

# Added value of subjective assessed functional capacity before non-cardiac surgery in predicting postoperative myocardial injury

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## Background

Functional capacity is used as an indicator for cardiac testing before non-cardiac surgery and is often performed subjectively. However, the value of subjectively estimated functional capacity in predicting cardiac complications is under debate. We determined the predictive value of subjectively assessed functional capacity on postoperative cardiac complications and mortality.

## Design

An observational cohort study in patients aged 60 years and over undergoing elective inpatient non-cardiac surgery in a tertiary referral hospital.

## Methods

Subjective functional capacity was determined by anaesthesiologists. The primary outcome was postoperative myocardial injury. Secondary outcomes were postoperative in-hospital myocardial infarction and one year mortality. Logistic regression analysis and area under the receiver operating curves were used to determine the added value of functional capacity.

## Results

A total of 4879 patients was included; 824 (17%) patients had a poor subjective functional capacity. Postoperative myocardial injury occurred in 718 patients (15%). Poor functional capacity was associated with myocardial injury (relative risk (RR) 1.7, 95% confidence interval (CI) 1.5–2.0;  $P < 0.001$ ), postoperative myocardial infarction (RR 2.9, 95% CI 1.9–4.2;  $P < 0.001$ ) and one year mortality (RR 1.7, 95% CI 1.4–2.0;  $P < 0.001$ ). After adjustment for other predictors, functional capacity was still a significant predictor for myocardial injury (odds ratio (OR) 1.3, 95% CI 1.0–1.7;  $P = 0.023$ ), postoperative myocardial infarction (OR 2.0, 95% CI 1.3–3.0;  $P = 0.002$ ) and one year mortality (OR 1.4, 95% CI 1.1–1.8;  $P = 0.003$ ), but had no added value on top of other predictors.

## Conclusions

Subjectively assessed functional capacity is a predictor of postoperative myocardial injury and death, but had no added value on top of other preoperative predictors.

## Keywords

Metabolic equivalent • cardiac function test • myocardial ischaemia • troponin

## Introduction

Cardiac events are among the most important complications after surgery and therefore preoperative cardiac risk assessment is

essential.<sup>1</sup> According to current guidelines, estimation of preoperative functional capacity is a key tool in cardiac risk assessment and is used to guide the need for additional cardiac testing.<sup>2,3</sup> A functional

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capacity of less than four metabolic equivalents (METs) is associated with an increased cardiac risk.<sup>2-5</sup>

The gold standard to determine a patient's functional capacity is cardiopulmonary exercise testing (CPET).<sup>6,7</sup> Although poor functional capacity as measured by CPET is a reasonable predictor of postoperative complications, CPET testing is not widely used, because it is time consuming and expensive. Therefore, in daily practice, preoperative functional capacity is often estimated by the patient's self-reported activity, clinical observation during preoperative assessment, or a questionnaire such as the Duke activity status index questionnaire (DASI).<sup>4,5,8,9</sup> Although subjective assessment of functional capacity is an easy and widely used method, there is conflicting evidence as to whether it is a good predictor of postoperative cardiac complications.<sup>4,5,8,10-17</sup> A large study recently showed that preoperative subjective assessment of functional capacity neither accurately identified patients with poor cardiopulmonary fitness nor predicted postoperative morbidity and mortality.<sup>17</sup> The authors therefore recommended that subjective assessment should no longer be used. Despite this, subjective preoperative assessment of functional capacity is a widespread practice and changing long existing habits and incorporating new evidence into guidelines often requires several studies that confirm previous findings.

Therefore, we aimed to determine the added value of subjectively assessed functional capacity for predicting postoperative myocardial injury and infarction in elective surgical patients, on top of other preoperative predictors.

## Methods

### Study population

This cohort study included patients aged 60 years and over who underwent elective non-cardiac surgery under general or spinal anaesthesia with an expected postoperative length of hospital stay of at least 24 hours. Surgery took place at the University Medical Center Utrecht, a tertiary referral hospital in The Netherlands, between 1 July 2011 and 31 December 2014. A part of this cohort was included in previous publications.<sup>18,19</sup> For patients who underwent surgery more than once within one year, only the first surgery was included in the analysis. The local medical ethics committee waived the need for informed consent because only routinely collected patient data were used and data were anonymised before analysis (University Medical Center Utrecht medical research ethics committee 11-120/C and 18-762/C).

