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The impact of socio-demographic factors on health-related quality of life after coronary artery bypass surgery

Anna Kathrin Assmann [a,†], Alexander Assmann [a,*,†] Sebastian Waßenberg[b] Besnik Kojcici[a] Nora K. Schaal[c] Artur Lichtenberg [a] Jürgen Ennker[d] and Alexander Albert[e,f]

[a] Department of Cardiac Surgery, Heinrich Heine University, Medical Faculty, Duesseldorf, Germany
[b] punkt05 Statistics Consultants, Life Science Centre, Duesseldorf, Germany
[c] Department of Experimental Psychology, Heinrich Heine University, Duesseldorf, Germany
[d] Department of Cardiac and Cardiovascular Surgery, Helios Hospital Krefeld, Germany
[e] Department of Cardiovascular Surgery, Klinikum Dortmund gGmbH, Dortmund, Germany
[f] Witten/Herdecke University, Witten, Germany

* Corresponding author: Department of Cardiac Surgery, Heinrich Heine University, Moorenstr. 5, 40225 Duesseldorf, Germany. Tel. +49-(0)211-81-18331; email: alexander.assmann@med.uni-duesseldorf.de (A. Assmann).

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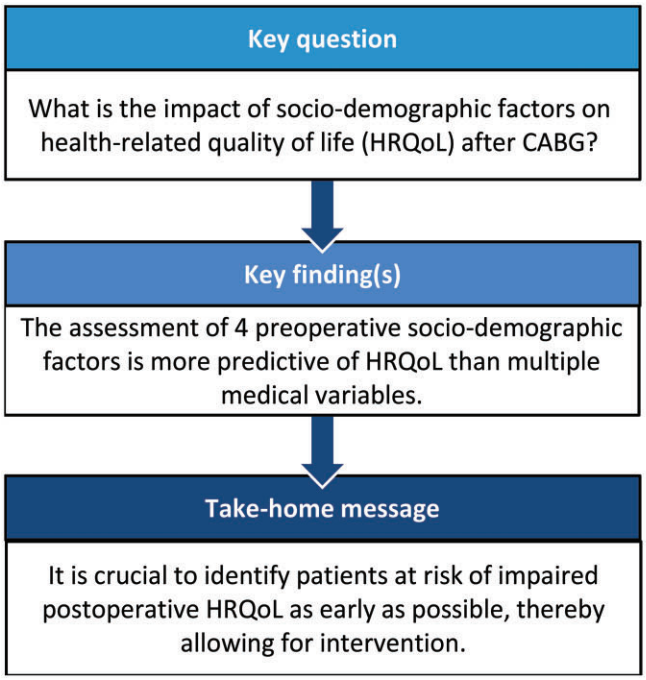

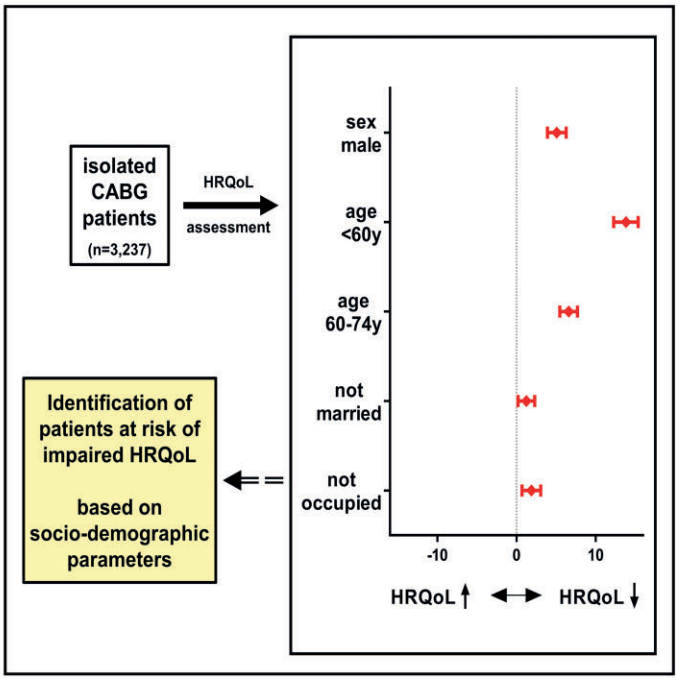

Abstract

OBJECTIVES: To achieve a beneficial impact on long-term outcome after coronary artery bypass grafting (CABG), the goal of the present study was the early identification of patients at risk of impaired postoperative health-related quality of life (HRQoL), particularly evaluating the significance of socio-demographic variables.

[†] Both authors contributed equally to this work.

METHODS: In this prospective, single-centre cohort study of patients having an isolated CABG (January 2004–December 2014), preoperative socio-demographic (preSOC) and preoperative medical variables as well as 6-month follow-up data including the Nottingham Health Profile were analysed in 3,237 patients.

RESULTS: All preSOC (gender, age, marriage and employment) and follow-up (chest pain, dyspnoea) variables proved to have significant influence on HRQoL ($P < 0.001$), male patients below 60 years being particularly impaired. The effects of marriage and employment on HRQoL are modulated by age and gender. The significance of the predictors of reduced HRQoL differs between the 6 Nottingham Health Profile domains. Multivariable regression analyses revealed explained proportions of variance amounting to 7% for preSOC and 4% for preoperative medical variables.

CONCLUSIONS: The identification of patients at risk of impaired postoperative HRQoL is decisive for providing additional support. This study reveals that the assessment of 4 preoperative socio-demographic characteristics (age, gender, marriage, employment) is more predictive of HRQoL after CABG than are multiple medical variables.

Keywords: Health-related quality of life • Socio-demographic variables • Nottingham Health Profile (NHP) • Coronary artery bypass grafting • Gender differences • Age

ABBREVIATIONS

CABG	Coronary artery bypass grafting
FU	Follow up
HRQoL	Health-related quality of life
NHP	Nottingham Health Profile
NYHA	New York Heart Association
preMed	Preoperative medical variables
preSOC	Preoperative socio-demographic variables
SEM	Standard error of the mean

INTRODUCTION

The major goals of coronary artery bypass grafting (CABG) are the prevention or treatment of myocardial ischaemia and relief from angina and dyspnoea and, thereby, the improvement of health-related quality of life (HRQoL). Previous studies have demonstrated that isolated CABG enhances postoperative HRQoL [1–3], with further improvement provided by cardiac rehabilitation programs [4]. However, some patients report remarkably reduced HRQoL independently of the medical success of CABG and the aftercare [5].

To identify those patients with long-lasting reduction of HRQoL, assessment 6 months after surgery is reasonable, because the rehabilitation program should be finished, and physical recovery should have occurred in the majority of patients [6]. For this purpose, the Nottingham Health Profile (NHP) is an established tool in cardiac surgery [1, 2, 7, 8].

