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CLINICAL INVESTIGATION

A simplified (modified) Duke Activity Status Index (M-DASI) to characterise functional capacity: a secondary analysis of the Measurement of Exercise Tolerance before Surgery (METS) study

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[12]The members of METS Study are listed in Appendix section

Abstract

Background: Accurate assessment of functional capacity, a predictor of postoperative morbidity and mortality, is essential to improving surgical planning and outcomes. We assessed if all 12 items of the Duke Activity Status Index (DASI) were equally important in reflecting exercise capacity.
Methods: In this secondary cross-sectional analysis of the international, multicentre Measurement of Exercise Tolerance before Surgery (METS) study, we assessed cardiopulmonary exercise testing and DASI data from 1455 participants. Multivariable regression analyses were used to revise the DASI model in predicting an anaerobic threshold (AT) >11 ml kg^{-1} min^{-1} and peak oxygen consumption (VO_2 peak) >16 ml kg^{-1} min^{-1}, cut-points that represent a reduced risk of postoperative complications.
Results: Five questions were identified to have dominance in predicting AT>11 ml kg^{-1} min^{-1} and VO_2 peak>16 ml.$kg^{-1}min^{-1}$. These items were included in the M-DASI-5Q and retained utility in predicting AT>11 ml.kg^{-1}.min^{-1} (area under the receiver-operating-characteristic [AUROC]-AT: M-DASI-5Q=0.67 *vs* original 12-question DASI=0.66) and VO_2 peak (AUROC-VO2 peak: M-DASI-5Q 0.73 *vs* original 12-question DASI 0.71). Conversely, in a sensitivity analysis we removed one potentially sensitive question related to the ability to have sexual relations, and the ability of the remaining four questions (M-DASI-4Q) to predict an adequate functional threshold remained no worse than the original 12-question DASI model. Adding a dynamic component to the M-DASI-4Q by assessing the chronotropic response to exercise improved its ability to discriminate between those with VO_2 peak>16 ml.kg^{-1}.min^{-1} and VO_2 peak<16 ml.kg^{-1}.min^{-1}.
Conclusions: The M-DASI provides a simple screening tool for further preoperative evaluation, including with cardiopulmonary exercise testing, to guide perioperative management.

Keywords: anaerobic threshold; cardiopulmonary exercise test; Duke Activity Status Index; functional capacity; maximal oxygen uptake; preoperative risk assessment; questionnaire

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Editor's key points

- Assessment of functional capacity as a predictor of postoperative morbidity and mortality is essential for improving surgical planning, preparation, and outcomes.
- The Duke Activity Status Index (DASI) is a 12-question tool to determine exercise capacity.
- The authors assessed cardiopulmonary exercise testing (CPET) and DASI data from 1455 participants from the Measurement of Exercise Tolerance before Surgery (METS) study.
- A simplified, recalibrated (modified 5 question or 4 question) version of the DASI (M-DASI) was accurate as a screening tool to distinguish patients who have adequate functional capacity from those who might benefit from further testing and prehabilitation.

The global population is characterised by advancing age and an increasing burden of comorbid disease (including deconditioning from sedentary lifestyles) with increasing healthcare utilisation.[1] These factors contribute to increased incidence of postoperative complications and prolonged length of hospital stay.[2–4] Assessment of functional capacity is central to the current American College of Cardiology/American Heart Association guidelines on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery.[5] Given that impaired functional capacity is a well-established predictor of postoperative morbidity and mortality[6,7] then accurate preoperative risk assessment of functional capacity is pivotal to improving surgical outcomes by allowing preoperative optimisation of modifiable risks such as deconditioning (prehabilitation) and facilitating perioperative management, including postoperative level of dependence planning.[8,9]

Cardiopulmonary exercise testing (CPET), using gas exchange-derived parameters such as oxygen consumption at anaerobic threshold (AT, ml kg^{-1} min^{-1}) and at peak exercise (VO_2 peak, ml kg^{-1} min^{-1}), provides the gold standard for objective assessment of functional capacity.[10] However, CPET is resource intensive and not accessible to all perioperative clinicians. The Duke Activity Status Index (DASI), using 12 questions to assess a person's ability to perform activities of daily living, was developed as a simple and inexpensive surrogate measure of VO_2 peak.[11] The DASI considers the total sum of responses to these 12 questions to estimate VO_2 peak (VO_2 peak=total DASI score×0.43+9.6). In patients with chronic obstructive pulmonary disease, the DASI has criterion validity for predicting functional capacity, with r=0.34 when correlated with measured VO_2 peak. In the perioperative setting, a limited number of small studies report that the DASI has moderate correlation with the VO_2 peak (R^2=0.2–0.45) as measured by CPET in patients undergoing intra-abdominal surgery.[12,13]