### Data collection

Data were obtained from electronic medical records. The Dutch municipal personal record database was consulted for mortality data.

### Preoperative assessment

All patients visited the preoperative anaesthesia assessment clinic where medical history, physical examination and, if indicated, further diagnostic testing was performed. Patients filled out a short questionnaire with regard to functional capacity (Supplementary Table 1). Functional capacity was estimated by anamnesis and physical examination by the attending anaesthesiologist or anaesthesia nurse. It was reported as poor (1-3 METs), moderate (4-7 METs), good (8-10 METs), high (>10 METs), or unknown in patients who were not able to perform any physical activity.

## Outcomes

The primary outcome was postoperative myocardial injury, defined as a troponin-I elevation (>60 ng/L) within the first three postoperative days. Troponin I was analysed using the third-generation enhanced AccuTnI assay (Beckman Coulter, Brea, CA, USA). According to our postoperative care protocol, troponin was measured routinely on these first 3 days after surgery. The cut-off value of 60 ng/L was the 99th percentile with a variation coefficient less than 10%, in accordance with the fourth universal definition of myocardial infarction.<sup>20</sup>

Secondary outcomes included postoperative in-hospital myocardial infarction (POMI), defined according to the fourth universal definition of myocardial infarction, and all-cause one year mortality.<sup>20</sup> Clinical assessment of POMI was performed by a consultant cardiologist, in addition to retrospective adjudication by an independent cardiologist (RBG).<sup>18,19</sup>

## Statistical analysis

Baseline characteristics were calculated as means, medians or percentages when appropriate. Data on functional capacity were missing in 7% of patients. These data were imputed using a multiple imputation model including patient characteristics, comorbidities and primary outcome data. Five datasets were imputed by the method of fully conditional specification.

Functional capacity was dichotomised into poor (<4 METs) and normal ( $\geq$ 4 METs), in accordance with international guidelines.<sup>2,3</sup> Patients in whom the functional capacity was reported as unknown were classified as having a poor functional capacity because the functional capacity in these patients is likely to be poor.<sup>4</sup>

Baseline characteristics were compared between patients with a poor and a normal functional capacity, by using the chi-square test for categorical variables and the t-test for continuous variables.

Next, the incidences of the primary and secondary outcomes were compared between patients with a poor and normal functional capacity using the chi-square test, and relative risks (RRs) were calculated. Univariable logistic regression analysis was used to determine the predictive value of functional capacity on myocardial injury. Consequently two regression models were built, in order to determine the added predictive value of functional capacity on top of other known preoperative predictors of mortality or cardiac complications, including the variables from the revised cardiac risk index (RCRI).<sup>21</sup> The first model included the individual variables from the RCRI, and variables that were significantly associated with the outcome in the univariable analysis. In the second model, functional capacity was added to the variables from the first model. The added predictive value of functional capacity was determined by comparing the area under the receiver operating curve (AUROC) of the two aforementioned models. Finally, the positive and negative predictive values of functional capacity were determined.

Subsequently, incidences of in-hospital POMI and one year mortality were compared between patients with a poor and normal functional capacity using the chi-square test, and RRs were calculated. Multivariable logistic regression analysis was used to determine the added predictive value of functional capacity on top of other preoperative predictors for in-hospital POMI and one year mortality. The variables used in the two regression models for one year mortality were the same as in the model for myocardial injury. Because the incidence of POMI was low, the number of variables in the two regression models for POMI was limited. Therefore only two variables were included in the first model, namely age and RCRI, and in the second model age, RCRI and functional capacity.

In a post-hoc sensitivity analysis, the analysis was repeated in complete cases only, hence after excluding patients with missing data for functional capacity.

Finally, differences between the patient's self-reported functional capacity and the physician's reported functional capacity were determined.

Throughout the analysis, a *P* value less than 0.05 was considered statistically significant. The statistical analysis was performed by using SPSS (release 25 for Windows).

## Results

In total, 4879 patients were included. Data on subjective functional capacity were missing in 357 patients (7%). Missing values were imputed and compared with the original data (Supplementary Table 2). After imputation 824 patients (17%) were classified as having poor functional capacity, and 4055 patients (83%) as having normal functional capacity. Patients with poor functional capacity were older and had more comorbidities as compared to patients with normal functional capacity (Table 1).

