outcomes than all categories of men, $p<.01$. Additionally, men were more likely to engage in exercise, and further exercised at higher intensity in all age groups than women, $p<.01$. Women over the age of 65 years were shown to be especially at risk in this study, having significantly lower physical and social functional status scores then all other participants, $p<.01$. Because this study had significant oversampling of women compared to other studies reviewed, it uniquely represented exercise outcomes in women with CAD after CABG surgery. The data demonstrate overall that increased exercise is associated with improved physical and social functional status outcomes long-term after CABG in both men and women. There were also trends for decreased frequency of exercise and decreased intensity of exercise in women, but those who did exercise experienced improved outcomes.

In a separate analysis of this same post-CABG cohort, moderate exercise was associated with reduced shortness of breath ($p=.01$) and fatigue ($p<.001$). A decrease in anginal chest pain was observed in those who exercised, but the decrease did not quite reach significance, $p=.07$.[16] Notably, a small total number of patients reported angina throughout the observational study period, perhaps making differences in angina secondary to exercise especially difficult to detect. In addition, significant increases in quality of life were reported by patients who engaged in exercise, compared to those who did not engage in exercise, $p=.05$.

A possible major limitation of this observational study is recall bias induced by the 5 to 6 year follow-up period; since self-report of activity and symptoms was used, this study may have been particularly vulnerable to recall bias. Additionally, there was no comparison group, and no active intervention took place in this study. In light of these limitations, several strengths are important to note. Included in this study was a long length of follow-up time, and the amount of data provided by those who did participate in the study was fairly complete in spite of this long follow-up. Also, the surveys used in this study were previously verified and are known to provide robust results. These studies are especially important in regards to long-term outcomes for women, as this study contained a substantial number of women, making comparisons between men and women more useful than in other studies where women comprised less than 30% of the sample. Prospective trials using a structured, monitored intervention setting are warranted to test further the associations found in this study.

The effect of leisure time physical activity (LTPA) on long-term outcomes 2 years following CABG was studied by Martini and colleagues.[17] In this observational cohort study, patients were classified as being active (those involved in physical activity at least three times a week and 20 minutes or more in the last 2 weeks) and sedentary (anything less than active)

according to LTPA. Patients also were given the Baecke Questionnaire of Habitual Physical Activity to confirm active *versus* sedentary physical activity status. The primary outcome of interest was major adverse cardiac events (death, hospital readmission, cerebrovascular accident, and myocardial infarction), with secondary outcomes of functional status measured by the 6-minute walk test and the Veterans Specific Activity Questionnaire. Of the 202 patients enrolled, 66 (33%) were considered active, and 136 were considered sedentary (67%). The only significant difference between the cohort was gender, with males making up 77.3% of the active population, and only 61% of the sedentary population, p=.02. After 2 years of follow up, there were 7 total major adverse cardiac events in the active group, and 13 in the sedentary group; the difference between groups at the 2-year time point was not statistically significant. The 6-minute walk test improved in both sedentary and active patients post-operatively, with consistently higher scores in the active group. Functional outcomes, as measured by the Veterans Specific Activity Questionnaire improved in both groups. Scores were the same in the pre-operative assessment; however, the score for the active group at 2 years of follow-up was significantly higher than the sedentary group score (8.50 vs 6.99, p=.02). From this observational study, long-term adverse cardiac events did not significantly differ between active and sedentary patients in terms of LTPA, but active patients benefited from a greater increase in functional status outcomes than sedentary patients.

While this study's main goal was to examine major adverse cardiac events, the small sample size left the study underpowered to detect small differences. Additionally, the statistical analysis was simplified to only look for differences between active and sedentary patient outcomes at specific time points; it would have been more useful to include regression modeling to predict major adverse cardiac events, or to model functional status outcomes more thoroughly. This limits the conclusions that one can draw from the study. The fact that several validated survey instruments were used enhances the usability and reproducibility of the findings, and the focus of LTPA is somewhat unique. This study indicates that encouraging any type of leisure time physical activity in patients post-CABG may lead to long-term improvements in functional status outcomes. Further research is warranted to determine the effect of LTPA on major cardiac events, as this study was underpowered to detect such changes.