The Measurement of Exercise Tolerance before Surgery (METS) study,[14] a large international multicentre study, compared the prognostic accuracy of subjective preoperative assessment, various tools measuring fitness (DASI and CPET) and pro-B-type natriuretic peptide to assess the composite primary endpoint of myocardial infarction or death within 30 days after major noncardiac surgery. The DASI score was associated with improved ability to predict the primary outcome of the composite of myocardial infarction or death within 30 days after surgery, whereas the other assessed tools, including CPET, had limited ability to do so. Importantly, CPET-derived VO_2 peak did have reasonable ability to discriminate the probability of moderate or severe in-hospital postoperative complications (odds ratio 0.86 per 3.5 ml kg^{-1} min^{-1} [1 metabolic equivalent] increased VO_2 peak, 95% confidence interval [95% CI] 0.78–0.97, P=0.007). Although DASI did not statistically improve the ability to predict postoperative morbidity, it may be a useful triage tool for referral to CPET services. This is especially important given that subjective clinician assessment only had 19.2% sensitivity (95% CI 14.2–25.0) for identifying patients with the inability to attain four metabolic equivalents (METS) (VO_2 peak<14 ml kg^{-1} min^{-1}) during CPET. However, the validity of the DASI, both in whole and in part, has not been thoroughly investigated against a robust dataset of patients who have completed CPET in the perioperative setting.

We hypothesised that not all activity domains assessed by the 12 questions of daily living within the original DASI questionnaire are necessary to estimate exercise capacity (predicting VO_2 peak). Using data from the recent METS study,[14] we aimed to assess whether some of the activity domains assessed by the DASI questionnaire are more discriminating than others, and, if so, whether a simplified, recalibrated (modified) version of the DASI (M-DASI) would be sufficiently accurate to be used as a screening tool to identify patients who have adequate functional threshold from those who would benefit from a more formal referral for objective CPET testing and possible prehabilitation of deconditioned patients before major elective noncardiac surgery. We then sought to ascertain if the M-DASI would be able to predict the secondary outcomes of the METS study.

Methods

This is a secondary cross-sectional analysis of the METS study;[14]; the METS study protocol has been published.[15] In brief, the main goal of the METS study was to compare the prognostic accuracy of subjective preoperative assessment tools measuring fitness (DASI, CPET) or pro-B-type natriuretic peptide to predict the composite primary endpoint of myocardial infarction or death within 30 days after major noncardiac surgery. Patients enrolled in this international multicentre prospective cohort study were aged 40 yr or above and deemed to have one or more risk factors for cardiac complications (e.g. a history of heart failure, stroke, or diabetes mellitus) or coronary artery disease and presenting for major elective noncardiac surgery. For this sub-study, we only included patients from the METS dataset who had both preoperative DASI and preoperative CPET data available. Unlike the initial METS study, patients were not ultimately required to undergo surgery. Patients with more than six DASI questions unanswered were excluded. In addition, those who did not achieve AT (3% of the participants) were excluded.

In the METS study, symptom-limited CPET was performed on a cycle ergometer under clinician supervision and based on institutional guidelines for participating centres.[6] CPET used a ramp protocol with a 3-min resting phase, 3 min of unloaded cycling, and then a ramp phase with increasing pedal resistance until exercise was terminated at the patient's volition (peak exercise capacity). Oxygen consumption and carbon dioxide production were monitored using breath-by-breath gas exchange analysis. For each patient, oxygen consumption at (ml kg^{-1} min^{-1}) and peak exercise (VO_2 peak, ml kg^{-1} min^{-1}) were determined according to current consensus guidelines.[10] AT provides an index of submaximal, sustainable exercise capacity, and is independent of patient volition, and this was identified using a three-point discrimination technique,[16] including, the modified V-slope method to identify the inflection point in the carbon dioxide output, the change in the ventilatory equivalents, and the end-tidal partial pressures of oxygen and carbon dioxide to confirm hyperventilation with respect to oxygen but not to carbon dioxide. Peak VO_2 was defined as the average oxygen consumption during the last 20 s of the ramp phase before achieving the peak limit of exercise tolerance.[10]

Statistical analysis

The cut-points of AT>11 ml kg^{-1} min^{-1} and VO_2 peak>16 ml kg^{-1} min^{-1} were considered as satisfactory functional capacity. These cut-points were based on literature suggesting that patients not achieving these levels of exercise capacity have an increased risk of postoperative morbidity.[6,17–20] Cut-points were adjusted to ensure that, as a screening tool, the M-DASI would capture most patients with a truly unsatisfactory AT or VO_2 peak, and this clarifies the deviation from the METS study where VO_2 peak>14 ml kg^{-1} min^{-1} (4 metabolic equivalents) and AT>11 ml kg^{-1} min^{-1} were used to define patients with satisfactory functional capacity.

