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Physical fitness after myocardial infarction compared with clinical reference values: a SWEDEHEART registry study

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ABSTRACT

Purpose The primary aim of this study was to describe physical fitness in a large real-world cohort of patients entering exercise-based cardiac rehabilitation (EBCR) after first-time myocardial infarction (MI). The secondary aim was to compare the results with clinical reference values.

Methods This registry-based cohort study used data from the Swedish Web-system for Enhancement and Development of Evidence-based care in Heart Disease Evaluated According to Recommended Therapies (SWEDEHEART) post-MI registry between 2016 and 2019. Patients with first-time MI who underwent physiotherapist-led assessments of physical fitness at EBCR entry were included. Exercise capacity was evaluated by a symptom-limited cycle ergometer test and muscular endurance by a unilateral heel-rise test. Results were compared with age-stratified and sex-stratified clinical reference values. Reference values for exercise capacity were based on the Swedish Kalmar dataset, the national standard reference in Sweden since 2014, and reference values for heel-rise performance were based on a Swedish normative dataset of healthy adults.

Results A total of 15 105 patients (mean age 62.5±9.1 years, 78.4% men) were included. Exercise capacity (Watt max from the exercise test) was higher in men than women across age groups, and muscular endurance declined with age, with a steeper age-related decline in women's heel rise performance. The mean exercise capacity of the study population corresponded to 64.7±27.4% of predicted values in men and 68.4±18.9% in women. Muscular endurance averaged 78.4%±51.0% of reference values in men and 61.7%±43.2% in women.

Conclusion At EBCR entry after a first-time MI, both exercise capacity and muscular endurance were substantially below age-specific and sex-specific reference values. These results underscore the importance of systematic baseline assessments and tailored rehabilitation interventions targeting both exercise capacity and muscular endurance.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Reduced physical fitness after myocardial infarction is common and is an important target in secondary prevention. Baseline exercise testing is recommended to support risk stratification and tailored exercise prescription. Yet, it remains unclear how large the fitness deficits are at entry to exercise-based cardiac rehabilitation and how these compare with clinical reference values.

WHAT THIS STUDY ADDS

⇒ In this nationwide Swedish Web-system for Enhancement and Development of Evidence-based care in Heart Disease Evaluated According to Recommended Therapies (SWEDEHEART) cohort, patients who entered exercise-based cardiac rehabilitation after myocardial infarction had markedly reduced exercise capacity and muscular endurance compared with reference values. The study provides age and sex specific descriptions of these deficits from routine clinical practice.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings provide clinically useful benchmarks for physical fitness at entry to exercise-based cardiac rehabilitation after myocardial infarction and highlight substantial deficits and wide variation in both exercise capacity and muscular endurance for men and women. Symptom-limited cycle ergometry and the heel rise test are feasible assessments that can support tailored exercise prescription and identify patients needing closer support.

INTRODUCTION

Cardiovascular diseases (CVD), including acute myocardial infarction (MI), are the leading cause of morbidity and mortality worldwide.[1] Although mortality rates following acute MI have declined, the risk of recurrent events remains high.[2]

Given this heightened residual risk, comprehensive strategies to improve prognosis are essential. Cardiac rehabilitation (CR) is one such evidence-based intervention, supported by both the European Society of Cardiology and the American Heart Association.[3 4] CR includes several core components; for example, risk factor management, patient education, psychosocial support and exercise training, with the latter consistently defined as a central component.[4] Exercise-based CR (EBCR), including both aerobic and muscle strength exercises, has been shown to reduce the risk of CVD mortality, hospital readmissions and recurrent MI.[5] Effective and safe EBCR requires baseline assessment of physical fitness, followed by individually prescribed exercise within a supervised, structured programme.[4 6] The central role of exercise training within CR reflects the strong prognostic value of physical fitness. In healthy populations, both exercise capacity and muscular performance vary by age and sex.[7–9] After MI, physical fitness may be further reduced due to a combination of pre-existing low fitness and additional disease-related limitations in the early recovery period.[10 11] Still, there is limited knowledge of how these patients perform in relation to age-specific and sex-specific clinical reference values when entering EBCR. Multiple studies have established physical fitness, including cardiorespiratory fitness (CRF), often quantified as peak oxygen uptake, as a strong predictor of CVD mortality in both healthy adults and those with a history of MI.[12–14] Importantly, improvements in CRF are associated with reduced mortality risk, regardless of baseline fitness or CVD disease status.[13] In routine clinical practice, gas exchange measurements are rarely available. Instead, exercise capacity is characterised using symptom-limited peak work rate (maximal Watts, Wmax) obtained during cycle ergometry, alongside tests of muscular endurance. Large real-world observations describing physical fitness among patients entering EBCR after MI, using routine clinical testing and interpreting results against clinical reference values, remain limited.