Oldenburg and colleagues conducted a randomized clinical trial to examine the effect of an exercise and behavioral intervention program on long-term outcomes in 86 patients who had CABG surgery.[18] The intervention consisted of 6 weekly group meetings beginning 4 to 8 weeks post-operatively and follow-up meetings at 8 months and 1 year. The weekly group meetings focused on components of self-management, including lifestyle modifications for diet and exercise. The meetings were structured for group discussions about selected topics, with an expert group facilitator. In addition, individual risk reduction plans were developed, progress was discussed, and patients were coached during subsequent meetings. An exercise program focused on gradual increases in activity (enough to break a sweat but not overexertion) was also conducted during these sessions.

The bio-behavioral intervention group was compared to a usual care group that received usual post-surgical follow-up care, as directed by patients' primary care provider. The usual

care group received no specific counseling or individualized plan as did the intervention group. Both intervention and usual care groups were similar in quality of life outcomes, as well as symptom relief and symptom recurrence. An increase in exercise capacity, measured by VO_2 Max while undergoing treadmill testing on the Bruce protocol, was noted in the intervention group, $p<.05$. This difference was thought to be due to increased follow through on prescribed home exercise regimens in the intervention group. In spite of this increase in physical activity, the BMI of patients in both cohorts rose over the course of the study. This finding is consistent with other post-CABG cohorts, but it should be noted that the increase in this study was to a lesser degree than other reports.[5,8] This finding of increased BMI is likely multifactorial, and would benefit from further investigation to clarify attributable factors in this relationship, as it would be desirable for many of these patients to lose or maintain weight after CABG.

Limitations of this study included a small sample size, reducing its power to detect differences in outcomes, the fact that 30% of eligible patients did not agree to participate in the study for unknown reasons, and limited information provided about the exact intervention. However, success in the exercise program of the intervention indicated behavioral interventions may have a role in increasing exercise activity over the long-term in patients who have had CABG surgery. This link warrants further investigation in the post-CABG population to build evidence for future practice guidelines.

Smith and colleagues sought to determine the sustainability of physical activity and quality of life in patients undergoing 6 months of in-home or in-hospital CR after CABG surgery.[19] One hundred ninety-eight patients in this randomized clinical trial were initially randomized to either 6 months of home-based CR or 6 months of hospital-based CR 6–8 weeks after CABG surgery. Groups were similar in terms of medical condition and demographics. Exercise prescriptions for both home and hospital groups were based on identical guidelines using peak oxygen consumption (VO2 max) and heart rate limits. Participants were then consented for a 12-month follow-up visit after completion of the CR program assigned. All participants received the same exercise plan upon discharge from CR to follow over the next 12 months, and no interim follow-up was conducted. At the 12-month follow-up, peak oxygen uptake, measured as VO2 max had declined from discharge of CR in the hospital group, while VO2 max was maintained in the home-based rehabilitation group ($p=.002$). The home-based group had higher habitual activity scores compared with hospital-based rehabilitation at 12 months as measured by the Physical Activity Scale for the Elderly scores (232.6 vs. 170.0, $p=.005$). Both groups had higher physical quality of life scores than the initial score prior to CR as measured by the Short From-36 (SF-36) questionnaire ($p=.002$). Patients in the home rehabilitation group also reported significantly increased social support than the hospital group as measured by the Interpersonal Support Evaluation List ($p<.05$ for all sub-scores). Participants in home-based CR (as opposed to hospital-based program) had increased VO2 max, increased habitual physical activity, and increased social support 12 months after a 6-month CR program after CABG surgery.

This study provides evidence that monitored home-based CR programs may provide superior long-term results to hospital-based programs. One theory to explain this finding involves greater self-efficacy in exercise behaviors and activities initiated in the home

environment, where patients live and conduct their usual daily routines. This finding is one of several strengths of this study, along with adequate power, validated measurement tools, and rigorous exercise programs that were similar across the groups. The major limitation of this trial is the inclusion criteria: patients must have been able to achieve 40% – 80% of age and sex predicted maximum exercise test level. This functionally limits the findings of the study to low-risk patients in the post-operative period following CABG. However, an important question remains as to the best course of treatment for moderate- to high-risk patients after CABG surgery. Further research is needed to address this issue in the moderate- and high-risk populations, as well as determine the optimal exercise program to initiate and monitor in the home environment.