It is crucial to identify patients at risk of impaired postoperative HRQoL before the impairment actually becomes evident—ideally preoperatively—because early additional interventions should be considered. For instance, Aguayo *et al.* reported that depression in 10–40% of patients having cardiac surgery was associated with a significantly worse outcome; thus, the early detection and management of depression are decisive in enhancing postoperative recovery and HRQoL by implementation of routine depression screening tools [9]. A study by Zywot *et al.* suggested that preoperative risk stratification regarding 30-day readmission is crucial to improve patient outcomes and thus HRQoL [10].

Furthermore, previous studies have reported associations between medical or socio-demographic preoperative variables and postoperative HRQoL in patients having cardiac surgery [1, 3, 7, 11, 12]. Nevertheless, the comparative significance of the different variables with regard to HRQoL affection remains unclear.

The goal of the present study was to determine preoperative risk factors for reduced postoperative HRQoL in a large cohort of patients having isolated CABG. In particular, the significance of socio-demographic variables in comparison to multiple medical characteristics was evaluated, additionally revealing the effects on each of the 6 NHP domains separately.

METHODS

Patients

A prospectively observed cohort of consecutive patients having isolated CABG (Heart Center Lahr/Baden, Germany; January 2004–December 2014) was contacted for a 6-month follow-up (FU) survey. For patient inclusion, data for each of the 6 NHP domains and for all preoperative socio-demographic variables (preSOC), preoperative medical variables (preMED) and FU variables had to be available (Supplementary Table 1), resulting in a study sample of 3,237 patients [CONSORT (CONsolidated Standards of Reporting Trials) diagram] (Supplementary Fig. 1). The independent variables were chosen according to previously published studies indicating their potential impact on HRQoL in patients having cardiac surgery [7, 8, 11–13].

Ethics statement. This study is part of a research project on HRQoL in cardiac surgery, approved by the regional ethics committee, conducted in accordance with the declaration of Helsinki and registered at the *Deutsche Register Klinischer Studien* (DRKS00018068). All participants signed an informed written consent form.

Health-related quality of life assessment

All patients received a questionnaire covering the symptoms chest pain and dyspnoea and additionally the first part of the NHP, a standardized international tool for the assessment of HRQoL [14]. The NHP is separated into 6 domains (emotional reaction, energy level, pain, physical abilities, sleep and social isolation) with domain scores ranging from 0 to 100, in which higher scores indicate worse HRQoL. The mean values of the NHP domain scores were defined as the primary outcome of the study.

Statistics

After calculating the patients' NHP domain scores, we subtracted the age- and gender-specific norm values [15] as recently published [8], receiving the individual deviations (normalized NHP domain scores). Finally, we calculated the mean deviation of all 6 domains (normalized NHP score), receiving an HRQoL score normalized to age- and gender-matched healthy persons, in which negative values represent better HRQoL.

Descriptive statistics present continuous variables as mean ± standard error of the mean and categorical variables as number of patients and percentage. The univariable statistics comprise independent sample *t*-tests with Welch's correction if indicated or one-way analysis of variance for categorical variables and linear regression analyses for continuous variables, each with normalized NHP scores as the dependent variable. The subgroup analyses regarding interactions between socio-demographic risk factors were conducted using Mann-Whitney U tests. In order to address different patterns of HRQoL impairment with regard to the 6 domains in patients with adverse preSOC and FU characteristics, matched one-way analysis of variance of the normalized NHP domain scores with the Greenhouse-Geisser correction and the Dunnett post hoc tests using the normalized NHP scores as a reference were performed. With regard to prediction of reduced HRQoL 6 months after CABG, a multivariable evaluation of preSOC, preMED and FU variables was conducted using hierarchical regression analyses with the normalized NHP score and the normalized NHP domain scores, respectively, as the dependent variable. For the normalized NHP score, 2 models were computed: model I (hierarchy steps preSOC+preMED+FU) and model II (hierarchy steps preSOC+FU). For all hierarchical regression analyses, the adjusted R^2 values for the preSOC, preMED and FU steps, as well as the unstandardized regression coefficients with 95% confidence intervals for all variables, are reported. Significance was assumed if $P < 0.05$. Analyses were exploratory in nature. Data analysis was conducted with SPSS Statistics for Windows (IBM, Armonk, NY, USA).

RESULTS

Patient characteristics

Data from 3,237 patients undergoing isolated CABG (2,082 off-pump cases) were analysed. The preoperative characteristics of the patients are presented in Table 1.

The normalized NHP score of the entire patient cohort amounted to -1.6 ± 0.26. Whereas patients with HRQoL superior to the reference group presented with a score of -9.5 ± 0.11, a total of 1,031 patients (31.9%) exhibited positive normalized NHP scores, which amounted to 15.4 ± 0.43 among those patients with impaired HRQoL.

Preoperative predictors and follow-up risk factors of impaired health-related quality of life

Univariable statistics showed a significant influence of most of the preSOC and FU variables on HRQoL, while several preMED characteristics also had a relevant impact [Table 1].

Multivariable regression analyses revealed that all preSOC and FU variables were independent predictors of HRQoL (each $P < 0.001$) (Fig. 1, Supplementary Table 2), whereas male patients and patients < 60 years were particularly impaired. On the one hand, preMED chronic comorbidities, such as diabetes mellitus type II ($P = 0.018$ without insulin, $P = 0.003$ with insulin), chronic obstructive pulmonary disease ($P = 0.007$) or previous stroke ($P = 0.001$), showed a significant effect in terms of reduction of HRQoL. Other preMED variables, such as symptoms categorized by the New York Heart Association (NYHA) and the Canadian Cardiovascular Society (CCS) classification systems or reduced left ventricular ejection fraction, did not predict HRQoL.

Hierarchical regression analyses were conducted with 2 different models to examine in particular the relevance of the preMED variables: model I showed a low R^2 value for preMED

Table 1: Characteristics of the coronary artery bypass graft cohort and results of univariable analyses

PreSOC variables		
Gender, male	2,684 (82.9%)	***P* < 0.001**
Age	<60 years: 746 (23.0%) 60-74 years: 1,823 (56.3%) ≥75 years: 668 (20.6%)	***P* < 0.001**
Not married	680 (21.0%)	*P* = 0.103
Not employed	2,331 (72.0%)	***P* < 0.001**
PreMED variables		
BMI	28.2 ± 0.08(kg*m^{-2})	***P* < 0.001**
ASA	I: 4 (0.1%) II: 135 (4.2%) III: 2,436 (75.3%) IV: 648 (20.0%) V: 14 (0.4%)	***P* = 0.006**
NYHA	I: 202 (6.2%) II: 917 (28.3%) III: 1,936 (59.8%) IV: 182 (5.6%)	*P* = 0.150
CCS classification	0: 1,549 (47.9%) I-III: 1,289 (39.8%) IV: 399 (12.3%)	*P* = 0.165
LVEF < 30%	120 (3.7%)	*P* = 0.167
AF	121 (3.7%)	***P* = 0.037**
PVD	264 (8.2%)	***P* = 0.003**
COPD	368 (11.4%)	***P* < 0.001**
Creatinine level	1.10 ± 0.01(mg*dl^{-1})	***P* = 0.012**
DM II w/o insulin	665 (20.5%)	***P* = 0.017**
DM II+insulin	376 (11.6%)	***P* < 0.001**
AMI < 48 h	412 (12.7%)	***P* = 0.013**
CPR < 48 h	8 (0.2%)	*P* = 0.757
Previous stroke	234 (7.2%)	***P* = 0.024**
Redo surgery	178 (5.5%)	*P* = 0.342
Emergency CABG	306 (9.5%)	*P* = 0.319
FU symptoms		
Chest pain	421 (13.0%)	***P* < 0.001**
Dyspnoea	720 (22.2%)	***P* < 0.001**
NYHA	I: 2,032 (62.8%) II: 676 (20.9%) III: 529 (16.3%)	***P* < 0.001**