The differences in patient characteristics between those patients with and those without satisfactory CPET capacity were assessed using the χ^2 or Mann–Whitney *U* test. Multivariable linear regression was used to recalibrate the weights of the original DASI questions to assess whether a positive response to each question was associated with an improvement in the measured exercise capacity. We assigned a missing response to any DASI question as a negative response, which would reduce the risk of inflating the predictive value of the DASI questions. Multivariable logistic regression was used to identify the significance of each DASI question in predicting AT>11 ml kg^{-1} min^{-1} and VO_2 peak>16 ml kg^{-1} min^{-1} (Table 1). A simplified modified DASI model (M-DASI) was then developed using only those DASI questions that were statistically significantly associated with both AT>11 ml kg^{-1} min^{-1} and VO_2 peak>16 ml kg^{-1} min^{-1}. Weighting of each question was not used in the M-DASI if the strength of associations (i.e. beta coefficients in regression model) between the DASI questions and outcome were similar. The discriminative ability of the M-DASI and the original DASI to predict a satisfactory CPET capacity was assessed using the area under the receiver-operating-characteristic (AUROC). AUROCs between 0.70 and 0.80 and >0.80 were considered as having reasonable and good discrimination, respectively.[21] The same method was then applied to investigate our secondary outcomes, which included the composite 30-day outcome of myocardial infarction or death, 30-day complications, 30-day mortality, or 1-yr mortality. We used the method suggested by Hanley and McNeil[22] to compare the AUROC derived from the same cases. Calibration of the M-DASI model was illustrated by the probability of achieving AT>11 ml kg^{-1} min^{-1}and VO_2 peak>16 ml kg^{-1} min^{-1}with the number of positive responses to the M-DASI model.

A series of sensitivity analyses were conducted to assess whether the predictive ability of the M-DASI would change after: (a) combining gender (given that males may have a higher average exercise capacity); (b) removing the question on the ability to have sexual relations (given the potential sensitivity of the question to patients); (c) analysing for a satisfactory peak HR response to exercise (given the importance of chronotropic response to predicting perioperative complications[23] and longevity[24]); or (d) adding ASA physical status (allowing comorbid disease to be factored into the score). All statistical analyses were conducted using MedCalc Statistical Software (version 18.11.3, Ostend, Belgium) and SPSS for Windows (version 23, IBM, Chicago, IL, USA), taking a two-sided alpha-error <0.05 as statistically significant.

Table 1 Anaerobic threshold: multivariable logistic regression assessing the relative importance of each Duke Activity Status Index (DASI) question in predicting AT>11 ml kg–^{1} min–^{1}

Questions	Odds ratio (95% confidence interval)	P-value
1. Are you able to take care of yourself?	0.82 (0.25–2.68)	0.74
2. Are you able to walk indoors?	0.62 (0.14–2.67)	0.52
3. Are you able to walk a block or two on level ground?	1.42 (0.69–2.91)	0.34
4. Are you able to climb a flight of stairs or walk up a hill?	***1.91 (1.07–3.41)***	***0.03***
5. Are you able to run a short distance?	0.91 (0.69–1.21)	0.53
6. Are you able to do light work around the house?	0.96 (0.35–2.67)	0.94
7. Are you able to do moderate work around the house?	1.08 (0.63–1.85)	0.78
8. Are you able to do heavy work around the house?	***1.73 (1.29–2.33)***	***<0.01***
9. Are you able to do yard work?	***1.62 (1.17–2.25)***	***0.04***
10. Are you able to have sexual relations?	***1.72 (1.34–2.21)***	***<0.01***
11. Are you able to participate in moderate recreational activities?	0.95 (0.71–1.27)	0.729
12. Are you able to participate in strenuous sports?	***1.38 (1.06–1.79)***	***0.02***

Peak VO_2: multivariable logistic regression assessing the relative importance of each DASI question in predicting pVO_2>16 ml kg–^{1} min–^{1}. The four questions that are significantly associated with peak VO_2 peak>16 ml kg^{-1} min^{-1} are shown in bold and italics.

Results

Of 1455 patients in the METS study who had completed a CPET assessment, fewer than 5% had missing data (Fig. 1). The cohort had a median participant age of 65 (inter-quartile range=57–72) years, two-thirds were ASA physical status 1 or 2, and level of functional capacity characterised by mean AT of 12.6 (standard deviation 4.1) ml kg^{-1} min^{-1}and mean VO_2 peak of 19.2 (standard deviation 6.5) ml kg-1 min-1, with 63.7% of patients achieving VO_2 peak>16 ml kg^{-1} min^{-1} during CPET. Patients who did not achieve a satisfactory AT (47%) or VO_2 peak (36.3%) were more likely to be older males, with higher BMI and higher ASA physical status, and correspondingly lower DASI scores (P=0.001; Supplementary Tables S1 and S2).