Diet and Exercise

The need for emphasis on dietary advice by health care providers to patients who had undergone CABG surgery was supported by Vachenauer et al.[20] In a large retrospective cohort study that collected 5-year follow-up data on 2,269 patients who had CABG surgery between 1990 and 2003, adherence to prescribed dietary recommendations and patient initiated requests for nutritional counseling both significantly decreased from the 1990 – 1998 to 2000 – 2003 CABG surgery groups, $p<.001$ and $p<.0001$, respectively. Fewer men than women followed strict dietary recommendations (20% vs. 41.5%, respectively, $p<.001$). Patients who had recurrent angina were more likely to seek and follow advice on diet and exercise than patients who did not experience angina (36.6% vs. 29.8%, respectively, $p=.016$). In addition, patients with greater physical limitation, as measured by New York Heart Association (NYHA) classification were more likely to adhere to recommended healthy diet advice (NYHA-III: 22.2% adherence vs. NYHA-II: 14.6% adherence vs. NYHA-I: 10.2% adherence, $p<.001$). Men aged 60 – 79 years were more likely to exercise than women of the same ages, $p<.001$.

This retrospective study showed a trend for reduced adherence with recommended treatments over time in patients that received instruction and advice about lifestyle modifications. Additionally, a tendency to wait for symptom recurrence prior to implementation of recommended lifestyle modifications was found. Delays in initiating and sustaining diet and exercise components of self-management, as part of usual daily routines can be especially problematic for patients who have had CABG surgery for relief of cardiac symptoms, but in whom latent CAD and atherosclerosis persists. Further research is needed that addresses barriers to dietary adherence over time in an effort to improve long-term outcomes in the post-CABG population and slow or prevent progressive worsening of atherosclerotic disease. This study found differences in adherence to recommended lifestyle modifications between age groups and gender, which have implications for future research and individualized intervention approaches. Research focused on age and gender differences in diet and exercise patterns, as well as motivations for following lifestyle modification recommendations in the post-CABG population is needed.

In addition to findings discussed earlier, long-term lifestyle modifications can be inferred from intensive CR programs used in post-myocardial infarction revascularization mixed cohort studies.[11] In a recent mixed cohort of 1,262 patients undergoing any form of coronary

revascularization (69% of whom received CABG while the others received primary PCI), diet control success was achieved in 909 (72%) patients and increases in exercise were observed in 644 (51%) patients after 1 year. Pre-event sedentary lifestyle was predictive of poor diet post-event (OR 8.9). In addition, older patients who had at least 1 comorbidity tended to abandon diet recommendations during the course of the first year after surgery (OR 3.1). Notably, this study utilized facilitator led support groups as opposed to structured, supervised regimens, which may more accurately reflect real world, natural environments than tightly controlled clinical trials.

In a similar fashion, multiple regression analysis was conducted on prospective observational cohort data by Lee to identify determinants of quality of life 5 years following CABG surgery.[21] Physical and mental quality of life was measured in 109 patients in face-to-face interviews 5 years after surgery using the SF-36. The SF-36 is a validated survey that is useful for quantifying health related quality of life, a measure of how patients fair psychosocially and physically in response to overall health condition. There are various component scores that are useful in pinpointing particular health aspects, such as mental and physical components. In the present study, the Allied Dunbar National Fitness Survey diet sheet was used to score actual dietary intake based on metrics indicating heart healthy diet choices. A non-validated physical activity questionnaire was used to quantify exercise for this study.[22] Using both the mental and physical component scores of the SF-36 as the dependent variables, hierarchic regression analysis was conducted using dietary quality and physical activity as independent variables. It is important to note that the physical component of the SF-36 is a measure of functional physical behaviors, not necessarily exercise or leisure activity. Investigators found that physical activity scores 5 years after surgery were positively associated with physical component scores of the SF-36 quality of life indicators, $p<.001$. Also, diet scores were significantly associated with mental quality of life,, $p<.035$, in as much as healthier diets measured by the questionnaire correspond to higher mental quality of life scores.