Descriptive and univariable statistics for preoperative and follow-up variables. *P*-values result from unpaired *t*-tests or one-way analysis of variance for categorical variables and linear regression analyses for continuous variables each with health-related quality of life as the dependent variable. AF: atrial fibrillation; AMI: acute myocardial infarction; ASA: American Society of Anesthesiologists; BMI: body mass index; CABG: coronary artery bypass graft; CCS: Canadian Cardiovascular Society; COPD: chronic obstructive pulmonary disease; CPR: cardiopulmonary resuscitation; DM: diabetes mellitus; FU: follow-up; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association; preMED: preoperative medical; preSOC: preoperative socio-demographic; PVD: peripheral vascular disease.

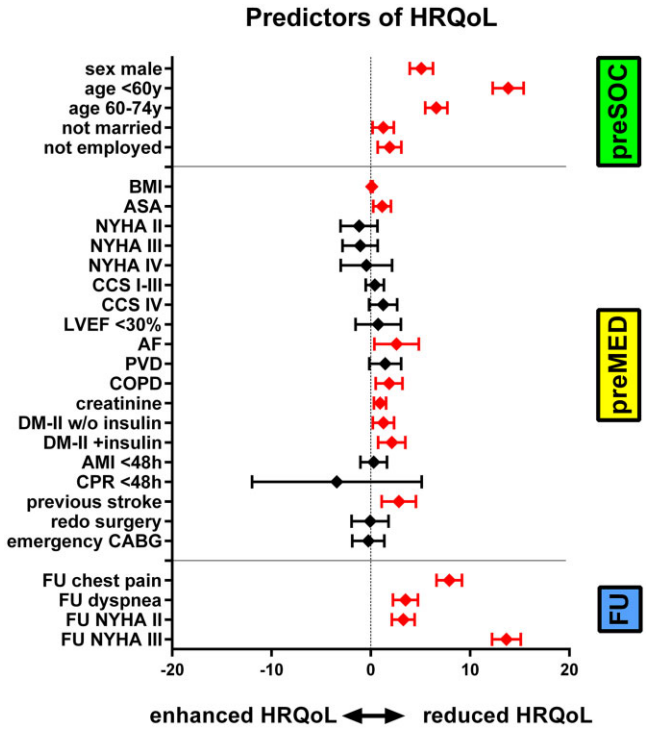

Figure 1: Predictors of health-related quality of life. Multivariable statistics of preSOC, preMED and FU analysed by a hierarchical regression analysis predicting reduced HRQoL 6 months after CABG. Unstandardized regression coefficients with 95% confidence intervals are plotted. For exact values, see Supplementary Table 2. AF: atrial fibrillation; AMI: acute myocardial infarction; ASA: American Society of Anesthesiologists; BMI: body mass index; CABG: coronary artery bypass graft; CCS: Canadian Cardiovascular Society; COPD: chronic obstructive pulmonary disease; CPR: cardiopulmonary resuscitation; DM: diabetes mellitus; FU: follow-up; HRQoL: health-related quality of life; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association; preMED: preoperative medical; preSOC: preoperative socio-demographic; PVD: peripheral vascular disease; w/o: without; y: year.

(0.04), whereas preSOC (0.07) and FU (0.21) had higher values, resulting in a total value of 0.32 (Fig. 2). In model II, the preSOC R^2 value was 0.07, and the FU value was 0.24, so the total R^2 value was 0.31.

Nottingham Health Profile domain analysis of risk factors of impaired health-related quality of life

Multivariable hierarchical regression analyses revealed a significant association of male gender and younger age with worse values in all NHP domains, whereas the status "unmarried" impaired only the social isolation domain, and the status "not employed" did not impair the energy level or the physical abilities (Table 2). None of the preMED variables significantly influenced any of the NHP domains, and only 3 variables (ASA classification, creatinine and previous stroke) impaired at least 3 domains. Physical abilities were most frequently influenced by preMED variables (by 10 out of 16). In the FU, the symptoms chest pain and dyspnoea, particularly NYHA III, showed a major impact on HRQoL reduction in all NHP domains.

R^2 values were low for the preMED variables in 5 of the 6 domains, whereas only the physical abilities presented a higher value (0.07) (Fig. 3). The preSOC variables influenced all normalized NHP domain scores, whereas the effect was largest for social

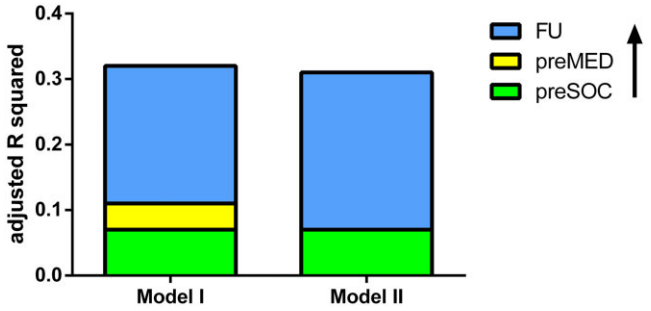

Figure 2: Significance of health-related quality of life predictors. Adjusted R^2 values for preoperative socio-demographic, preoperative medical and follow-up variables analysed by hierarchical regression analyses (black arrow, hierarchical direction) predicting reduced health-related quality of life 6 months after coronary artery bypass graft. Model I hierarchy steps: preoperative socio-demographic+preoperative medical+follow-up. Model II hierarchy steps: preoperative socio-demographic+follow-up. Significant F-change values <0.001 for all steps.

isolation (0.06), pain (0.06) and physical abilities (0.05). The FU variables had a major impact on the energy level (0.21) and the physical abilities (0.16); social isolation (0.02) was marginally influenced.

The impact of each domain score on HRQoL was evaluated in the subgroups. All subgroups except age ≥75 years presented a heterogeneous extent of the impact of HRQoL among the 6 domains (Table 3). Patients with male gender or age <60 years showed particularly impaired energy levels, whereas the domains social isolation and pain were less affected. At the ages of 60 to 74, physical abilities have the largest negative impact on HRQoL. Unmarried patients suffered most from social isolation, and unemployed patients, from low energy levels. Patients who had CABG and who had chest pain or dyspnoea were most severely impaired in the energy level domain, and patients who were NYHA III were additionally impaired in the physical abilities domain.