With the exception of the question '*Are you able to walk indoors?*' in relation to measured AT, the responses to all other 11 questions in the DASI questionnaire were significantly

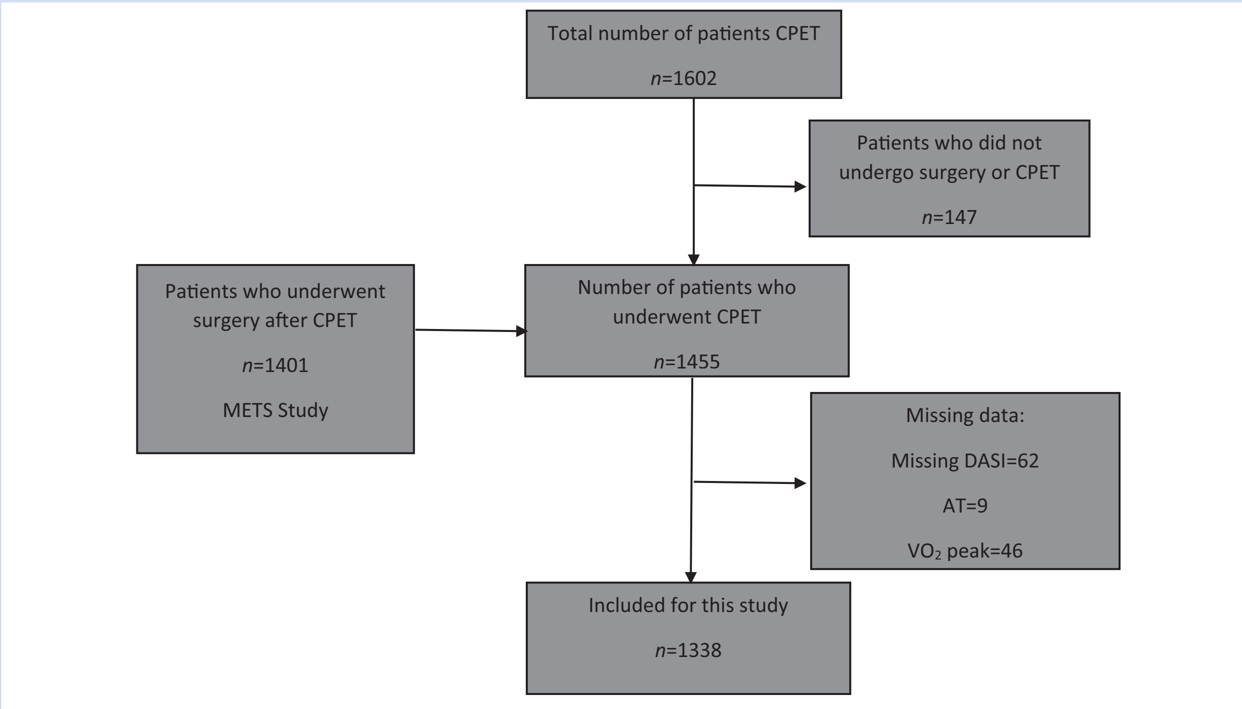

Fig 1. CONSORT diagram. AT, anaerobic threshold; CPET, cardiopulmonary exercise testing; DASI, Duke Activity Status Index; METS, Measurement of Exercise Tolerance before Surgery; VO_2, oxygen consumption.