Investigators concluded that several factors, including diet and physical activity, are associated with health related quality of life outcomes 5 years after CABG. Several limitations warrant mention, including non-validated physical activity evaluation, small sample size, and potential concerns with the regression coefficients, as there were no diagnostics discussed, leaving several questions about the model robustness related to multicollinearity and confounding. However, it is important to note that the SF-36 was used to measure functional status outcomes, and there was complete follow-up on the patients included in the study, both strengths of the study. Further research is needed to confirm the associations found in this study using validated instruments for assessing long-term diet and exercise behaviors in patients who have undergone post-CABG surgery.

Discussion

Highlighted in this review is the current evidence on the long-term impact of diet and exercise lifestyle modifications in the post-CABG population. In the studies reviewed, exercise resulted in significant increases in functional status and quality of life. Functional outcomes were significantly improved with exercise compared to functional outcomes in

persons who did not engage in regular exercise. These factors are directly related to increased psychological well-being, which can contribute to improved CAD outcomes.[23] Additionally, CR has been shown to reduce depression in CABG patients, although long-term effects remain unclear.[24] Although decreases in the number of symptoms patients experienced did not reach statistical significance in all of the reviewed studies, it is possible that focused and individualized attempts to increase aerobic fitness level and respiratory function may improve symptoms and physical functioning over time. Research has shown that exercise after CABG can improve autonomic stability and symptoms in the short-term, but long-term results remain unclear as illustrated in this review.[25–28] Additional research is needed to determine definitively the effects of diet and exercise on CAD symptoms after CABG surgery.

Overall study findings suggest that even intense cardiac interval training was safe and effective in the CABG surgery patient population, but that lower levels of exercise also provided benefit. Patients need to adopt an individualized and feasible exercise routine after CABG surgery to achieve maximal recovery benefit and prevent progressive atherosclerotic disease. Further research is needed to determine the optimum type of exercise routine for each patient, to further define gender and age-specific differences in exercise recommendations, to identify barriers to and facilitators of continued engagement in exercise, and to specify the most useful objective physiological outcomes in post-CABG exercise routines.

Based on the few available studies reviewed, enhancing healthy dietary patterns after CABG surgery in an effort to avoid or slow progressive worsening of CAD warrants increased attention by researchers and health care providers. Several of the studies demonstrated poor adherence to guideline-based diet and exercise recommendations. Even with intense short-term interventions, long-term dietary patterns often returned to baseline. It is well known that lifestyle interventions, including diet and exercise interventions can be used to lower cholesterol in the short-term with CABG patients, but success with long-term reductions remains elusive.[29,30] Disease endpoints were demonstrably more difficult to quantify in the CABG surgery population, as few studies have examined outcomes in terms of worsening symptoms or disease recurrence. Significant differences between women and men in adopting dietary recommendations were found, which warrant further investigation.[31] Research on gender and age differences in adherence to dietary recommendations post-CABG surgery is needed. In addition, intervention studies are needed that effectively improve adherence and sustain high levels of engagement in therapeutic self-management behaviors over time. Interestingly, patients with recurrent angina (opposed to patients without recurring angina) were more likely to seek information and adhere to recommended dietary changes, perhaps because their symptoms provided a reminder of their disease process. Research is needed that focuses on patient education about atherosclerosis and possible intervention strategies to ensure patients are aware of continued risks, despite reduced or absence of symptoms after CABG surgery. There may be a significant role for multidisciplinary teams of primary care providers to help post-CABG patients sustain necessary lifestyle modifications, and this role needs to be a primary focus of future research.

Adherence to lifestyle modifications continues to be a pervasive health care problem in the CABG surgery population.[10] In a recent randomized trial at a large, Midwestern university medical center where optimal medical treatment guidelines were implemented, including discharge teaching by a multidisciplinary team of pharmacists, dieticians, and rehabilitation nurses, an additional educational intervention was provided for the study group 4 – 6 weeks following the CABG surgery hospitalization. Long-term improvements in both the prescribed medication regimen and lifestyle modifications after CABG surgery were suboptimal in both groups.[32] Although significant increases in patient understanding and motivation were found over the course of the study, $p<.05$, significant decreases were found for medication compliance rates for important cardiovascular medications (aspirin, angiotensin converting enzyme inhibitors, and beta blockers) at 3 and 6 months, $p<.05$ for both the control and intervention groups. While patients were motivated to follow guidelines, medication compliance rates decreased over the 1-year post-CABG period. Since surgical follow-up typically ends within weeks after surgery, long-term effects of lifestyle modifications must be monitored and reinforced with patients by health care providers other than patients' cardiothoracic surgeon to ensure long-term benefit of recommended diet and exercise regimens.