### Primary outcome

Postoperative myocardial injury occurred in 718 patients (15%): in 184 patients (22%) with poor functional capacity as compared to 534 patients (13%) with normal functional capacity (RR 1.7, 95% confidence interval (CI) 1.5–2.0; *P* < 0.001). The AUROC of the model including only functional capacity was 0.55. The positive predictive value of poor functional capacity on myocardial injury was 22% and the negative predictive value was 87%. After adjustment for other preoperative predictors (age, sex, body mass index (BMI), American Society of Anesthesiology (ASA) classification, comorbidities and high-risk surgery), functional capacity was an independent predictor of postoperative myocardial injury (Table 2). However, adding functional capacity to a multivariable model including these predictors did not improve the predictive value for postoperative myocardial injury (AUROC 0.70 vs. 0.70, respectively).

The post hoc sensitivity analysis including complete cases only yielded similar results.

### Secondary outcomes

POMI was diagnosed in 39 patients (5%) with poor functional capacity as compared to 67 patients (2%) with normal functional capacity (RR 2.9, 95% CI 1.9–4.4, *P* < 0.001). One year mortality occurred in 170 patients (21%) with poor functional capacity as compared to 499 patients (12%) with normal functional capacity (RR 1.7, 95% CI 1.4–2.0; *P* < 0.001). After adjustment, functional capacity was an independent predictor of POMI (Table 3) and one year mortality (Table 4). The predictive value of a model for myocardial infarction, consisting of age and RCRI from the adjusted regression model, had an AUROC of 0.71. Adding functional capacity to this model did not change this (AUROC 0.71).

The predictive value of the multivariable model for mortality (consisting of the variables age, sex, BMI, ASA classification, comorbidities and high-risk surgery) had an AUROC of 0.65. Adding functional capacity to this model did not change the predictive value (0.65).

The post hoc analysis in patients without missing data again showed comparable results for all these outcomes.

With regard to the self-reported functional capacity, 690 patients (14%) did not report their functional capacity. Of the 4189 patients who did report, 1469 patients (35%) reported no limitations. The 2720 patients with self-reported limitations stated that this was most

often due to nerve/joint/muscular problems (*N* = 393, 14%), low endurance (*N* = 404, 15%), fatigue (*N* = 262, 10%), or multiple reasons (*N* = 1469, 50%). When comparing patients' and physicians' estimations in the 4189 patients with self-reported functional capacity, we found a discrepancy in 2134 patients (51%). Fifty patients (1%) who self-reported having 'no limitations', were classified by the physician as having poor functional capacity, and 2084 (50%) patients who self-reported having limitations were classified by the physician as having normal functional capacity. Functional capacity was estimated by both patient and physician as poor in 636 patients (15%) and as normal in 1419 patients (34%).

## Discussion

In this cohort study including older patients undergoing elective non-cardiac surgery, subjective estimation of functional capacity before surgery was significantly associated with postoperative myocardial injury, POMI and mortality. Patients assessed as having poor functional capacity had a slightly increased risk of postoperative myocardial injury (OR 1.3), POMI (OR 1.7) and death (OR 1.4). However, in predicting these events such subjective assessment had no added value on top of other preoperative predictors.

### The literature

Several other studies investigated the relationship between subjectively assessed functional capacity and postoperative (cardiac) complications, with conflicting results.

Reilly and colleagues found that self-reported poor functional capacity was an independent predictor of cardiac ischaemia and cardiovascular complications on top of other patient characteristics, including age, in patients undergoing major surgery.<sup>4</sup> A study by Shah and colleagues in patients with pulmonary hypertension also showed that a patient's self-reported poor functional capacity was associated with longer lengths of hospital stay and major complications.<sup>15</sup> However, in those studies the added value of functional capacity was not determined, nor were troponin levels monitored.