Interactions among socio-demographic risk factors

When stratified by age, the status "unmarried" resulted in significantly reduced HRQoL only in patients younger than 60 years (Fig. 4A). Gender-specific analyses revealed that below 60 years, unmarried female patients had decreased HRQoL, whereas among older unmarried patients, men showed decreased HRQoL compared to married men (Fig. 4B) and to unmarried women ($P < 0.001$).

The status of being unemployed decreased the HRQoL only in male patients below 60 years (Fig. 4C, D). Unemployed men had significantly reduced HRQoL compared to unemployed women <60 years ($P = 0.002$) and ≥60 years ($P < 0.001$). The normalized NHP scores of unemployed men below 60 years did not differ in dependency on unemployment versus retirement [9.3 (interquartile range 1.4–26.9) versus 7.1 (3.3–27.0); $P = 0.776$].

DISCUSSION

The present study focused on the significance of preSOC characteristics in comparison to medical variables with regard to postoperative HRQoL in patients undergoing isolated CABG. By means of uni- and multivariable analyses in a large cohort, we found that 4 easily available socio-demographic variables

Table 2: Predictors of health-related quality of life

	Emotional reaction	Energy level	Pain	Physical abilities	Sleep	Social isolation
PreSOC variables						
Gender, male	**4.01***** [2.49-5.53]	**7.54***** [4.93-10.16]	**6.35***** [4.87-7.84]	**4.42***** [3.00-5.84]	**5.47***** [3.10-7.84]	**2.83***** [1.64-4.02]
Age < 60 years	**12.21***** [10.19-14.23]	**18.82***** [15.35-22-29]	**12.49***** [10.51-14.46]	**13.65***** [11.76-15.53]	**16.65***** [13.51-19.80]	**9.25***** [7.68-10.83]
Age, 60-74 years	**5.74***** [4.30-7.18]	**8.63***** [6.15-11.11]	**6.40***** [4.99-7.81]	**8.27***** [6.92-9.61]	**5.40***** [3.16-7.65]	**5.14***** [4.01-6.26]
Not married	0.48 [-0.89-1.86]	0.84 [-1.53-3.21]	-0.13 [-1.47-1.22]	-0.14 [-1.42-1.15]	1.23 [-0.91-3.38]	**5.27***** [4.20-6.35]
Not employed	**1.73*** [0.19-3.27]	1.13 [-1.52-3.77]	**2.23**** [0.72-3.73]	1.29 [-0.14-2.73]	**3.29**** [0.90-5.69]	**1.72**** [0.52-2.93]
PreMed variables						
BMI	-0.11 [-0.24-0.01]	0.21 [0.00-0.43]	**0.20**** [0.08-0.33]	**0.33***** [0.21-0.45]	-0.05 [-0.24-0.15]	0.00 [-0.09-0.10]
ASA	1.14 [-0.02-2.31]	0.87 [-1.13-2.88]	**1.89**** [0.75-3.03]	**1.49**** [0.41-2.58]	0.46 [-1.35-2.27]	**1.01*** [0.10-1.92]
NYHA II	-1.32 [-3.72-1.08]	-0.12 [-4.25-4.02]	0.01 [-2.34-2.36]	-0.78 [-3.02-1.46]	-3.22 [-6.96-0.52]	-1.66 [-3.54-0.22]
NYHA III	-0.22 [-2.52-2.08]	-0.31 [-4.27-3.64]	-0.54 [-2.79-1.70]	-0.99 [-3.13-1.16]	-3.24 [-6.82-0.34]	-1.08 [-2.88-0.72]
NYHA IV	-0.27 [-3.62-3.07]	1.62 [-4.13-7.37]	0.34 [-2.93-3.60]	-1.10 [-4.22-2.02]	-1.88 [-7.08-3.33]	-1.28 [-3.89-1.34]
CCS I-III	0.21 [-0.97-1.39]	0.57 [-1.46-2.59]	0.94 [-0.21-2.09]	-0.34 [-1.44-0.76]	0.91 [-0.92-2.75]	0.24 [-0.68-1.16]
CCS IV	1.36 [-0.48-3.20]	2.68 [-0.48-5.84]	1.58 [-0.22-3.37]	1.46 [-0.25-3.18]	0.84 [-2.02-3.70]	-0.44 [-1.87-1.00]
LVEF < 30%	-1.24 [-4.20-1.71]	2.04 [-3.04-7.12]	-0.19 [-3.07-2.70]	**4.81***** [2.05-7.56]	-2.03 [-6.63-2.56]	1.13 [-1.18-3.44]
AF	1.54 [-1.37-4.45]	**7.71**** [2.71-12.72]	0.78 [-2.06-3.63]	**2.95*** [0.23-5.67]	2.10 [-2.44-6.63]	0.53 [-1.74-2.81]
PVD	0.66 [-1.42-2.74]	1.53 [-2.05-5.10]	**4.16***** [2.12-6.19]	**2.79**** [0.85-4.73]	-1.12 [-4.36-2.11]	0.72 [-0.90-2.35]
COPD	1.24 [-0.51-2.99]	**3.93*** [0.92-6.94]	1.00 [-0.71-2.71]	**2.44**** [0.80-4.07]	2.65 [-0.07-5.38]	-0.19 [-1.56-1.18]
Creatinine level	-0.29 [-1.08-0.50]	**1.44*** [0.09-2.80]	0.64 [-0.13-1.41]	**1.11**** [0.37-1.84]	**2.55***** [1.32-3.78]	0.18 [-0.43-0.80]
DM II w/o insulin	0.78 [-0.61-2.16]	**3.5**** [1.12-5.88]	0.99 [-0.36-2.34]	**1.39**** [0.10-2.68]	0.56 [-1.60-2.71]	0.53 [-0.55-1.61]
DM II+insulin	0.37 [-1.41-2.16]	**5.05**** [1.98-8.13]	1.73 [-0.02-3.47]	**4.82***** [3.15-6.49]	0.38 [-2.40-3.16]	0.34 [-1.05-1.74]
AMI < 48h	-1.30 [-3.03-0.43]	0.57 [-2.40-3.54]	1.07 [-0.62-2.75]	0.42 [-1.19-2.03]	0.96 [-1.73-3.65]	0.08 [-1.27-1.43]
CPR < 48h	2.40 [-8.66-13.46]	-5.15 [-24.17-13.88]	-4.85 [-15.66-5.95]	-2.92 [-13.25-7.41]	-8.21 [-25.44-9.02]	-1.74 [-10.39-6.90]
Previous stroke	**2.29*** [0.05-4.53]	**4.16*** [0.30-8.01]	1.47 [-0.72-3.66]	**5.95***** [3.86-8.04]	0.88 [-2.60-4.37]	**2.22*** [0.47-3.97]
Redo surgery	-0.61 [-3.01-1.79]	-0.75 [-4.88-3.39]	-0.50 [-2.85-1.84]	-0.68 [-2.93-1.56]	1.85 [-1.89-5.59]	0.31 [-1.57-2.19]
Emergency CABG	-0.61 [-2.70-1.49]	-0.39 [-3.99-3.22]	-1.42 [-3.47-0.62]	0.26 [-1.70-2.21]	0.62 [-2.64-3.88]	0.10 [-1.53-1.74]
FU						
Chest pain	**7.42***** [5.75-9.09]	**13.28***** [10.41-16.15]	**8.84***** [7.21-10.47]	**4.19***** [2.64-5.75]	**10.88***** [8.28-13.48]	**2.83***** [1.52-4.13]
Dyspnoea	0.87 [-0.76-2.51]	**11.48***** [8.67-14.28]	**2.1**** [0.51-3.7]	**4.77***** [3.24-6.29]	**2.65*** [0.11-5.19]	-0.87 [-2.15-0.40]
NYHA II	**2.71***** [1.22-4.21]	**7.22***** [4.65-9.78]	0.95 [-0.5-2.41]	**1.69*** [0.30-3.08]	**5.46***** [3.14-7.78]	**1.64**** [0.48-2.81]
NYHA III	**11.01***** [9.12-12.89]	**27.22***** [23.97-30.47]	**8.29***** [6.44-10.13]	**14.82***** [13.06-16.58]	**15.04***** [12.10-17.98]	**5.63***** [4.15-7.11]