In a recent review of factors affecting CR referral and participation in coronary heart disease (CHD), Menezes and colleagues found that referral for CR was disproportionately lower for women than men, even though both men and women had similar clinical profiles.[33] Across the review of 23 studies by Menezes et al., reasons for gender differences in CR referral included age, personal resources, low rates of physician referral, and weak recommendations to patients for participating in CR programs. These findings in the CHD population are disturbing; given that initial referral for CR can sustain engagement in exercise in the post-CABG population for the improvement of long-term outcomes. Additional research is needed to examine reasons for non-referral and lack of participation in CR programs and to identify factors influence sustained exercise, as well as whether a true gender difference exists. In another recent review, similar findings were reported by Swift et al., where patients who had undergone urgent or elective percutaneous coronary intervention and who engaged in CR had as great as a 45% reduction in all-cause mortality regardless of age and gender.[34] Thus, these findings are significant for patients who not only underwent CABG surgery, but also those who have had percutaneous interventions, as well as those with medical management.

Some general conclusions can be made to summarize the differences between men and women found in our review. Several of the studies reviewed suggest that men are more likely than women to exercise multiple times per week, and men, on average, exercise with higher intensity levels. It is important to note that women who do participate in exercise have similar, and at times even greater, benefit than men in terms of quality of life and functional outcomes.[35] Conversely, men (vs. women) are less likely to adhere long-term to dietary advice. This seeming paradox may have to do with differences in perceived importance of diet and exercise recommendations between men and women. Additionally, it is important to note that women who undergo CABG, on average, are older than men due to later onset of CAD in the female population. This may mean that women are deconditioned

and have lower functional status due to advanced age at the time of surgery. Men who undergo CABG at a later age have similar decreased functional status and exercise capacity, so age may very well be a confounding factor when examining gender differences.[36] We did note that these general findings were remarkably similar between all of the studies we reviewed that had substantial numbers of women enrolled. Additional research is warranted to tease out reasons for these observed differences between gender and age groups.

Notably, many of the studies reviewed had significant weaknesses that precluded drawing definitive conclusions about the CABG cohort of patients. Methods employed to measure attributes of diet and exercise across studies varied widely, as did the interventions themselves and how the interventions were implemented with the post-CABG population. Variation in study designs and reported findings rendered comparisons across studies and conduct of a meta-analysis virtually impossible. As indicated earlier, several studies had significant selection biases. For example, several studies selected patients who had opted to enroll in lifestyle modification programs prior to study enrollment. These patients may have been motivated to follow intervention instructions compared to those who did not self-select to enroll. Many of the reviewed studies were designed as observational studies, making it difficult to determine exactly what intervention component, if any, led to improved outcomes. While both observational and intervention study designs can be designed for rigor, studies included in this review often lacked designs to reduce threats to internal validity. Future studies need clear conceptual and operational definitions of diet and exercise, as well as validated and reliable data collection instruments. Because long-term outcome data are sorely needed in the CABG population, studies designed to measure long-term outcomes are needed. For example, epidemiological observational designs can be used, as well as intervention studies with 1- to 2-year follow-up data collection. Retrospective large database queries can be made to national and regional (e.g., state) healthcare data bases, as well as institutional (e.g., hospital and clinic) chart reviews for secondary analysis studies. Multidisciplinary, multi-site clinical trials on specific diet and exercise interventions outcomes in the post-discharge environment are needed.