Although reduced physical fitness after MI is well recognised, there is still limited knowledge of how patients entering EBCR perform in relation to clinical reference values. Previous studies have often focused on selected populations, a single aspect of physical fitness or absolute exercise capacity measures without comparison with age-specific and sex-specific expected values. A better understanding of the magnitude of impairment at EBCR entry may improve clinical assessment, goal-setting and interpretation of test results in routine care. The primary aim of this study was to describe physical fitness in a large real-world cohort of patients entering EBCR after MI. The secondary aim was to compare these results with clinical reference values.

METHODS

Data sources

This cohort study is based on data from the Swedish Websystem for Enhancement and Development of Evidence-based care in Heart Disease Evaluated According to Recommended Therapies (SWEDEHEART) registry, including patients between 1 January 2016 and 31 December 2019.[15] SWEDEHEART consists of several subregistries, including SWEDEHEART-acute coronary syndrome (ACS) which collects data related to the acute phase of care post-MI, and SWEDEHEART-CR which includes data on secondary prevention.[16] In the assessment of physical fitness, physiotherapists register a symptom-limited cycle ergometer exercise test and a unilateral heel-rise test at the start and end of EBCR. In clinical practice, an additional shoulder flexion test is included but was not analysed in the present study due to the lack of reference values. Both SWEDEHEART-ACS and SWEDEHEART-CR have a centre-level coverage of 100%. SWEDEHEART-CR has patient-level coverage exceeding 75%.[17] Data quality in SWEDEHEART has been assessed through serial nationwide audits against electronic medical records. In the most recent published audit, SWEDEHEART-CR showed high overall data completeness (94.5%) and accuracy (95.8%).[18] Socioeconomic data, including educational attainment, income, marital status and region of birth, were obtained from the Statistics Sweden registry.

Reference values

Clinical reference values for exercise capacity were drawn from the Swedish ‘Kalmar dataset’, comprised of 1790 individuals referred for exercise testing, with no cardioactive medication and no cardiopulmonary symptoms during testing, reaching at least 15 on the Borg rating of perceived exertion (RPE) scale, that is, normal outcome. The Kalmar dataset has served as the national standard reference for exercise testing in Sweden since 2014.[19] Clinical reference values for muscular endurance were derived from a Swedish dataset (n=566) containing normative values for heel raises among healthy adults.[20]

Study population

Inclusion criteria were registration in SWEDEHEART between 1 January 2016 and 31 December 2019 and a first-time diagnosis of acute MI type 1 coded as I21 according to the International Classification of Diseases, 10th revision. Until 31 December 2018, the eligible age range in SWEDEHEART-CR was 18–74 years; from 1 January 2019 to 31 December 2019 it was extended to 18–79 years. The exclusion criterion was Borg RPE<15 at the end of the cycle ergometer exercise test, since such tests were considered unlikely to provide a valid estimate of exercise capacity (eg, premature termination due to symptoms, pain or other non-fitness limiting factors).