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

Multivariable statistics of preoperative socio-demographic, preoperative medical and follow-up variables were analysed by a hierarchical regression analysis predicting reduced health-related quality of life separately analysed in all NHP domains 6 months after CABG. Unstandardized regression coefficients with 95% confidence intervals re displayed. AF: atrial fibrillation; AMI: acute myocardial infarction; ASA: American Society of Anesthesiologists; BMI: body mass index; CABG: coronary artery bypass graft; CCS: Canadian Cardiovascular Society; COPD: chronic obstructive pulmonary disease; CPR: cardiopulmonary resuscitation; DM: diabetes mellitus; FU: follow-up; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association; preMED: preoperative medical; preSOC: preoperative socio-demographic; PVD: peripheral vascular disease; w/o: without.

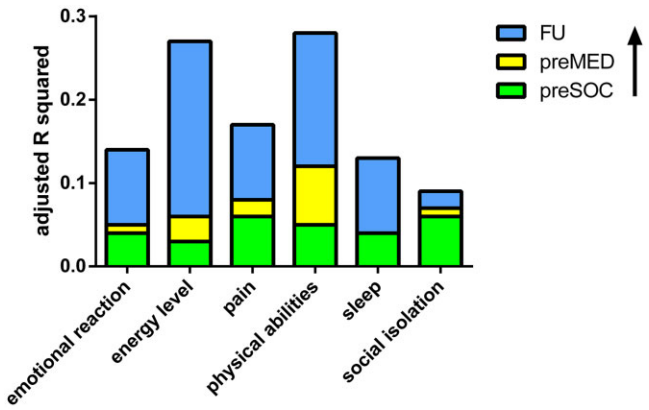

Figure 3: Significance of health-related quality of life predictors. Adjusted R^2 values for preoperative socio-demographic, preoperative medical and follow-up variables analysed by hierarchical regression analyses (model I; black arrow, hierarchical direction) predicting reduced health-related quality of life analysed separately in all NHP domains 6 months after coronary artery bypass graft. Significant F-change values <0.001 for all steps.

(gender, age, marriage and employment) significantly influence the postoperative HRQoL and are more predictive than a multitude of preoperative medical parameters that are typically analysed as potential risk factors of morbidity, mortality and HRQoL in patients having cardiac surgery [8, 12, 16].

Socio-demographic predictors

Although age [2] and gender [17] have been previously identified as influencing the HRQoL after CABG, the impact of marital and employment status and the potential interactions between these socio-demographic variables have remained unclear. Our study revealed that younger age, male gender, not married and unemployed status are independent predictors of impaired postoperative HRQoL.

The reports in the literature regarding the influence of age are contradictory. Whereas Herlitz *et al.* observed a tendency toward lower HRQoL in older versus younger patients who had CABG [18], Peric *et al.* reported superior postoperative improvement in older patients [2], whereas age was not an independent predictor of HRQoL deterioration, which may be attributed to only 226 analysed patients. Our study in 3,237 patients who had CABG supports the hypothesis that younger patients are at higher risk of reduced age- and gender-matched HRQoL.

Table 3: Influence of the different Nottingham Health Profile domains on health-related quality of life

	NHP	NHP domains						*P*-value
	Mean	Emotional reaction	Energy level	Pain	Physical abilities	Sleep	Social isolation	
All	-1.56 ± 0.26	-1.14 ± 0.30	**-0.01***** ± 0.55	**-2.72***** ± 0.29	-1.16 ± 0.30	-2.24 ± 0.46	-2.09 ± 0.23	<0.001
PreSOC variables								
Gender, male	-1.07 ± 0.27	-0.73 ± 0.32	**0.42**** ± 0.59	**-1.80*** ± 0.30	-0.71 ± 0.31	-1.71 ± 0.48	**-1.88**** ± 0.23	**<0.001**
Age < 60 years	4.29 ± 0.57	4.07 ± 0.78	**8.47***** ± 1.16	**2.35***** ± 0.62	3.63 ± 0.49	5.95 ± 0.98	**1.28***** ± 0.56	**<0.001**
Age, 60-74 years	-2.05 ± 0.31	-1.58 ± 0.34	-1.19 ± 0.69	-2.75 ± 0.36	**-0.82***** ± 0.36	**-3.91***** ± 0.58	-2.07 ± 0.26	**<0.001**
Age ≥ 75 years	-6.76 ± 0.59	-5.76 ± 0.60	-6.27 ± 1.33	**-8.29*** ± 0.70	-7.46 ± 0.88	-6.83 ± 1.03	-5.90 ± 0.50	0.135
Not married	-0.68 ± 0.62	-0.95 ± 0.69	1.52 ± 1.30	**-3.62***** ± 0.70	-1.28 ± 0.74	-1.26 ± 1.10	**1.51**** ± 0.70	**<0.001**
Not employed	-2.33 ± 0.31	-1.88 ± 0.34	**-1.16*** ± 0.67	**-3.41***** ± 0.37	-1.80 ± 0.39	-3.23 ± 0.55	-2.50 ± 0.26	**<0.001**
Follow-up								
Chest pain	9.31 ± 0.93	8.01 ± 1.12	**20.66***** ± 1.87	7.28 ± 1.19	**6.78**** ± 1.02	11.66 ± 1.53	**1.48***** ± 0.88	**<0.001**
Dys-pnoea	7.13 ± 0.62	**4.41***** ± 0.76	**20.59***** ± 1.40	**2.87***** ± 0.77	8.19 ± 077	6.95 ± 1.11	**-0.18***** ± 0.58	**<0.001**
NYHA I	-5.20 ± 0.25	**-3.68***** ± 0.30	**-8.29***** ± 0.52	-4.79 ± 0.31	-4.76 ± 0.31	**-6.49**** ± 0.49	**-3.19***** ± 0.22	**<0.001**
NYHA II	-0.75 ± 0.53	-0.73 ± 0.64	**3.05***** ± 1.23	**-3.01***** ± 0.62	-1.84 ± 0.59	0.01 ± 1.03	**-1.98*** ± 0.51	**<0.001**
NYHA III	11.3 ± 0.82	**8.09***** ± 1.02	**27.88***** ± 1.72	**5.62***** ± 1.04	**13.49*** ± 0.98	11.19 ± 1.44	**1.98***** ± 0.84	**<0.001**

*P < 0.05; **P < 0.01; ***P < 0.001).