Several gaps in knowledge persist. For example, a nutritious cardiac dietary program needs to be clearly described to patients preparing to undergo CABG surgery, with adequate methods for confirming understanding and ability to follow through with self-management of therapeutic diet regimens post-operatively and over the course of patients' lifetime. Although CR has been used with success during the post-operative recovery period, continued, long-term exercise patterns remain sub-optimal. It is unknown whether lack of long-term adherence to diet and exercise regimens is due to symptom resolution after CABG surgery, weak CR referral and lack of meaningful coaching on the need for life-long therapeutic lifestyle regimens and options, or changes in social and demographic characteristics among patients, families, and communities. Future research that tests comprehensive diet and exercise interventions and assesses long-term engagement by patients is needed to determine whether secondary prevention, self-management interventions effectively improve long-term outcomes in CABG surgery patients. Clinical practice guidelines need to include evidence on diet and exercise as critical secondary prevention measures to attenuate progressive worsening of CAD following CABG surgery. In the current health care milieu, self-management behavioral interventions, including

therapeutic diet and exercise regimens need to be used with the same vigor as medication therapy to improve long-term CABG outcomes and reduce health care costs.

Conclusion

As the population ages and surgical technologies improve, the number of individuals undergoing CABG surgery will continue to rise. As such, it will important for health care providers to structure appropriate long-term follow-up care for this growing population, with the goal of effective secondary prevention of CAD, reducing hospitalizations and repeat revascularization procedures, and decreasing overall health care costs. Diet and exercise lifestyle modifications have been shown in the limited studies available to have a potential significant role in improving post-CABG outcomes; thus, research that will effectively optimize and sustain the positive effects of diet and exercise modifications will contribute to build the evidence for clinical practice.

Abbreviations

CABG	Coronary Artery Bypass Graft
CAD	Coronary Artery Disease
BMI	Body Mass Index
SF-36	Short Form-36 Survey
NYHA	New York Heart Association
CR	Cardiac Rehabilitation
CHD	Coronary Heart Disease

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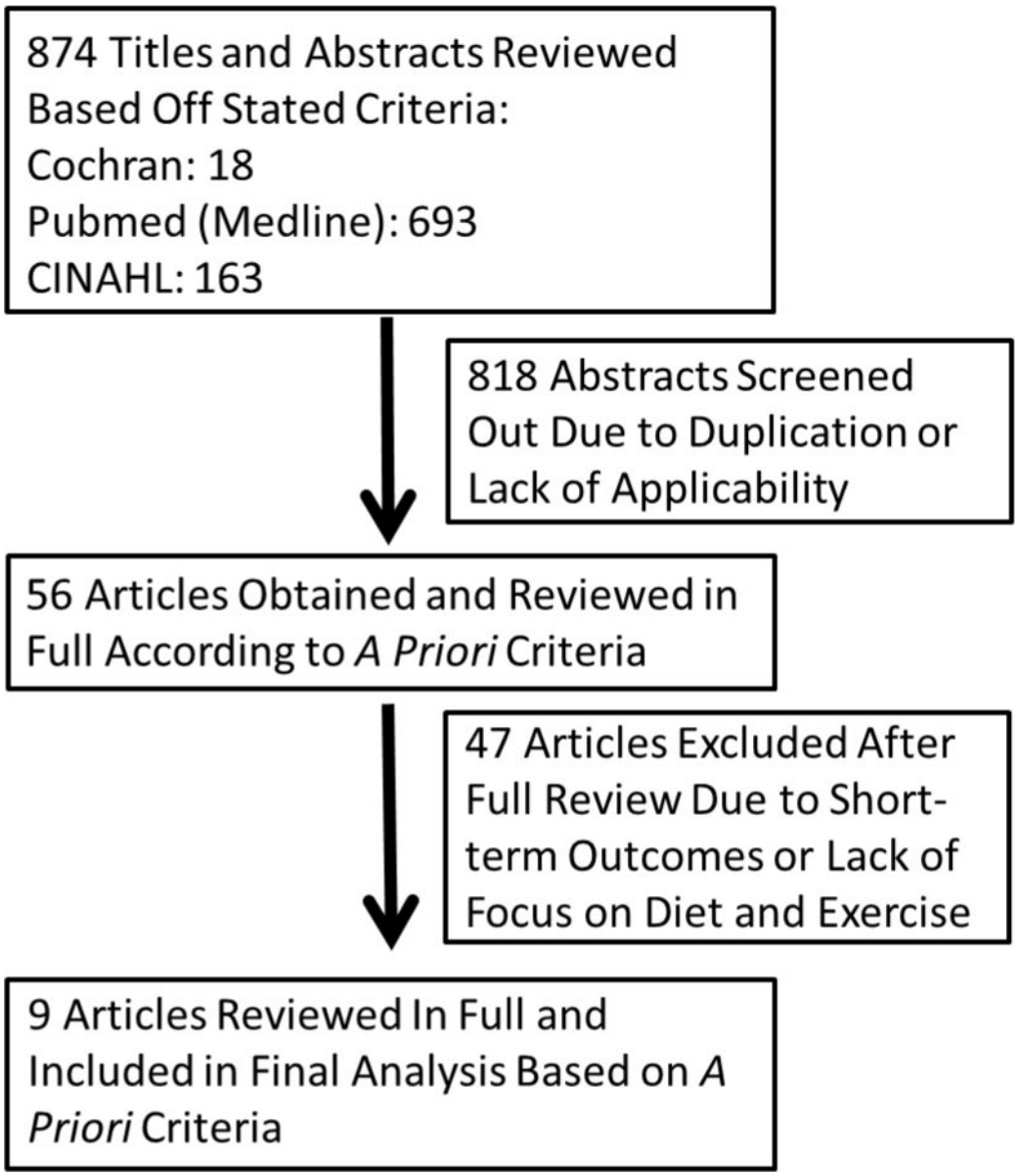