Procedures

Exercise capacity was assessed during the first physiotherapist visit after hospital discharge, using a cycle ergometer exercise test following the WHO protocol,[21] with a stepwise work rate increase of 25 Watts (W) every 4.5 min.[22] The initial work rate, either 25 W or 50 W, was individualised based on the patient’s self-reported previous activity level. Heart rate and blood pressure were monitored at regular intervals throughout the test, and the patient was asked to rate the exertion[23] at each work rate stage. The test was intended to be symptom-limited. For safety reasons, RPE 17 was used as a termination criterion. Additional termination criteria followed a standardised Swedish clinical routine for symptom-limited bicycle exercise testing, broadly aligned with established guidelines.[24] Only participants who rated perceived exertion ≥15 at test termination were included in the study. Tests stopped at lower exercise intensities due to limiting symptoms (eg, chest discomfort, musculoskeletal pain or other patient-related reasons) were thus not included. Peak work rate in W and the duration of the final stage (minutes and seconds) were recorded and combined to define Wmax according to the Strandell formula[22] as maximal power=submaximal power + (25×d/4.5), where submaximal power is the workload preceding the final, uncompleted stage and *d* is the number of minutes completed at the final workload. Although the achieved workload is more accurately described as peak workload rather than a true maximal value, the results were expressed as computed Wmax to enable comparison with the reference dataset, in which this term is used. Information on equipment, calibration routines and inter-rater reliability between assessors is not available in SWEDEHEART.

Muscular endurance was assessed using a unilateral heel-rise test, as a clinical measure of lower-limb muscular endurance. The test was conducted on the patient's preferred leg, with the patient standing on one leg on a 10° tilted wedge, using light fingertip support against a wall for balance while the opposite leg was slightly elevated. After one maximal heel-rise was performed to mark the target height, the patient continued the movement at a pace of 30 repetitions per minute, guided by a metronome. The test ended when the patient could no longer reach the marked height, bent their knee or failed to keep the pace.

Detailed procedures for the tests are described elsewhere[25] and are clearly outlined in a national standardised manual used throughout Sweden, which serves as a reference for all physiotherapists conducting the assessments. Results from the physiotherapist-led assessments were documented in SWEDEHEART-CR as part of routine clinical practice.

Outcome variables

The outcome variables were exercise capacity and muscular endurance.

Conversions

The sum of the total work performed in all stages of the exercise test was calculated as an individual constant (K).[26] This enabled us to compare the results from the stage-based exercise test (Wmax) to the Swedish reference values[19] for predicted exercise capacity (predicted Wmax) as if the same test protocols had been used. The following formula was used: $\sum t_i W_i^5 = K$ where t_i represents the duration and W_i the work rate at the *i*th stage. *K* was then converted to the maximal work rate that each individual could maintain for 6 min (Wmax6' = $(K/6)^{1/5}$),[27] and subsequently re-calculated to a standard protocol with an increment of 15 W/min for men and 10 W/min for women as $(36a(\text{Wmax6'})^5)^{1/6}$, where 'a' represents the increase in work rate per minute.[28] Finally, the computed Wmax was compared with the predicted Wmax by calculating the percentage of predicted exercise capacity (computed Wmax/predicted Wmax × 100).

Statistical analysis

Continuous variables were summarised as means with SD, upper 95th and lower fifth percentiles and categorical variables as counts and percentages. To align with the underlying reference datasets, age was categorised as follows: for exercise capacity, 5-year bands of 21–25 years, 26–30 years, 31–35 years, 36–40 years, 41–45 years, 46–50 years, 51–55 years, 56–60 years, 61–65 years, 66–70 years, 71–75 years and 76–80 years were used; for muscular endurance (heel-rise) 10-year bands were used (20–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years and 70–79 years). Exercise capacity outcomes were presented as relative differences versus sex-specific and age-specific reference values (% of predicted), whereas muscular endurance was presented as absolute differences in repetitions to maximise clinical interpretability. One-sample t-tests were used to compare observed results with reference population norms stratified by sex and age. Normality within each sex and age stratum was assessed by visual inspection of distribution plots, and outliers were inspected graphically using histograms and boxplots. Given the large sample sizes, the one-sample t-test was considered robust to modest deviations from normality.