The added value on top of other known information was determined in a study by Wiklund and colleagues in 5939 patients undergoing elective non-cardiac surgery.<sup>5</sup> The authors found that subjective assessment of functional capacity predicted postoperative cardiac complications in univariable analysis, but that it had no added predictive value on top of age and ASA classification, which is in accordance with our study.<sup>5</sup> The METS study, a recent cohort study in 1401 patients undergoing major non-cardiac surgery, showed no added predictive value of the physician's subjective assessment of functional capacity on patient outcomes, including myocardial injury, 30 day mortality and one year mortality.<sup>17</sup>

The lack of an additive effect of subjectively assessed functional capacity may be explained by the physicians' inability to estimate functional capacity correctly based on anamnesis and short clinical observation. This was also observed in the METS study; only 15% of patients with a low DAS1 were correctly assessed by physicians as having low functional capacity. However, in patients with higher DAS1 scores, 97% of the physicians estimated them as having moderate to good exercise capacity.<sup>22</sup> The DAS1 questionnaire is a more objective measure of functional capacity and an easier and cheaper

**Table 1** Baseline characteristics in patients with poor and normal functional capacity.

	Poor functional capacity N = 824	Normal functional capacity N = 4055	P value
Mean age in years (SD)	73.6 (7.9)	70.1 (6.8)	<0.001
Sex (female/male)	424/400 (51/49)	1905/2150 (47/53)	0.020
Mean BMI in kg m <sup>-2</sup> (SD)	27.0 (5.5)	26.0 (4.2)	<0.001
Smoking	180 (22)	689 (17)	0.001
COPD	139 (17)	308 (8)	<0.001
Hypertension	547 (66)	2,089 (52)	<0.001
Diabetes	254 (33)	613 (15)	<0.001
History of ischaemic heart disease	218 (26)	537 (13)	<0.001
History of chronic heart failure	57 (7)	52 (1)	<0.001
History of (paroxysmal) atrial fibrillation	128 (16)	336 (8)	<0.001
Pacemaker and/or ICD	53 (6)	62 (2)	<0.001
History of cerebrovascular disease	232 (28)	541 (13)	<0.001
History of preoperative renal failure	129 (16)	260 (6)	<0.001
History of peripheral vascular disease	164 (20)	362 (9)	<0.001
Beta-blocker	346 (42)	1,176 (29)	<0.001
Calcium antagonist	190 (23)	698 (17)	<0.001
ACE inhibitor/angiotensin receptor blocker	379 (46)	1,460 (36)	<0.001
Diuretics	321 (39)	1,014 (25)	<0.001
Aspirin	329 (40)	1,135 (28)	<0.001
Warfarin	140 (17)	324 (8)	<0.001
Oral antidiabetics	173 (21)	446 (11)	<0.001
Insulin	91 (11)	203 (5)	<0.001
Statins	396 (48)	1,622 (40)	<0.001
High-risk surgery	273 (33)	1513 (37)	0.031
ASA classification			
I	9 (1)	559 (14)	<0.001
II	297 (36)	2884 (71)	
≥III	518 (63)	612 (15)	
RCRI class			
I	263 (32)	1911 (47)	<0.001
II	279 (34)	1404 (35)	
III	160 (19)	561 (14)	
IV	12 (15)	179 (4)	
Surgical specialty			
General	152 (19)	902 (22)	<0.001
Neurosurgery	162 (20)	808 (20)	
Ear nose throat	107 (13)	566 (14)	
Vascular	182 (22)	616 (15)	
Orthopaedics	159 (19)	441 (11)	
Urogenital	63 (8)	721 (18)	
Self-reported limitation in functional capacity			
Yes	636 (77)	2084 (51)	<0.001
Missing	138 (17)	552 (14)	

Figures are numbers (%) of patients, unless stated otherwise.

ACE: angiotensin-converting enzyme; ASA classification: physical status according to the American Society of Anesthesiology; BMI: body mass index; COPD: chronic obstructive pulmonary disease; ICD: implantable cardioverter defibrillator; RCRI: revised cardiac risk index.

Diabetes included patients with oral antidiabetics and/or insulin. History of ischaemic heart disease is defined as a history of previous myocardial infarction and/or previous revascularisation. Heart failure is defined as a left ventricular ejection fraction less than 40%. History of cerebrovascular disease is defined as a history of transient ischaemic attack and/or cerebrovascular accident. Renal failure is defined as a glomerular filtration rate less than 45 ml/minute.