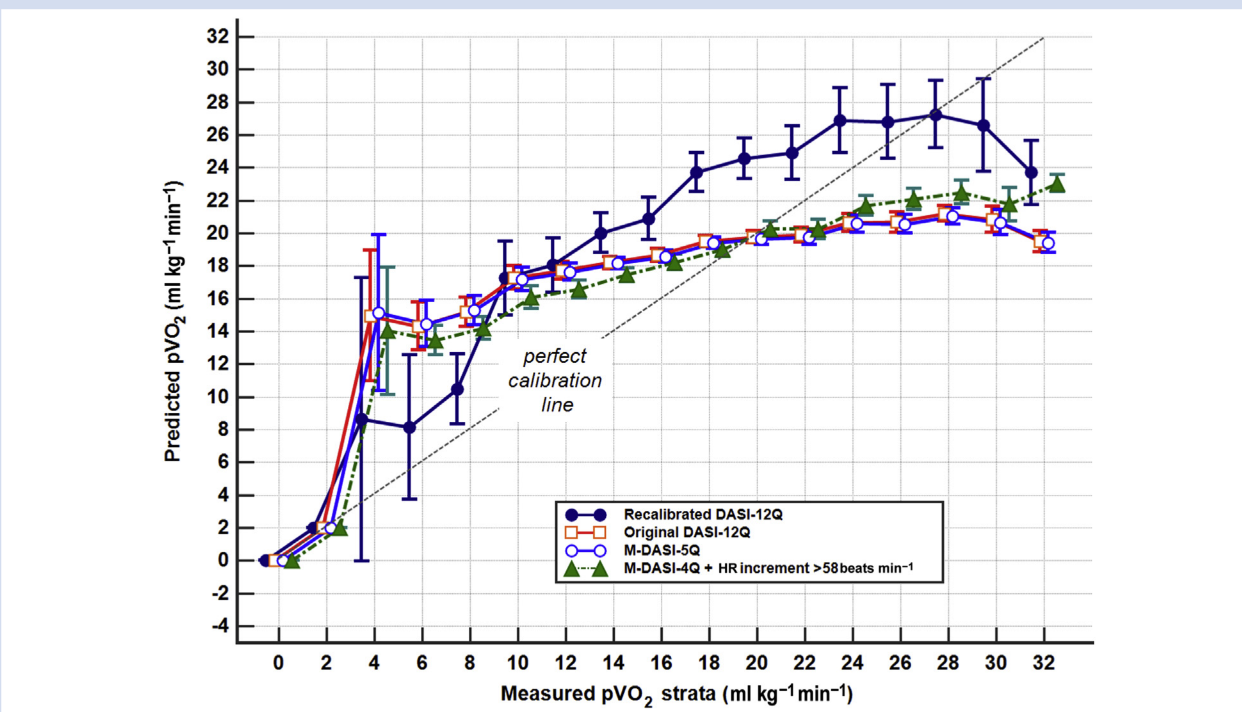

Fig 2. Relationships between pVO_2 (ml kg^{-1} min^{-1}) predicted by the original DASI, recalibrated DASI-12Q, M-DASI-5Q, or M-DASI-4Q with HR increment >58 beats min^{-1} models and the measured pVO_2 (ml kg^{-1} min^{-1}). DASI, Duke Activity Status Index; pVO_2, peak oxygen consumption.

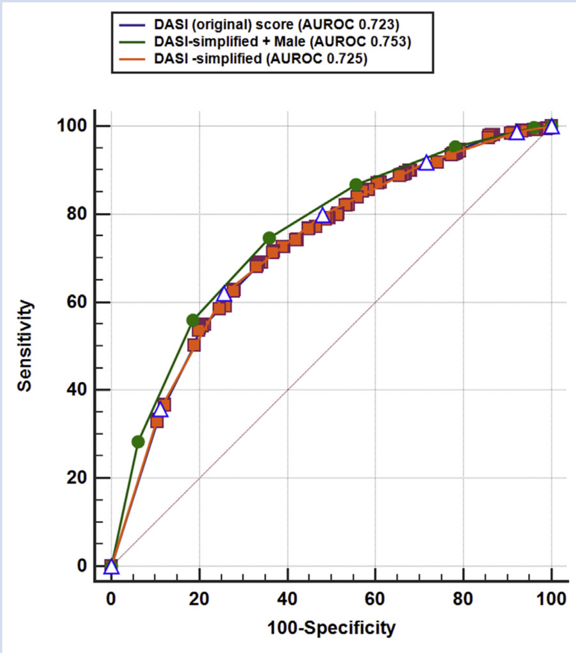

Fig 3. Peak VO_2: area under the receiver-operating-characteristic (AUROC) of original DASI model, modified DASI (M-DASI-5Q) (one point for each of the most important five questions only), or M-DASI-5Qsex (with male adding one extra point) to predict peak oxygen consumption (pVO_2) >16 ml kg^{-1} min^{-1} on cardiopulmonary exercise testing. DASI, Duke Activity Status Index.

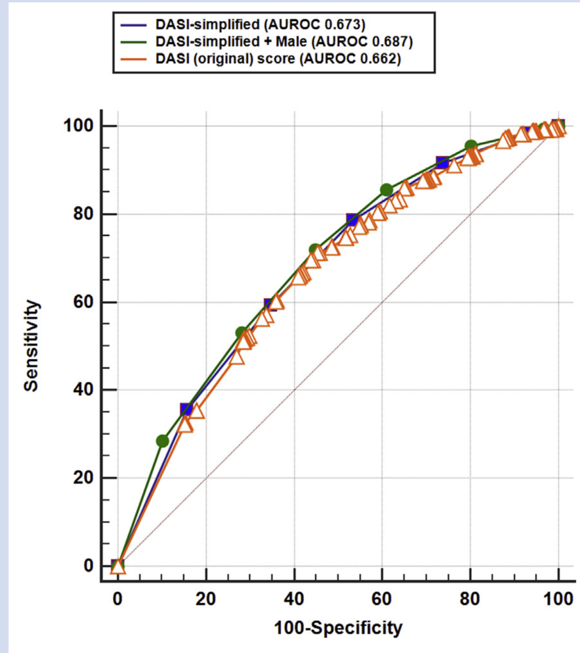

Fig 4. Anaerobic threshold: area under the receiver-operating-characteristic (AUROC) of DASI original model, simplified or modified DASI (M-DASI) (one point for each of the most important five questions only), or M-DASI-5Q-sex (with male adding one extra point) to predict anaerobic threshold (AT) >11 ml kg^{-1} min^{-1} on cardiopulmonary exercise testing. DASI, Duke Activity Status Index.

different between those with and without satisfactory functional capacity as measured by CPET. The calibration curve showed that the DASI predicted VO_2 peak significantly overestimated the measured VO_2 peak for those with VO_2 peak<20 ml kg^{-1} min^{-1}, but significantly underestimated the measured VO_2 peak for those with VO_2 peak>20 ml kg^{-1} min^{-1} (Fig. 2). Recalibrating the weights of the 12 DASI questions improved the calibration of the prediction (predicted VO_2 peak=13.1+2.1×stairs+1.3×heavy housework+1.9×yardwork+1.8×sexual relations+2.3×strenuous exercise−0.1×take care of self−0.9×walk indoors+1×walk 200 yards+0.8×run short distance−0.2×light housework−0.1×moderate housework−0.3×moderate recreational activities). The recalibrated equation showed that the ability to take care of self, walk indoors, do light or moderate housework, and moderate recreational activities were negatively associated with the measured VO_2 peak, suggesting that any positive responses to these five questions were not useful and, indeed, could lead to overestimation of the measured VO_2 peak (Appendix 1).