The analyses were descriptive and aimed to compare observed physical fitness with established clinical reference values. Therefore, no multivariable modelling, model selection procedures or adjustment for potential confounders were performed. Missing data were handled using an available-case approach, with no imputation performed. For the one-sample t-tests, assumptions of independence of observations and approximate normality of the outcome distributions within each sex and age stratum were evaluated. All tables and figures were generated directly from SAS using reproducible code, and the output was cross-checked to ensure consistency between raw data and reported results. All analyses were performed using SAS V.9.4 (SAS Institute, Cary, North Carolina, USA). Statistical significance was set at $p<0.05$.

Use of AI tools

Beyond standard reference searches and manual text refinement, the AI tool Research Rabbit was used to identify relevant references through network-based literature exploration, and ChatGPT and Copilot were used for translation and text editing.

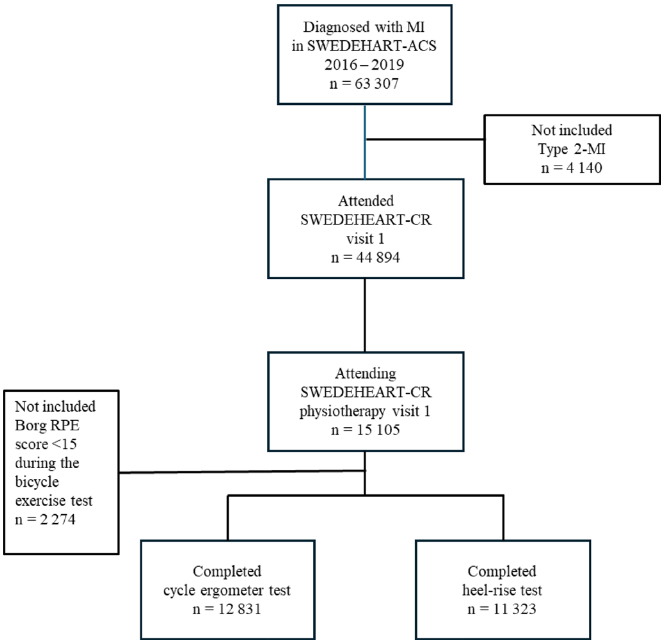

Figure 1 Study flow chart. CR, cardiac rehabilitation; MI, myocardial infarction; RPE, rating of perceived exertion; SWEDEHEART, Swedish Web-system for Enhancement and Development of Evidence-based care in Heart Disease Evaluated According to Recommended Therapies.

Patient and public involvement

Patients and members of the public were not involved in the design, conduct, reporting or dissemination plans of this registry-based study. As the study was based on routinely collected nationwide registry data, there was no direct patient or public involvement in recruitment, data collection or choice of outcome measures.

RESULTS

Out of 63 307 patients diagnosed with first-time MI during the inclusion period, n=4140 were excluded due to a diagnosis of MI type 2. n=44 894 had data registered in SWEDEHEART CR, of which 15 105 patients attended a first physiotherapy visit. Out of those attending the visit, n=12 831 completed a cycle ergometer exercise test with a rating of ≥15 on the Borg RPE scale and n=11 323 completed a heel-rise test (figure 1). The physiotherapy assessment was performed a median of 35 days after hospital discharge (Q1 21, Q3 56; table 1).

Demographics and patient characteristics

Baseline characteristics for the 12 831 included patients who completed the cycle ergometer test with Borg RPE ≥15 are summarised in table 1. The cohort had a mean age of 62.5±9.1 years and was predominantly male (78.4%). Mean BMI was 27.9±4.7 kg, and 61.1% were current or former smokers. Non-ST-elevation myocardial infarction was more common than ST-elevation myocardial infarction, and most patients had preserved left ventricular ejection fraction at discharge. Characteristics for participants with Borg RPE <15 are provided in online supplemental table S1.

Physical fitness within the study cohort

Men tended to achieve higher absolute maximal work rate (Wmax) than women in all age groups, and Wmax declined with increasing age in both sexes (figure 2, online supplemental Table S2a and b). Among men, mean Wmax ranged from 143.3±19.1 W in the youngest group (21–25 years) to 79.4±26.8 W in the oldest (76–80 years). In women, participant numbers were low in the youngest age groups; in the age groups with adequate sample size, mean Wmax declined from 40 years onwards reaching 50.0±18.2 W in the oldest age group (76–80 years). In women, participant numbers were low in the 20–39 year groups for muscular endurance tests; these groups are therefore not included in the age-pattern summary. From 40 years to 79 years, women showed a clear decline in heel-rise performance. Among men, heel-rise performance was highest in younger ages, remained largely stable through midlife and was lower in the oldest groups (tables 2 and 3).