**Table 2** Association between patient characteristics and postoperative myocardial injury.

Variable	Odds ratio (unadjusted)	95% CI	P value	Odds ratio (adjusted)	95% CI	P value
Poor functional capacity	1.9	1.6–2.4	<0.001	1.3	1.0–1.7	0.023
ASA						
II	1.9	1.3–2.6	<0.001	1.2	0.9–1.8	0.243
III–IV	3.6	2.5–5.0	<0.001	1.3	0.9–2.0	0.168
Age	1.05	1.04–1.06	<0.001	1.04	1.02–1.05	<0.001
Female sex	0.8	0.7–0.9	0.001	0.92	0.8–1.1	0.337
BMI	0.98	0.96–0.99	0.009	0.97	0.95–0.99	0.001
Smoking	1.3	1.1–1.6	0.005	1.4	1.1–1.8	0.001
COPD	1.5	1.2–1.9	0.002	1.07	0.8–1.4	0.634
Diabetes	1.5	1.3–1.8	<0.001	1.2	0.99–1.5	0.056
Hypertension	1.6	1.4–1.9	<0.001	1.2	1.01–1.5	0.031
History of ischaemic heart disease	2.0	1.6–2.4	<0.001	1.2	1.02–1.5	0.049
History of chronic heart failure	4.1	2.8–6.1	<0.001	2.3	1.5–3.6	0.001
History of (paroxysmal) atrial fibrillation	1.9	1.5–2.4	<0.001	1.4	1.08–1.8	0.010
Pacemaker and/or ICD	2.4	1.6–3.7	<0.001	1.2	0.8–1.9	0.412
History of cerebrovascular disease	1.3	1.0–1.5	<0.033	0.8	0.6–0.9	0.013
History of peripheral vascular disease	2.0	1.6–2.5	<0.001	1.3	0.98–1.6	0.078
Preoperative renal failure	3.3	2.7–4.2	<0.001	2.1	1.9–2.8	<0.001
High-risk surgery	2.3	1.9–2.7	<0.01	2.2	1.9–2.6	<0.001

ASA classification: physical status according to the American Society of Anesthesiology; BMI: body mass index; CI: confidence interval; COPD: chronic obstructive pulmonary disease; ICD: implantable cardioverter defibrillator.

**Table 3** Association between patient characteristics and postoperative myocardial infarction.

Variable	Odds ratio (unadjusted)	95% CI	P value	Odds ratio (adjusted)	95% CI	P value
Poor functional capacity	2.9	1.9–4.4	<0.001	2.0	1.3–3.0	0.002
RCRI						
II	2.3	1.3–4.0	0.002	2.2	1.3–3.8	0.004
III	3.8	2.1–6.9	<0.001	3.2	1.8–5.8	<0.001
IV	8.1	4.3–15	<0.001	5.8	3.1–11	<0.001
ASA						
II	9.8	1.3–71	0.024			
III–IV	27	3.7–194	0.001			
Age	1.06	1.03–1.08	<0.001	1.04	1.01–1.06	0.008
Female sex	0.8	0.5–1.2	0.272			
BMI	0.96	0.9–1.0	0.098			
Smoking	1.6	1.0–2.5	0.039			
COPD	1.8	1.0–3.1	0.035			
Diabetes	1.3	0.8–2.1	0.286			
Hypertension	2.4	1.6–3.7	<0.001			
History of ischaemic heart disease	3.4	2.3–5.1	<0.001			
History of chronic heart failure	3.2	1.5–7.1	0.004			
History of (paroxysmal) atrial fibrillation	3.0	1.9–4.8	<0.001			
Pacemaker and/or ICD	2.6	1.1–6.0	0.027			
History of cerebrovascular disease	1.4	0.9–2.6	0.163			
History of peripheral vascular disease	3.1	2.0–4.8	<0.001			
Preoperative renal failure	4.4	2.8–6.8	<0.001			
High-risk surgery	2.0	1.4–3.0	<0.001			

ASA classification: physical status according to the American Society of Anesthesiology; BMI: body mass index; CI: confidence interval; COPD: chronic obstructive pulmonary disease; ICD: implantable cardioverter defibrillator; RCRI: revised cardiac risk index.