Normalized scores (mean±SEM) for all Nottingham Health Profile domains. *P*-values from matched one-way analysis of variance with the Greenhouse-Geisser correction, addressing interdomain differences. Bold domain scores significantly differ from the respective mean scores, as calculated by Dunnett post hoc tests.

FU: follow-up; NYHA: New York Heart Association; preSOC: preoperative socio-demographic.

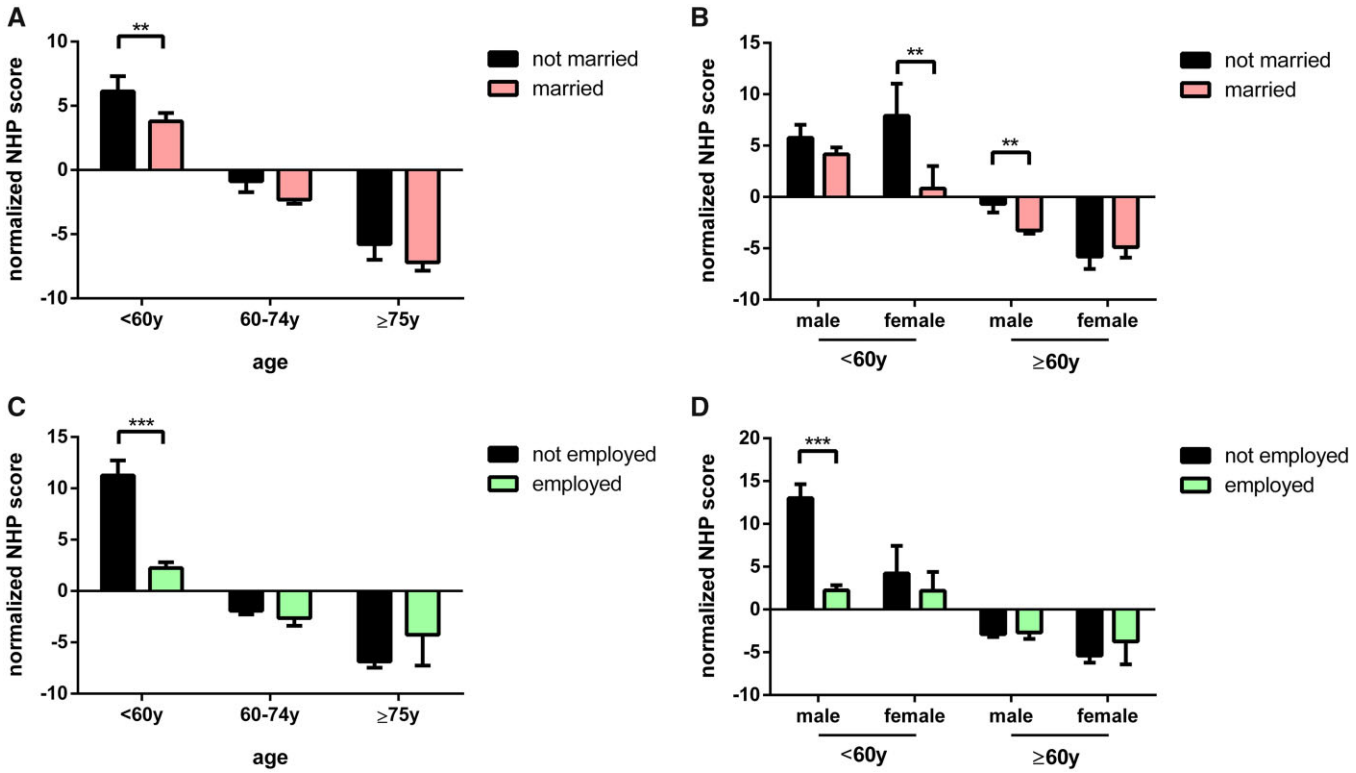

Figure 4: Interactions between socio-demographic predictors. Age- and gender-grouped analyses of the effects of marital status (**A, B**) and employment (**C, D**) on health-related quality of life. **P<0.01;***P<0.001.

The finding of a higher risk for young patients has different facets. From a mathematical point of view, it has to be mentioned that in the healthy reference group, people <60 years have low NHP scores (<10), whereas the scores for people >75 years range up to 29 [15]. Considering that the HRQoL in our study was assessed as the difference of the individual NHP scores from the reference group scores (normalized NHP score) and that the NHP score ranges from 0 to 100, subjectively unimpaired patients (with an individual score of 0), if they are older, reach much higher NHP score differences and thus have much more improved normalized NHP scores. In turn, younger patients with severely impaired HRQoL can reach mathematically substantially worse normalized NHP scores than older patients. When focusing on psychological aspects, young patients may judge postoperative restrictions more drastic than elderly patients who might be more indolent, particularly in the face of physical impairment.

For instance, there is evidence that the somatosensory pain threshold increases in elderly people compared to young people [19, 20], indicating that young people are more sensitive to pain.

In our study, male patients had remarkably reduced HRQoL compared to women. At first glance, this finding seems to contradict findings from previous studies: Martin *et al.* reported that the baseline of female patients having CABG and the 6-month FU HRQoL were lower than in men [17]; Peric *et al.* showed improved performance in the NHP sleep domain for men versus women 2 years after CABG [7]; and Falcoz *et al.* found lower HRQoL 2 years after CABG in women compared to men, whereas the postoperative improvement was significant for both genders [11]. In contrast to previous studies, our analyses are based on normalization, considering age- and gender-matched healthy persons as reference groups [15]; additionally, women of the reference population have substantially higher NHP score values, indicating worse perceived HRQoL. Thus, in order to reveal gender effects, normalization based on a reference population, or at least on the course of the score over time, is required.

A beneficial effect of marriage on postoperative HRQoL in patients who have had CABG has not been described before. Interestingly, only younger women (<60 years) and elderly men (≥60 years) showed a significant benefit when married. It may be speculated that emotional patterns in a relationship and age-dependent variations of the need for mutual psychological and physical care (particularly in older people) might explain this age-dependent shift of the protective effect of marriage for coronary patients. Besides the age and gender of patient having CABG, the personalities of the patient and of the spouse have been shown to play an important role for the postoperative HRQoL of the married patient as well as his/her spouse [21]. Predominantly neuroticism and depressive symptoms have been identified as negatively influencing factors.

In the context of patients undergoing CABG, employment thus far has mainly been addressed only as a dependent variable, coding as postoperative return to work and not as a potential predictor of HRQoL. The present study revealed a significant impairment from missing employment only for male patients below 60 years. This finding may be explained by higher perceived significance of employment among men compared to women, whereas "no employment" seems to be an issue even if retirement is the underlying reason. The gender difference might be due to the fact that until today, men on average earn more money and work in more prestigious positions compared to women [22].