Reference comparison

The mean exercise capacity (expressed as computed Wmax) of the study population corresponded to 64.7±27.4% of the predicted value in men and 68.4±18.9% in women, respectively (figure 3a, b, online supplemental table S3a and b). The relative exercise capacity per age stratum in men and women are presented in tables 4 and 5. Women in the EBCR population had higher relative exercise capacity than men across most age groups. A cumulative distribution plot of % predicted Wmax showed that most patients in both sexes had values below 100% of predicted Wmax, with a slight rightward shift in women compared with men (figure 4).

Heel-rise performance, expressed as absolute number of repetitions, was consistently lower than the sex- and age-specific reference across all strata. Mean performance was 15.3±9.4 repetitions in men and 11.9±8.3 in women, corresponding to 78.4%±51.0% and 61.7%±43.2% of the reference values, respectively. In men, mean repetitions declined from 21.6±8.1 (20–29 years) to 12.9±9.6 (70–79 years), with absolute deficits when compared with references ranging from −15.9 to −1.6 repetitions (all $p<0.05$). In women, small sample sizes in the 20–39 year strata warrant caution; from 40 years to 79 years, mean repetitions declined from 16.1±8.4 to 9.7±8.1, with absolute deficits ranging from −17.4 to −6.7 repetitions (all $p<0.05$) (tables 4 and 5).

DISCUSSION

In our nationwide registry-based study, patients entering EBCR after MI showed markedly reduced physical fitness compared with clinical reference values. This pattern was seen both for exercise capacity and for lower-limb muscular endurance, indicating that reduced physical fitness at rehabilitation entry is not limited