**Table 4** Association between patient characteristics and one year mortality.

Variable	Odds ratio (unadjusted)	95% CI	P value	Odds ratio (adjusted)	95% CI	P value
Poor functional capacity	1.9	1.5–2.3	<0.001	1.4	1.1–1.8	0.003
ASA						
II	1.4	1.0–1.9	0.031	1.6	1.2–2.2	0.005
III–IV	2.6	1.9–3.6	<0.001	2.7	1.8–4.0	
Age	1.04	1.02–1.05	<0.001	1.02	1.01–1.04	<0.001
Female sex	0.7	0.6–0.9	0.001	0.7	0.6–0.9	<0.001
BMI	0.9	0.93–0.97	<0.001	0.94	0.92–0.96	<0.001
Smoking	0.9	0.7–1.2	0.483	0.9	0.7–1.1	0.364
COPD	1.1	0.8–1.4	0.513	0.9	0.6–1.2	0.345
Diabetes	1.3	1.1–1.6	0.013	1.3	1.0–1.6	0.045
Hypertension	0.9	0.8–1.0	0.159	0.8	0.6–0.9	0.004
History of ischaemic heart disease	1.3	1.0–1.6	0.026	0.9	0.7–1.2	0.580
History of chronic heart failure	2.0	1.3–3.1	0.002	1.2	0.7–1.2	0.512
History of (paroxysmal) atrial fibrillation	1.4	1.1–1.8	0.006	1.1	0.8–1.4	0.476
Pacemaker and/or ICD	1.2	0.7–2.0	0.522	1.1	0.4–1.2	0.157
History of cerebrovascular disease	0.8	0.7–1.1	0.131	0.6	0.5–0.8	0.001
History of peripheral vascular disease	1.0	0.7–1.3	0.860	0.7	0.5–1.0	0.032
Preoperative renal failure	2.1	1.6–2.7	<0.001	1.6	1.2–2.0	0.001
High-risk surgery	1.0	0.9–1.2	0.804	1.0	0.8–1.2	0.996

ASA classification: physical status according to the American Society of Anesthesiology; BMI: body mass index; CI: confidence interval; COPD: chronic obstructive pulmonary disease; ICD: implantable cardioverter defibrillator.

method of estimating functional capacity as compared to CPET testing.<sup>8–12,16,23–25</sup> In the METS study, the DASI was significantly associated with myocardial injury and death after adjustment for other variables.<sup>17</sup>

Another test to determine functional capacity more objectively is the six-minute walk test (6MWT). Several studies have determined the relation between the 6MWT and postoperative (cardiac) complications and mortality.<sup>23,26–28</sup> Those studies showed conflicting results but overall no good relation between the 6MWT and postoperative complications.<sup>25</sup> However, some more recent studies showed a good relation between a low 6MWT and cardiopulmonary complications.<sup>26,27</sup> Finally, a recent study by Shulman and colleagues in patients undergoing major surgery showed that the 6MWT was predictive of death and myocardial infarction.<sup>28</sup>

Gait speed is another test for functional capacity and is used in elderly patients in the assessment of frailty.<sup>29</sup> There is a relation between low gait speed and increased mortality in elderly patients undergoing cardiac surgery.<sup>30,31</sup> In a study by Kamiya and colleagues gait speed was comparable to the 6MWT in a subgroup of patients undergoing cardiac surgery.<sup>31</sup> No studies have compared gait speed with 6MWT with regard to myocardial injury and mortality in patients undergoing non-cardiac surgery.

### Strengths and weaknesses

A major strength of our study is the routine postoperative assessment of myocardial injury by troponin measurements, which makes it unlikely that early postoperative cardiac events were missed.

Although this clinical protocol was not always followed as troponin was not measured in 10% of the patients, these missing data were likely to be random as reported previously in a part of this cohort.<sup>19</sup>

This study also has some weaknesses. First, data on functional capacity were missing in 7% of patients. However, these data were imputed because these were likely not to be missing at random, and we also performed a post hoc complete case analysis that did not change the results. Second, because CPET was not performed, we could not determine whether the subjectively estimated functional capacity correlated to the actual functional capacity. Finally, as the assessment of functional capacity was not standardised, this may have varied between individual physicians, which may have influenced the results. However, this variation in assessments also reflects daily practice.

### Clinical implications and addition of knowledge

Few aforementioned studies determined the added value of functional capacity tests. Our study, including a large number of patients, confirmed the results from the METS study and adds new insight on the additive effect of subjective functional capacity on other preoperative predictors.<sup>17</sup>

### Future directions

Given the findings from those studies it could be considered to use more objective tools to assess preoperative functional capacity, such as the DASI or other structured questionnaires. Currently, the MET



REPAIR study is recruiting patients to assess the value of preoperative functional capacity as assessed by a structured questionnaire in predicting (cardiac) complications and death.<sup>32</sup> It is of interest whether this has any added value on top of other preoperative variables to predict cardiac complications. In the light of limited (human) resources in medicine, questionnaires such as the DASI and more objective tools to estimate functional capacity such as the 6MWT and gait speed should only be used if they have any additive value, because although these are simple to perform they still cost time and manpower.