Age and gender seem to have a higher impact on postoperative HRQoL than employment and marital status. This finding may be due to the fact that, besides psychosocial and psychosomatic implications, age and gender also have physical effects on cardiac pathology. For instance, younger patients who require CABG frequently exhibit faster development and progression of atherosclerosis than patients who reach the stage of surgical indication at an advanced age. This situation might also impair HRQoL during the postoperative course.

Beyond employment status, socio-economic deprivation has been reported to influence the outcome after CABG. In a recent analysis performed by Thompson *et al.*, the Michigan Value Collaborative and the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative, patients with high socio-economic deprivation were shown to suffer from increased morbidity and even in-hospital death [23]. The interplay between employment status, actual socio-economic deprivation and postoperative HRQoL should be subject to further investigation.

Medical risk variables

Among multiple preoperative medical characteristics, especially angina, dyspnoea and severely impaired cardiac function, peripheral vascular disease and myocardial infarction or cardiopulmonary resuscitation preceding CABG were not independent predictors of HRQoL, although these parameters have been previously reported to be relevant risk factors for higher morbidity after CABG [24, 25]. These findings could be explained by a higher acceptance of cardiovascular disease and associated symptoms by these patients, which may result in lower perceived impairment. Non-cardiac chronic diseases, such as diabetes, chronic obstructive pulmonary disease or stroke, exhibited larger negative impacts on HRQoL. Naturally, a severe chronic disease in addition to the cardiac pathology impacts the HRQoL to a greater extent than the coronary disease alone.

In contrast to preoperative dyspnoea and angina, the symptoms of dyspnoea and chest pain at 6 months FU were relevant risk factors for impaired HRQoL, which is not surprising, because both can severely impact daily life [26, 27]. The rate of patients with chest pain at 6 months (13%) was slightly higher than that reported in the literature [28]. The symptom "chest pain" can not only reflect the diagnosis "angina" but also muscle- or bone-related or psychosomatic pain. As we recently reported for cardiosurgical patients [8], dyspnoea and particularly chest pain at 6 months should be evaluated in terms of preSOC variables, because their relevance for HRQoL seems to interact with the presence of socio-demographic risk factors.

Nottingham Health Profile domain analyses

To the best of our knowledge, this is the first study to investigate the influence of socio-demographic and medical factors on the separate NHP domains. Interesting results showed that the socio-demographic variables had the largest impact in the social isolation domain. This finding can be partially explained by the facts that not being able to work and the disruption to the routines of one's marriage contribute to the preSOC parameters. Whereas sleep, emotional reactions and even pain and physical abilities were remarkably influenced by the preSOC variables, the preMED characteristics exhibited a relevant effect only in the domain of physical abilities. It is of particular interest that the preSOC variables significantly impacted not only psychological aspects of HRQoL, but also predominantly somatic outcomes, such as pain and physical abilities, which reflect a complex interplay between socio-demographic, psychosomatic and physical aspects. This finding is all the more noteworthy because improvement of the somatic outcome is a primary goal of cardiac surgery. Thus, attention should be paid to the preSOC parameters in patients who have had CABG.

Patients at risk and early intervention

Our data confirm that CABG is an operation that allows for good postoperative HRQoL despite the fact that the patients are diagnosed with severe cardiac disease. Actually, 6 months after CABG,

2 out of 3 patients in our study presented with perceived HRQoL not inferior to the status of the healthy reference population. Nevertheless, at 6 months, 32% of the patients who had CABG still exhibited reduced HRQoL. Independently of the medical success aspects of the operation, such as revascularization, myocardial preservation or avoidance of surgery-associated complications, a perceived reduction of the patient's HRQoL is a major issue that also impairs the net benefit of the therapy. Therefore, it is crucial to identify patients at risk of impaired postoperative HRQoL as early as possible.

Psychological interventions provide additional opportunities to optimize HRQoL and thereby the whole postoperative outcome. In a recent study, it was demonstrated that a preoperative psychological intervention beneficially influences the outcome expectations after CABG and thereby improves the physical and mental postoperative outcomes [29]. However, it was also shown that such interventions are more effective when tailored to the individual risk profile [30, 31], underlining the importance of identifying HRQoL predictors.

Limitations

This study is an analysis of prospectively collected data in a single centre in Germany. Other health systems or different cultures with patients potentially exhibiting different risk factors, particularly regarding socio-demographic characteristics or perceived disability, were not included. Out of 8,202 patients who underwent CABG, only 39.5% provided FU data that could be included in the analyses, whereas a significant quantity of HRQoL data still exist. However, a potential selection bias has to be considered, because the actual HRQoL may have influenced the patients' decisions to respond to the FU survey. Furthermore, the NHP survey was performed only at 1 timepoint postoperatively; in contrast, other groups have reported surveys taken prior to the operation [32, 33]. However, the goal of our approach was to normalize age- and gender-matched reference groups so that postoperative HRQoL deviations of patients who had CABG versus healthy people could be demonstrated.

Conclusions

The identification of patients at risk of impaired postoperative HRQoL is decisive in order to provide additional and, in particular, patient-adjusted support. This study reveals that the assessment of only 4 preSOC characteristics (age, gender, marriage and employment) is more predictive of HRQoL after CABG than multiple medical variables, whereas psychological as well as somatic aspects of HRQoL are influenced. Furthermore, age and gender seem to modulate the influence of marriage and employment on postoperative HRQoL.

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Conflicts of interest: None.

Data availability

The data underlying this article will be shared in response to a reasonable request to the corresponding author.

Author contributions

Anna Kathrin Assmann: data analysis, drafting the manuscript; **Alexander Assmann:** conception of the work, data analysis, drafting the manuscript; **Sebastian Waßenberg:** statistical analysis; **Besnik Kojcici:** data acquisition, review and editing; **Nora K. Schaal:** review and editing; **Artur Lichtenberg:** supervision; **Jürgen Ennker:** supervision; **Alexander Albert:** conception of the work, review and editing.