Five (out of the 12) DASI questions were identified to have dominance in predicting a satisfactory exercise capacity (AT>11 ml kg^{-1} $min^{-1}$and VO_2 peak>16 ml kg^{-1} min^{-1}; Table 1), with *similar* adjusted odds ratios in association with a satisfactory AT or VO_2 peak value. A modified DASI (M-DASI) model was thus constructed by assigning equal weights to these five dominant questions (M-DASI-5Q; with one point assigned per positive response to each of the five questions: maximum score is 5 and minimum score is 0).

The bar charts in Figs. 2 and 3 represent the probability of achieving an AT>11 ml kg^{-1} min^{-1} and VO_2 peak>16 ml kg^{-1} min^{-1} during CPET in relation to the number of positive responses to the five dominant DASI questions. For example, if a patient reported the ability to perform four out of five M-DASI tasks, the probability to achieve an AT>11 ml kg^{-1} min^{-1} and VO_2 peak>16 ml kg^{-1} min^{-1} during CPET would be 58.7% (95% CI 53.1–64.0) and 76.1% (95% CI 71.0–80.5), respectively. Conversely, if a patient could not perform any of the five M-DASI tasks, the probability of achieving an AT>11 ml kg^{-1} min^{-1} and VO_2 peak>16 ml kg^{-1} min^{-1} during CPET would only be 20% (95% CI 11.8–31.8) and 23% (95% CI 13.7–36.1), respectively.

By removing DASI questions that were not positively associated with the measured VO_2 peak, the M-DASI-5Q had a similar discriminative power as the original 12-question DASI model in predicting (1) VO_2 peak (AUROC-VO_2 peak: M-DASI-5Q 0.73 *vs* original 12 question DASI 0.71; Fig. 3), and (2) AT>11 ml kg^{-1} min^{-1} (AUROC-AT: M-DASI-5Q=0.67 *vs* original 12-question DASI=0.66; Fig. 4).

The M-DASI could be further improved by incorporating gender (M-DASI-5Q-sex; assigning males one additional point), but the increment in its discrimination ability was relatively small and will unlikely improve clinical utility. Conversely, removing the question related to ability to have sexual relations (i.e. M-DASI-4Q) did not substantially affect its ability to predict AT>11 ml kg^{-1} min^{-1} (AUROC 0.66, 95% CI 0.63–0.69) and VO_2 peak>16 ml kg^{-1} min^{-1} (AUROC 0.71, 95%

CI 0.69–0.74) compared with the original 12-question DASI model (Table 2).

The optimal HR increment from baseline to discriminate between those with a satisfactory and unsatisfactory VO_2 peak was 58 (95% CI 56–62) beats min^{-1}, with a sensitivity of 59.3% and specificity of 81.5%. Combining four DASI questions (M-DASI-4Q) with the ability to mount a peak HR response of >58 beats min^{-1} compared with baseline further improved its ability to discriminate between patients who achieved a VO_2 peak>16 ml kg^{-1} min^{-1} and those with a VO_2 peak<16 ml kg^{-1} min^{-1} (AUROC 0.78, 95% CI 0.76–0.80). Combining ASA physical status score with M-DASI-4Q did not improve the performance of the model compared with the original DASI (difference in AUROC-VO_2 peak: 0.01, 95% CI −0.01 to 0.02) (Table 2). Only the recalibrated 12-question DASI (AUROC 0.59, 95% CI 0.51–0.69) and the M-DASI-4Q with HR response >58 beats min^{-1} (AUROC 0.60, 95% CI 0.51–0.69) were significantly predictive of 1-yr mortality.

Discussion

The modified four-question DASI (M-DASI-4Q) provides an equivalent ability to predict VO_2 peak compared with the original DASI, although this does not translate to predicting postoperative outcomes. Gender and peak HR response of >58 beats min^{-1} all marginally improved the ability to discriminate VO_2 peak>16 ml kg^{-1} min^{-1} and AT>11 ml kg^{-1} min^{-1}.