## Conclusion

In patients undergoing non-cardiac surgery, subjectively assessed preoperative functional capacity was a predictor of postoperative myocardial injury, infarction and death, but had no added value on top of other preoperative predictors.

## Supplemental material

Supplementary material is available at *European Journal of Preventive Cardiology* online.

## Author contributions

JARW, WAK and MM contributed to the conception or design of the work. MM drafted the manuscript. All authors contributed to the acquisition, analysis or interpretation of data to the work and revised the manuscript critically and gave final approval and agree to be accountable for all aspects of the work ensuring integrity and accuracy.

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Previous work

A part of the raw data collected in this study was used in a previous study:

Van Waes JA, Grobden RB, Nathoe HM, et al. One-year mortality, causes of death, and cardiac interventions in patients with postoperative myocardial injury. *Anesth Analg* 2016; 123: 29–37.

Van Waes JA, Nathoe HM, de Graaff JC, et al. Myocardial injury after noncardiac surgery and its association with short-term mortality. *Circulation* 2013; 127: 2264–2271.

## References

- Sellers D, Srinivas C, Djaiani G. Cardiovascular complications after non-cardiac surgery. *Anaesthesia* 2018;**73**(Suppl. 1):34–42.
- Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2014 ACC/AHA Guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines. *J Am Coll Cardiol* 2014;**64**: e77–e137.
- Kristensen SD, Knuuti J, Saraste A, et al. 2014 ESC/ESA Guidelines on non-cardiac surgery: cardiovascular assessment and management: the Joint Task Force on non-cardiac surgery: cardiovascular assessment and management of the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA). *Eur J Anaesthesiol* 2014;**31**:517–573.
- Reilly DF, McNeely MJ, Doerner D, et al. Self-reported exercise tolerance and the risk of serious perioperative complications. *Arch Intern Med* 1999;**159**: 2185–2192.
- Wiklund RA, Stein HD, Rosenbaum SH. Activities of daily living and cardiovascular complications following elective, noncardiac surgery. *Yale J Biol Med* 2001;**74**: 75–87.
- Levett DZH, Jack S, Swart M, et al. Perioperative cardiopulmonary exercise testing (CPET): consensus clinical guidelines on indications, organization, conduct, and physiological interpretation. *Br J Anaesth* 2018;**120**:484–500.
- Lee CHA, Kong JC, Ismail H, et al. Systematic review and meta-analysis of objective assessment of physical fitness in patients undergoing colorectal cancer surgery. *Dis Colon Rectum* 2018;**61**:400–409.
- Melon CC, Eshtiaghi P, Luksun WJ, et al. Validated questionnaire vs physicians' judgment to estimate preoperative exercise capacity. *JAMA Intern Med* 2014;**174**: 1507–1508.
- Hlatky MA, Boineau RE, Higginbotham MB, et al. A brief self-administered questionnaire to determine functional capacity (the Duke Activity Status Index). *Am J Cardiol* 1989;**64**:651–654.
- Biccard BM. Relationship between the inability to climb two flights of stairs and outcome after major non-cardiac surgery: implications for the pre-operative assessment of functional capacity. *Anaesthesia* 2005;**60**:588–593.
- Brunelli A, Refai M, Xiume F, et al. Performance at symptom-limited stair-climbing test is associated with increased cardiopulmonary complications, mortality, and costs after major lung resection. *Ann Thorac Surg* 2008;**86**:240–247; discussion 7–8.
- Girish M, Trayner E Jr, Dammann O, et al. Symptom-limited stair climbing as a predictor of postoperative cardiopulmonary complications after high-risk surgery. *Chest* 2001;**120**:1147–1151.
- James S, Jhanji S, Smith A, et al. Comparison of the prognostic accuracy of scoring systems, cardiopulmonary exercise testing, and plasma biomarkers: a single-centre observational pilot study. *Br J Anaesth* 2014;**112**:491–497.
- Kaw R, Nagarajan V, Jaikumar L, et al. Predictive value of stress testing, revised cardiac risk index, and functional status in patients undergoing non cardiac surgery. *J Cardiothorac Vasc Anesth* 2019; 33: 927–932.
- Shah AC, Ma K, Faraoni D, et al. Self-reported functional status predicts post-operative outcomes in non-cardiac surgery patients with pulmonary hypertension. *PLoS One* 2018;**13**:e0201914–e0201914.
- Struthers R, Erasmus P, Holmes K, et al. Assessing fitness for surgery: a comparison of questionnaire, incremental shuttle walk, and cardiopulmonary exercise testing in general surgical patients. *Br J Anaesth* 2008;**101**:774–780.
- Wijeyesundera DN, Pearse RM, Shulman MA, et al. Assessment of functional capacity before major non-cardiac surgery: an international, prospective cohort study. *Lancet* 2018;**391**:2631–2640.
- van Waes JA, Grobden RB, Nathoe HM, et al. One-year mortality, causes of death, and cardiac interventions in patients with postoperative myocardial injury. *Anesth Analg* 2016;**123**:29–37.
- van Waes JA, Nathoe HM, de Graaff JC, et al. Myocardial injury after noncardiac surgery and its association with short-term mortality. *Circulation* 2013;**127**: 2264–2271.
- Thygesen K, Alpert JS, Jaffe AS, et al. Fourth universal definition of myocardial infarction (2018). *Eur Heart J* 2019; 40: 237–269.
- Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation* 1999;**100**:1043–1049.
- Wijeyesundera DN, Beattie WS, Hillis GS, et al. Integration of the Duke Activity Status Index into preoperative risk evaluation: a multicentre prospective cohort study. *Br J Anaesth*. Epub ahead of print 19 December 2019. DOI: 10.1016/j.bja.2019.11.025.
- Marjanski T, Whnuk D, Bosakowski D, et al. Patients who do not reach a distance of 500 m during the 6-min walk test have an increased risk of postoperative complications and prolonged hospital stay after lobectomy. *Eur J Cardiothorac Surg* 2015;**47**:e213–e219.