REFERENCES

[1] Herlitz J, Brandrup-Wognsen G, Caidahl K, Hartford M, Haglid M, Karlson BW *et al.* Determinants for an impaired quality of life 10 years after coronary artery bypass surgery. Int J Cardiol 2005;98:447–52.
[2] Peric V, Jovanovic-Markovic S, Peric D, Rasic D, Novakovic T, Dejanovic B *et al.* Quality of Life in Patients of Different Age Groups before and after Coronary Artery By-Pass Surgery. Ann Thorac Cardiovasc Surg 2015; 21:474–80.
[3] Perrotti A, Ecarnot F, Monaco F, Dorigo E, Monteleone P, Besch G *et al.* Quality of life 10 years after cardiac surgery in adults: a long-term follow-up study. Health Qual Life Outcomes 2019;17:88.
[4] Corrà U, Piepoli MF, Carré F, Heuschmann P, Hoffmann U, Verschuren M,] European Association of Cardiovascular P, Rehabilitation Committee for Science G, Eacpr et al Secondary prevention through cardiac rehabilitation: physical activity counselling and exercise training: key components of the position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitation. Eur Heart J 2010;31:1967–74.
[5] Falcoz PE, Chocron S, Stoica L, Kaili D, Puyraveau M, Mercier M et al Open heart surgery: one-year self-assessment of quality of life and functional outcome. Ann Thorac Surg 2003;76:1598–604; discussion 1604. discussion 604.
[6] Dunckley M, Ellard D, Quinn T, Barlow J. Recovery after coronary artery bypass grafting: patients' and health professionals' views of the hospital experience. Eur J Cardiovasc Nurs 2007;6:200–7.
[7] Peric V, Stolic R, Jovanovic A, Grbic R, Lazic B, Sovtic S et al Predictors of Quality of Life Improvement after 2 Years of Coronary Artery Bypass Surgery. Ann Thorac Cardiovasc Surg 2017;23:233–8.
[8] Schaal NK, Assmann A, Rosendahl J, Mayer-Berger W, Icks A, Ullrich S et al Health-related quality of life after heart surgery - Identification of high-risk patients: a cohort study. Int J Surg 2020;76:171–7.
[9] Aguayo E, Lyons R, Juo YY, Bailey KL, Seo YJ, Dobaria V et al Impact of New-Onset Postoperative Depression on Readmission Outcomes After Surgical Coronary Revascularization. J Surg Res 2019;233:50–6.
[10] Zywot A, Lau CSM, Glass N, Bonne S, Hwang F, Goodman K et al Preoperative Scale to Determine All-Cause Readmission After Coronary Artery Bypass Operations. Ann Thorac Surg 2018;105:1086–93.
[11] Falcoz PE, Chocron S, Laluc F, Puyraveau M, Kaili D, Mercier M et al Gender analysis after elective open heart surgery: a two-year comparative study of quality of life. Ann Thorac Surg 2006;81:1637–43.
[12] Juenger J, Schellberg D, Kraemer S, Haunstetter A, Zugck C, Herzog W et al Health related quality of life in patients with congestive heart failure: comparison with other chronic diseases and relation to functional variables. Heart 2002;87:235–41.

[13] Han KT, Park EC, Kim JH, Kim SJ, Park S. Is marital status associated with quality of life? Health Qual Life Outcomes 2014;12:109.
[14] Hunt SM, McKenna SP, McEwen J, Backett EM, Williams J, Papp E. A quantitative approach to perceived health status: a validation study. J Epidemiol Community Health 1980;34:281–6.
[15] Hunt SM, McEwen J, McKenna SP. Perceived health: age and sex comparisons in a community. J Epidemiol Community Health 1984;38: 156–60.
[16] Guida P, Mastro F, Scrascia G, Whitlock R, Paparella D. Performance of the European System for Cardiac Operative Risk Evaluation II: a meta-analysis of 22 studies involving 145,592 cardiac surgery procedures. J Thorac Cardiovasc Surg 2014;148:3049–57 e1.
[17] Martin LM, Holmes SD, Henry LL, Schlauch KA, Stone LE, Roots A et al Health-related quality of life after coronary artery bypass grafting surgery and the role of gender. Cardiovasc Revasc Med 2012;13:321–7.
[18] Herlitz J, Wiklund I, Sjoland H, Karlson BW, Karlsson T, Haglid M et al Impact of age on improvement in health-related quality of life 5 years after coronary artery bypass grafting. Scand J Rehabil Med 2000;32:41–8.
[19] Pickering G, Jourdan D, Eschalier A, Dubray C. Impact of age, gender and cognitive functioning on pain perception. Gerontology 2002;48: 112–8.
[20] Lautenbacher S, Kunz M, Strate P, Nielsen J, Arendt-Nielsen L. Age effects on pain thresholds, temporal summation and spatial summation of heat and pressure pain. Pain 2005;115:410–8.
[21] Ruiz JM, Matthews KA, Scheier MF, Schulz R. Does who you marry matter for your health? Influence of patients' and spouses' personality on their partners' psychological well-being following coronary artery bypass surgery. J Pers Soc Psychol 2006;91:255–67.
[22] Magnusson C, Nermo M. Gender, Parenthood and Wage Differences: the Importance of Time-Consuming Job Characteristics. Soc Indic Res 2017;131:797–816.
[23] Thompson MP, Yaser JM, Fliegner MA, Syrjamaki JD, Nathan H, Sukul D, Michigan Value Collaborative and the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative et al High Socioeconomic Deprivation and Coronary Artery Bypass Grafting Outcomes: insights From Michigan. The Annals of Thoracic Surgery 2022;113:1962–70.
[24] Sergeant P, Blackstone E, Meyns B. Early and late outcome after CABG in patients with evolving myocardial infarction. Eur J Cardiothorac Surg 1997;11:848–56.
[25] Bonacchi M, Parise O, Matteucci F, Tetta C, Moula AI, Micali LR et al Is Peripheral Artery Disease an Independent Predictor of Isolated Coronary Artery Bypass Outcome? Heart Lung Circ 2020;29:1502–10.
[26] Mahler DA, Selecky PA, Harrod CG, Benditt JO, Carrieri-Kohlman V, Curtis JR et al American College of Chest Physicians consensus statement on the management of dyspnea in patients with advanced lung or heart disease. Chest 2010;137:674–91.
[27] Jonsbu E, Martinsen EW, Morken G, Moum T, Dammen T. Illness perception among patients with chest pain and palpitations before and after negative cardiac evaluation. Biopsychosoc Med 2012;6:19.
[28] Pocock SJ, Henderson RA, Seed P, Treasure T, Hampton JR. Quality of life, employment status, and anginal symptoms after coronary angioplasty or bypass surgery. 3-year follow-up in the Randomized Intervention Treatment of Angina (RITA) Trial. Circulation 1996;94: 135–42.
[29] Rief W, Shedden-Mora MC, Laferton JA, Auer C, Petrie KJ, Salzmann S et al Preoperative optimization of patient expectations improves long-term outcome in heart surgery patients: results of the randomized controlled PSY-HEART trial. BMC Med 2017;15:4.
[30] Rollman BL, Belnap BH, LeMenager MS, Mazumdar S, Houck PR, Counihan PJ et al Telephone-delivered collaborative care for treating post-CABG depression: a randomized controlled trial. JAMA 2009;302: 2095–103.
[31] Lie I, Arnesen H, Sandvik L, Hamilton G, Bunch EH. Effects of a home-based intervention program on anxiety and depression 6 months after coronary artery bypass grafting: a randomized controlled trial. J Psychosom Res 2007;62:411–8.
[32] Klersy C, Collarini L, Morellini MC, Cellino F. Heart surgery and quality of life: a prospective study on ischemic patients. Eur J Cardiothorac Surg 1997;12:602–9.
[33] Sjoland H, Caidahl K, Wiklund I, Haglid M, Hartford M, Karlson BW et al Impact of coronary artery bypass grafting on various aspects of quality of life. Eur J Cardiothorac Surg 1997;12:612–9.