Strengths and limitations

Our study is the largest, heterogenous, sample size study to date to assess and recalibrate the relationship between the DASI and VO_2 peak. Prior uses of the DASI have been based on small population studies and have had limited validation for use in surgical cohorts, therefore this study is likely to provide invaluable information to clinicians. However, there are a number of limitations. First, although the M-DASI is easy to use, as with all surveys or questionnaires, all the M-DASI questions can still be subjected to misinterpretation. Further study is thus needed to validate the accuracy of M-DASI externally and to confirm the utility of combining M-DASI with HR responses to exercise. Second, we did not assess whether M-DASI would be as good as the original DASI or CPET findings in predicting postoperative complications. Third, factors affecting the internal validity of the measured AT and VO_2 peak in the original METS study may introduce error into our study. Such factors include: (1) the AT calculation lends itself to substantial interobserver variation, and in the METS study this value was not centrally adjudicated; and (2) VO_2 peak is highly dependent on patient volition. Fourth, the original METS study included patients who were relatively young (median age 65 yr), healthy (two-thirds had ASA physical status <3), fit (two-thirds had VO_2 peak>16 ml kg^{-1} min^{-1}, with a mean VO_2 peak of 19 ml kg^{-1} min^{-1}), and an inherent potential bias toward recruiting patients with a willingness to exercise (with only one-third of eligible patients consenting to recruitment). As such, studies are needed to validate the utility of the M-DASI as a screening tool in older patients or those with significant multiple comorbidities scheduled for major noncardiac surgery.

Differences in prior literature

Our findings are similar to previous results obtained in small cohort studies (n=50, abdominal surgery[12]; n=43, intracavity cancer surgery[13]), in which the DASI was a reasonably sensitive and specific predictor of AT (≥11 ml kg^{-1} min^{-1}: AUROC 0.767, 95% CI 0.630–0.994; P=0.0002) and VO_2 peak (>15 ml kg^{-1} min^{-1}: AUROC 0.765, 95% CI 0.620–0.900; P=0.002).[12] Owing to our larger sample size using the METS study dataset[14] our results have increased precision as reflected by the narrower CIs.

Discriminatory ability of individual DASI questions

We noted that there were some discrepancies in patient interpretation of the DASI questions, with positive responses

Table 2 Comparison of the area under the receiver-operating-characteristic (AUROC) curves for the original Duke Activity Score Index (DASI) model and the modified versions of the DASI (M-DASI) to predict preoperative functional capacity as measured by cardiopulmonary exercise testing in the Measurement of Exercise Tolerance before Surgery (METS) study

	AUROC-AT: for predicting AT>11 ml kg^{-1} min^{-1}	Difference in AUROC-AT compared with the original DASI	AUROC-pVO_2: for predicting pVO_2>16 ml kg^{-1} min^{-1}	Difference in AUROC-pVO_2 compared with the original DASI
Original DASI (12 questions weighted)	0.66	Reference	0.71	Reference
Modified DASI-5Q (5 questions only unweighted)	0.67	0.01 (95% CI 0.006–0.022)	0.73	0.04 (95% CI 0.03–0.05)
Modified DASI-5Q-sex (5 questions unweighted+male sex)	0.69	0.03 (95% CI 0.01–0.04)	0.76	0.05 (95% CI 0.04–0.07)
Modified DASI-4Q (removing the question on ability to have sexual relations from the modified DASI-5Q)	0.66	0.001 (95% CI −0.01 to 0.01)	0.71	0.01 (95% CI −0.01 to 0.02)
Modified DASI-4Q-sex (Modified DASI-4Q+male sex)	0.68	0.02 (95% CI 0.002–0.037)	0.75	0.03 (95% CI 0.01–0.05)
Modified DASI-4Q + ASA physical status	0.66	0.02 (95% CI 0.001–0.03)	0.71	0.01 (95% CI −0.01 to 0.02)
Modified DASI-4Q + HR increment (Modified DASI-4Q+ability to achieve peak HR>58 beats min^{-1} from baseline)	0.69	0.04 (95% CI 0.02–0.07)	0.78	0.06 (95% CI 0.04–0.08)

AT, anaerobic threshold; CI, confidence interval; pVO_2, peak oxygen consumption. The four questions that are significantly associated with peak VO_2 peak>16 ml kg^{-1} min^{-1} are shown in bold and italics.

to some more demanding exercise tasks while giving negative responses to some less demanding tasks. This explained why positive responses to five questions on least demanding exercise tasks were associated with a reduction in measured VO_2 peak. This may, at least in part, explain why a simplified version of the DASI was as good as the original DASI model. A simplified DASI would improve ease of administration, compliance, and possibly validity by focusing on the most discriminative questions related to moderate and intense activities, which are less likely to be misinterpreted. A single question (ability to climb one flight of stairs), often used during preoperative assessment of patients, had low predictive ability (AUROC=0.55 for VO_2 peak>16 ml kg^{-1} min^{-1}), which emphasises the need to qualify functional status using multiple questions (e.g. four or five questions) for validity.

Rationale for the M-DASI-4Q

Although the accuracy of M-DASI was improved by incorporating patient gender into the model, the improvement was only marginal and unlikely to add clinically important value. Taking into consideration that the cut-points of AT and VO_2 peak may be applicable equally to females and males,[19] we suggest that the M-DASI without patient gender is the preferred version of the simplified DASI and potentially may have good clinical utility. Our results also showed that eliminating the potentially sensitive question on sexual relations did not substantially weaken the discriminative ability of the M-DASI. However, combining a satisfactory HR response with the four-question M-DASI (M-DASI-4Q) did improve the discriminative ability, suggesting that there is potential in combining HR responses to exercise, which could be elicited without formal CPET testing, with a simple four-questionnaire DASI in assessing exercise capacity before surgery.