Table 1 Baseline characteristics at index hospitalisation

	Statistics	Women n=2769	Men n=10 062	Total n=12 831
Age, years	n	2769	10 062	12 831
	Mean (SD)	63.7 (8.8)	62.2 (9.2)	62.5 (9.1)
Country or region of birth	Sweden	2374 (85.7%)	8346 (83.0%)	10 720 (83.6%)
	Scandinavia except Sweden	150 (5.4%)	331 (3.3%)	481 (3.7%)
	EU except Scandinavia	94 (3.4%)	308 (3.1%)	402 (3.1%)
	Europe except Scandinavia and EU	73 (2.6%)	387 (3.8%)	460 (3.6%)
	Outside of Europe	78 (2.8%)	688 (6.8%)	766 (6.0%)
Employment status	Working	987 (38.1%)	4818 (51.4%)	5805 (48.5%)
	On sick leave	121 (4.7%)	205 (2.2%)	326 (2.7%)
	Unemployed	41 (1.6%)	175 (1.9%)	216 (1.8%)
	Retired	1432 (55.2%)	4101 (43.7%)	5533 (46.2%)
	Student/other	12 (0.50%)	79 (0.80%)	91 (0.80%)
Education level	Primary school education <9 years	227 (8.2%)	1046 (10.5%)	1273 (10.0%)
	Primary school education 9 years	308 (11.2%)	1314 (13.2%)	1622 (12.7%)
	Secondary education	1447 (52.5%)	4778 (47.9%)	6225 (48.9%)
	Post-secondary education/postgraduate education	773 (28.1%)	2843 (28.5%)	3616 (28.4%)
Household disposable income category	Low	409 (14.8%)	2116 (21.1%)	2525 (19.7%)
	Medium	883 (31.9%)	3173 (31.6%)	4056 (31.7%)
	High	1475 (53.3%)	4748 (47.3%)	6223 (48.6%)
Married or living with a partner	Co-habiting	1490 (53.8%)	6102 (60.8%)	7592 (59.3%)
	No partner/divorced/widow/widower	1277 (46.2%)	3935 (39.2%)	5212 (40.7%)
Smoking status	Current smoker	778 (28.7%)	2138 (21.8%)	2916 (23.3%)
	Former smoker	892 (32.9%)	3688 (37.5%)	4580 (36.5%)
	Never smoked	1043 (38.4%)	3998 (40.7%)	5041 (40.2%)
BMI, kg/m²	n	2689	9748	12 437
	Mean (SD)	27.7 (5.4)	27.9 (4.2)	27.9 (4.5)
Systolic blood pressure, mm Hg	n	2769	10 044	12 813
	Mean (SD)	153.0 (28.3)	151.2 (26.1)	151.6 (26.6)
Diastolic blood pressure, mm Hg	n	2706	9756	12 462
	Mean (SD)	87.2 (15.9)	89.9 (15.6)	89.3 (15.7)
LDL-cholesterol, mmol/L	n	2540	9265	11 805
	Mean (SD)	3.2 (1.2)	3.1 (1.1)	3.1 (1.1)
Creatinine, µmol/L	n	2761	10 041	12 802
	Mean (SD)	68.1 (31.3)	85.6 (34.4)	81.8 (34.5)
PCI or CABG before index hospitalisation	Yes	252 (9.1%)	1534 (15.2%)	1786 (13.9%)
Hypertension	Yes	571 (20.6%)	2022 (20.1%)	2593 (20.2%)
Previous stroke	Yes	102 (3.7%)	345 (3.4%)	447 (3.5%)
Diabetes mellitus	Yes	481 (17.4%)	1915 (19.0%)	2396 (18.7%)
Betablocker at discharge	Yes	2335 (84.4%)	8239 (81.9%)	10 574 (82.4%)
Statins at discharge	Yes	2678 (96.7%)	9881 (98.2%)	12 559 (97.9%)
ACEi/ARB at discharge	Yes	2320 (83.8%)	8618 (85.7%)	10 938 (85.3%)

Continued

Table 1 Continued

	Statistics	Women n=2769	Men n=10 062	Total n=12 831
LVEF	Normal (≥50%)	1905 (73.4%)	6479 (69.1%)	8384 (70.1%)
	Slightly reduced (40–49%)	490 (18.9%)	1974 (21.1%)	2464 (20.6%)
	Moderately reduced (30–39%)	170 (6.5%)	759 (8.1%)	929 (7.8%)
	Severely reduced (<30%)	31 (1.2%)	160 (1.7%)	191 (1.6%)
Type of MI	NSTEMI	1667 (60.2%)	5717 (56.8%)	7384 (57.5%)
	STEMI	1102 (39.8%)	4345 (43.2%)	5447 (42.5%)
Distance to CR centre, km	n	2769	10 062	12 831
	Mean (SD)	16.6 (8.5)	16.7 (8.3)	16.7 (8.3)
Peak RPE (Borg)	15	859 (31.0%)	2171 (21.6%)	3030 (23.6%)
	16	363 (13.1%)	1850 (18.4%)	2213 (17.2%)
	17	1462 (52.8%)	5592 (55.6%)	7054 (55.0%)
	18	51 (1.8%)	359 (3.6%)	410 (3.2%)
	19	31 (1.1%)	82 (0.8%)	113 (0.9%)
	20	3 (0.1%)	8 (0.1%)	11 (0.1%)
Time between discharge and first physiotherapy visit, days	n	2761	10 029	12 790
	Mean (SD)	46.20 (38.1)	45.17 (38.2)	45.39 (38.2)
	Median (IQR)	35.0 (22.0–57.0)	34.0 (21.0–56.0)	35.0 (21.0–56.0)

ACEi/ARB, angiotensin-converting enzyme inhibitor/angiotensin II receptor blocker; BMI, body mass index; CABG, coronary artery bypass grafting; CR, cardiac rehabilitation; LDL, low-density lipoprotein cholesterol; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.

to exercise capacity alone. Exercise capacity at EBCR entry corresponded to a mean of 64.7± 27.4% in men and 68.4± 18.9% in women of the reference population. Muscular endurance, assessed using the heel-rise test, was benchmarked against external reference data, and performance was consistently below expected levels.