Figure 1.
Literature review search flow diagram based on a priori inclusion criteria.

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Table 1

Effect of diet and exercise on post-CABG outcomes.

Author	Study Aim	Subjects	Methods	Principal Findings	Quality	Conclusions
Diet Alone						
Hartwell *et al.* (2003)[13]	Asses the effectiveness of dietary advice provided to CABG patients.	15 men	Observational prospective cohort study where a food frequency questionnaire was used to evaluate diet in patients pre-operatively, 2 months post-operatively, and 1 year post CABG. Patients received standard dietary counseling pre and post-operatively.	Total fat, saturated fat, and cholesterol all increased over the year of follow-up.	This was a small, low powered study. There was no rigorous intervention. Follow-up and completion of questionnaire was good.	Further research is needed to understand barriers to proper diet in post CABG patients.
Exercise Alone						
Treat-Jacobson *et al.* (2004)[15]	Compare exercise behavior and functional status outcomes in men and women 5–6 years post CABG enrolled in the Minnesota site of the post CABG Biobehavioral Study.	163 men and women (same cohort as below)	Observational prospective cohort followed via telephone interview and self-administered questionnaires.	Women had lower physical and social functioning scores than men, however men were more likely to exercise regularly. Exercisers had higher functional scores than non-exercisers.	Large study design with high participation rate. Higher than average percent of women in the study. No control group or specific intervention.	Exercise is related to better functional outcomes 5–6 years post CABG.
Treat-Jacobson *et al.* (2007)[16]	Compare exercise behavior, functional status, symptoms, and quality of life in men and women 5–6 years post CABG enrolled in the Minnesota site of the post CABG Biobehavioral Study.	163 men and women (same cohort as above)	Observational prospective cohort followed via telephone interview and self-administered questionnaires.	Regular exercise and increased functional status scores were associated with decreased shortness of breath and fatigue, increased perception of health, and increased quality of life measures.	Large study design with high participation rate. Higher than average percent of women in the study. No control group or specific intervention.	Exercise is related to increase quality of life and greater symptom control in the CABG population.
Martini *et al*. (2010)[17]	Determine the effect of Leisure Time Physical Activity (LTPA) on long-term prognosis of patients 2 years post CABG.	202 men and women	Observational prospective cohort comparing major adverse cardiac events (MACE) and functional status outcomes between sedentary and active groups of LTPA.	LTPA decreased from pre to post-operative time period. There were less MACE in the active group, but this was not statistically significant. Increased LTPA was associated with improved functional status.	Study was underpowered to detect significant differences in MACE. Validated questionnaires were used to measure LTPA and outcomes. No regression model constructed.	LTPA does not significantly impact MACE during 2 years of follow-up. However, Increased activity is associated with improved functional outcomes in this same time interval.