Utility of the DASI questionnaire in predicting postoperative outcomes

Poor preoperative functional capacity is associated with adverse postoperative outcomes after various types of noncardiac surgery, including in the recent METS study.[14,23,25–28] Accurate assessment of functional capacity for risk stratification is crucial in preoperative work-up, patient optimisation (e.g. prehabilitation), and level of dependence planning postoperatively (e.g. postoperative high dependency unit/ICU *vs* surgical ward destination). Although DASI has been validated to be a reliable functional assessment tool in patients with cardiac, chronic respiratory, and renal diseases,[28–30] evidence supporting its role in surgical patients before the METS study is limited. A secondary analysis of the same METS data set suggests that a cutpoint at a score of 34 may represent a threshold for identifying patients at risk for myocardial injury, myocardial infarction, moderate-to-severe complications, and new disability (ref BJA 2020 - PMID; 31864719). Our sub-study suggests that a modified DASI could be linked to 1-yr mortality. This improved discriminatory ability of the DASI is likely attributable to known surgical morbidity associated with impaired HR response[23] and general cardiovascular mortality.[29] Similarly, a recalibrated DASI score was also associated with 1-yr mortality, suggesting that the DASI has an intrinsic ability to discriminate between potential survivors and non-survivors.

Utility of the M-DASI-4Q in prehabilitation

Prehabilitation before major surgery uses a multimodal approach, including a structured exercise program, and nutritional, haematinic, and psychological support, to optimise modifiable risk, including preoperative deconditioning, to mitigate physiological stress perioperatively to achieve better outcome and earlier recovery.[30–33] The evidence of prehabilitation on functional capacity and postoperative outcome is conflicting.[32,34,35] Despite improvement in preoperative functional capacity, older studies failed to show a statistically significant difference in postoperative complications.[33,36,37] Conversely, recent published RCTs report halving of postoperative complications in the prehabilitation arms.[34,38] Studies of prehabilitation also report improved patient well-being,[34] ability to sustain functional capacity during neoadjuvant chemoradiotherapy, improved fitness before surgery,[30,33] reduced postoperative complications,[30] and recently intriguing findings of augmented pathological tumour regression.[39] Identifying higher risk groups through formal CPET testing is resource intensive. Because discrepancies between patients' own assessment and their real exercise capacity often exist,[40] using the M-DASI as a screening tool supplemented by field walk tests, such as the six-minute walk test or the incremental shuttle walk test, may further improve the accuracy of the assessment of functional capacity and outcomes.[41–43] The M-DASI and standardised field walking tests are easy to perform/administer, cost-effective, and may provide high clinical utility as screening tools before CPET.

M-DASI-4Q in screening for CPET

CPET remains the gold standard in evaluating overall exercise capacity.[10,44] Results obtained from CPET are highly reproducible[45–47] and predictive of postoperative complications across different surgical subspecialties.[6,7] Although the METS study failed to show good utility of CPET as a predictor of the composite of myocardial infarction and death within 30 days postoperatively, it was a reasonable predictor of all-cause postoperative morbidity.[14] A recent survey from the UK highlighted that a substantial proportion of centres without CPET had tried and failed to set up such services because of insufficient funding,[38] notwithstanding the evidence that hospitals with CPET services appeared to have improved postoperative outcomes including 18% reduction (relative risk 0.82, 95% CI 0.70–0.96, P=0.0157) in 90-day mortality associated with centres that had onsite CPET facilities.[48] The M-DASI should not be considered as a replacement for CPET (unless such resources are not available) but rather as a triage tool for those patients who would benefit from a more formal assessment using field walking tests or CPET. Importantly, CPET has the added benefit of a diagnostic component to discriminate the underlying cause of exercise limitation.

Conclusions

Accurate assessment of preoperative functional capacity is crucial in risk stratification and determining the level of perioperative support required for patients undergoing major surgery. Both the original and modified DASI (M-DASI) have a reasonable ability to discriminate between patients with and without satisfactory functional capacity as defined by AT>11 ml kg^{-1} min^{-1} and VO_2 peak>16 ml kg^{-1} min^{-1} (AUROC>0.70). In centres where resources to provide CPET are limited, the M-

DASI-4Q with and without peak HR response may serve as a screening tool to select the most appropriate patients for referral for CPET for objective assessment of functional capacity. Further research is needed to confirm whether M-DASI with and without HR responses to exercise is as accurate as CPET parameters in predicting postoperative outcomes, especially in older deconditioned individuals.

Authors' contributions

Study design: BR, HI, KMH, BHC, DW
Manuscript writing: BR, HI, MHGL, CHAL, KMH, BHC, DW
Data management: MHGL
Data interpretation: CHAL, BHC, DW
Data analysis: KMH
Data collection: BHC, DW

Declarations of interest

The authors declare that they have no conflicts of interest.

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Appendix. METS study collaborators listing

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Appendix A. Supplementary data

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