These exercise capacity results align with prior work by Ades *et al*,[10] who reported peak oxygen uptake (VO_2) values averaging about 60% of age-matched norms, despite differences in test modality (treadmill vs cycle ergometer) and outcome measures (peak VO_2 vs peak work rate). Ades *et al*[10] benchmarked CRF against age-predicted values from Fleg *et al*,[9] although the cohorts differed in age and body composition, the magnitude of deficit was comparable. Consistently, Waghmare *et al*[29] reported mean peak VO_2 ≈72% of healthy controls values in patients with suspected coronary artery disease (CAD). While these measures are not directly comparable, similar relative deficits across studies suggest that routine symptom-limited cycle ergometer peak work rate reflects clinically meaningful limitation of exercise capacity entry to EBCR after MI. Thus, previous studies have shown that exercise capacity is often reduced at entry to EBCR. Our study adds to this evidence by quantifying the magnitude of this reduction in relation to clinical reference values. Recent data also support the clinical relevance of early EBCR after MI. A 2025 intervention study showed that starting a 5-week CR programme a mean of 17 days after MI was associated with improved exercise tolerance.[30] In this context, the marked deficits observed at entry to EBCR in our cohort underscore the importance of early baseline assessment to identify patients with greater limitations and guide individualised EBCR.

A similar pattern is seen for muscular performance. However, it is important to distinguish between different components of muscular fitness, such as strength, endurance and power. Few studies have compared lower-limb strength or endurance in patients with cardiac disease versus healthy controls outside chronic heart failure populations, but available data indicate meaningful deficits. Ghroubi *et al*[31] reported reduced quadriceps (−28%) and hamstring (−22%) strength in patients with CAD versus age-matched controls, whereas Gayda *et al*[32] found no difference in maximal quadriceps strength, discrepancies likely reflecting small samples and methodological heterogeneity. In contrast, a more robust study by Baum *et al*[33] showed significantly lower leg strength in patients with CAD, with age-dependent and sex-dependent differences and reductions up to 35%–40% in younger groups. In the present study, the heel-rise test was used as a measure of lower-limb muscular endurance rather than maximal strength or muscle power. Although these components are not interchangeable, the available literature and our findings both support the presence of impaired lower-limb muscular performance in patients with CAD.

According to national interpretation thresholds, mean exercise capacity in the cohort was classified as moderately