Author	Study Aim	Subjects	Methods	Principal Findings	Quality	Conclusions
Oldenburg *et al.* (1995)[18]	Evaluate the efficacy of rehabilitation programs in CABG patients in terms of risk factor modification, quality of life, and symptom control.	86 men and women	Randomized clinical trial with those in the intervention group undergoing weekly meetings for 6 weeks, with periodic booster sessions, aimed at lifestyle modifications.	Few differences in risk factors developed between groups; major difference was increased aerobic capacity and exercise adherence in the intervention group. All patients experienced increased quality of life.	Medium sized randomized trial, many metrics measured. However, generalizability of such intense meetings may be difficult.	Modest success with intervention may point to unexplored differences in the CABG population from other cardiac patients. Increased aerobic activity observed with intervention is beneficial for long-term symptom reduction.
Smith *et al.* (2004)[19]	Examine sustainability of physical activity, quality of life, and social support in patients 12 months after in hospital or in home cardiac rehabilitation following CABG	198 men and women	Randomized clinical trial examining outcomes 12 months after a 6 month cardiac rehabilitation program completed in either the home or the hospital (randomized allocation). Outcomes included peak oxygen uptake, quality of life, physical activity, and social support.	Peak oxygen uptake declined in the hospital based rehab group, while uptake was retained in the home group. Physical quality of life was higher in the home vs hospital rehab group, while mental quality of life was similar between groups. Patients receiving home based rehabilitation had higher physical activity scores after 12 months compared with hospital based rehab.	This was a relatively large randomized trial, with good long-term follow-up and retention. Various outcomes are compared thoroughly between the two groups. Good generalizability to low risk population; however, medium and high risk populations not studied.	Patients who receive cardiac rehabilitation in the home environment following CABG may have increased physical activity and quality of life compared to hospital based programs 12 months after rehabilitation ends.
Diet and Exercise						
Vachenauer *et al.* (2008)[20]	Evaluate lifestyle modifications after CABG and correlate these changes to freedom from symptoms.	2269 men and women	Retrospective observational survey of patients over a 10 year period collecting lifestyle modification data via questionnaires for up to 5 years post CABG.	Desire for nutritional counseling, along with dietary habit change decreased over time periods of the study. Fewer men than women adhered to dietary guidelines, while fewer women than men adhered to exercise guidelines. There were notable differences across various age ranges in these categories as well. Patients with recurrent symptoms were more likely to seek out and follow dietary advice.	Large powered study, diverse patient population followed over long-term. No actual intervention tested.	Attention of nutrition deteriorates over time in CABG patients. Patients would benefit from dietary education and increased physical activity, especially in select gender and age groups shown to be especially at risk. Patients should be encouraged to follow recommendations prior to symptom recurrence.
Griffo *et al.* (2012)[11]	Determine the impact of cardiac rehabilitation program on lifestyle modifications and determine predictors of poor behavioral change in patients post CABG or percutaneous coronary intervention.	1262 men and women (69% underwent CABG)	Observational prospective cohort design following consecutive revascularization patients through a comprehensive cardiac rehabilitation program. Risk factors, habits, and medications were monitored out to 1 year.	72% of patients adhered to diet, while only 51% adhered to exercise recommendations. Sedentary lifestyle prior to the event was associated with poor dietary habits, while older patients with comorbidities were more likely to discontinue most therapies and diet recommendations. Medication adherence was much higher than lifestyle modification adherence.	Multicenter, high power study with detailed long-term follow-up. Several metrics measured in single study. Mixed cohort (not exclusively CABG patients).	Cardiac rehabilitation is a reliable treatment option for patient undergoing CABG in conjunction with lifestyle modifications and medication adherence. Further research is needed on those behavioral characteristics found to be counterproductive.
Lee *et al.* (2009)[21]	Identify the determinants of physical and mental quality of life 5 years after CABG surgery	109 men and women	Observational prospective cohort study using a face to face interview 5 years after surgery to determine quality of life using the SF-36. Various risk factor scores were used as independent	Increased exercise and physical activity were associated with increased physical health related quality of life. Proper diet (measured by increased score) was found to be related to increasing mental health related quality of life.	This was a small observational cohort. However, complete data was available on included patients. Physical activity was measured using a non-validated form. Validated	Physical activity is associated with increased physical quality of life, while diet is associated with mental quality of life in CABG patients 5 years after surgery. Further studies warranted to clarify possible

Author	Study Aim	Subjects	Methods	Principal Findings	Quality	Conclusions
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