24. Stokes JW, Wanderer JP, McEvoy MD. Significant discrepancies exist between clinician assessment and patient self-assessment of functional capacity by validated scoring tools during preoperative evaluation. *Perioper Med (Lond)* 2016;**5**:18–18.
25. Moran J, Wilson F, Guinan E, et al. The preoperative use of field tests of exercise tolerance to predict postoperative outcome in intra-abdominal surgery: a systematic review. *J Clin Anesth* 2016;**35**:446–455.
26. Inoue T, Ito S, Kanda M, et al. Preoperative six-minute walk distance as a predictor of postoperative complication in patients with esophageal cancer. *Dis Esophagus*, Epub ahead of print 20 May 2019. DOI: 10.1093/dote/doz050.
27. Micciche V, Esposito C, Santaniello W, et al. Six-minute walk test in pre-operative evaluation of patients for upper abdominal surgery. *Eur J Anaesthesiol* 2019;**36**: 164–166.
28. Shulman MA, Cuthbertson BH, Wijeyesundera DN, et al. Using the 6-minute walk test to predict disability-free survival after major surgery. *Br J Anaesth* 2019;**122**:111–119.
29. Chainani V, Shaharyar S, Dave K, et al. Objective measures of the frailty syndrome (hand grip strength and gait speed) and cardiovascular mortality: a systematic review. *Int J Cardiol* 2016;**215**:487–493.
30. Afilalo J, Sharma A, Zhang S, et al. Gait Speed and 1-Year Mortality Following Cardiac Surgery: a landmark analysis from the Society of Thoracic Surgeons Adult Cardiac Surgery Database. *J Am Heart Assoc* 2018;**7**: e010139–e010139.
31. Kamiya K, Hamazaki N, Matsue Y, et al. Gait speed has comparable prognostic capability to six-minute walk distance in older patients with cardiovascular disease. *Eur J Prev Cardiol* 2018;**25**:212–219.
32. Mauermann E, De Hert S, Dell-Kuster S, et al. Re-evaluation of peri-operative cardiac risk (the MET REPAIR study): study protocol of a prospective, multi-centre cohort study sponsored by the European Society of Anaesthesiology. *Eur J Anaesthesiol* 2017;**34**:709–712.