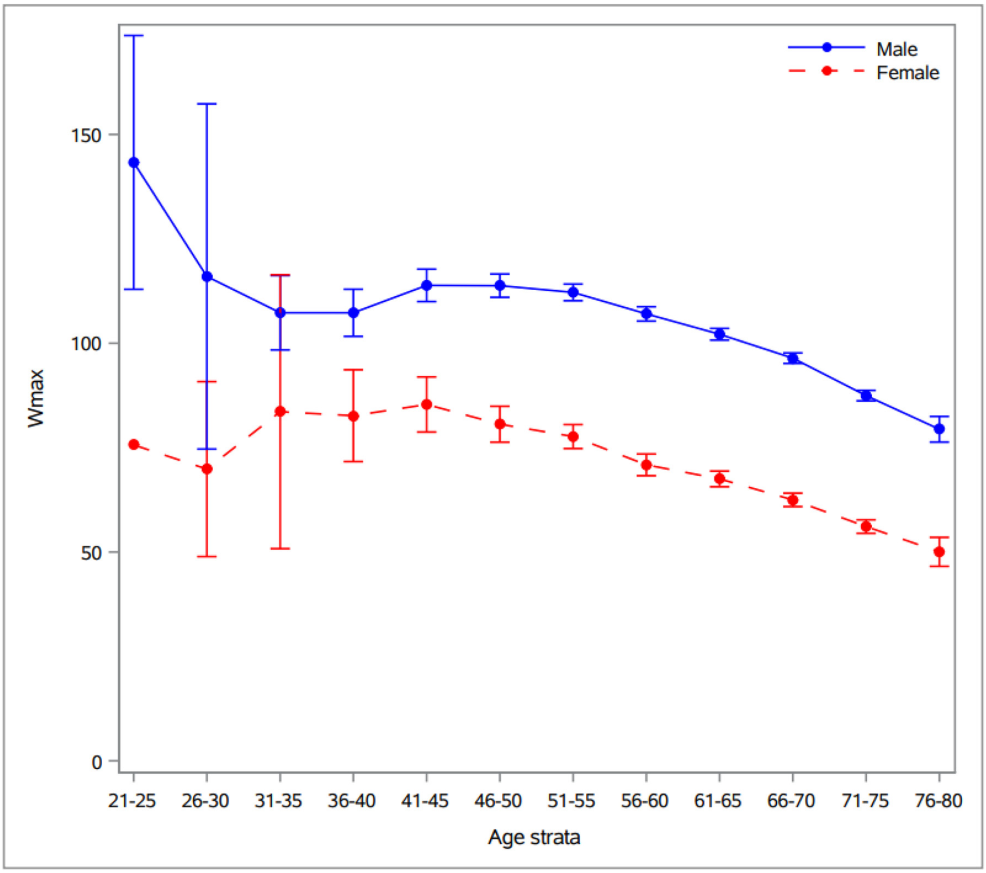

Figure 2 Mean maximal work rate (Wmax) with 95% confidence intervals by age strata and sex. Wmax, maximal Watts.

reduced (50–69.9% of predicted).[34] Although classified as moderately reduced on average, it should not be interpreted as clinically trivial, since the wide dispersion of values indicates that many patients enter EBCR with substantially lower exercise capacity. Prognostic studies in CR populations show a clear graded relationship between aerobic capacity and long-term outcomes, where higher measured peak VO_2 is associated with markedly lower cardiac mortality and even small differences are clinically meaningful.[14 35] Although exercise capacity was expressed as per cent of predicted Wmax from routine cycle ergometry rather than gas exchange-derived peak VO_2, prior work suggests that cycle-based performance measures can still reflect clinically meaningful limitation, although the exact percentage of predicted values may differ somewhat across settings due to differences in testing protocols and how peak performance is calculated. Finally, expected improvements in physical fitness during CR are commonly in the range of 5–10%,[36] supporting the value of systematic baseline testing to set realistic goals and make progress visible over time, particularly for those starting at the lowest levels.

The observed deficits at EBCR entry likely reflect a combination of pre-existing low fitness, a recognised CVD risk factor and additional short term limitations in

Table 2 Heel-rise (men)

		Age categories (years)											
Parameter	**Statistics**	**20–29**	**P value**	**30–39**	**P value**	**40–49**	**P value**	**50–59**	**P value**	**60–69**	**P value**	**70–79**	**P value**
Heel-rise test	n	12		104		718		2141		3484		2245	
	Mean (SD)	21.6 (8.1)		17.7 (8.5)		17.7 (8.4)		17.1 (8.9)		15.2 (9.5)		12.9 (9.6)	
Heel-rise reference	n	12		104		718		2141		3484		2245	
	Mean	37.4		32.8		28.3		23.7		19.1		14.5	
Heel-rise test – heel-rise reference	n	12		104		718		2141		3484		2245	
	Mean (SD)	−15.9 (8.1)	<0.0001	−15.1 (8.5)	<0.0001	−10.6 (8.4)	<0.0001	−6.7 (8.9)	<0.0001	−3.9 (9.5)	<0.0001	−1.6 (9.6)	<0.0001

The p value reflects the test of whether the difference between the performed and reference heel rises was statistically significant.

Table 3 Heel-rise (women)

Parameter	Statistics	20–29	P value	30–39	P value	40–49	P value	50–59	P value	60–69	P value	70–79	P value
		Age categories (years)											
Heel-rise test	n	4		24		156		543		1069		823	
	Mean (SD)	12.8 (4.1)		12.0 (6.0)		16.1 (8.4)		14.0 (8.2)		12.0 (8.1)		9.7 (8.1)	
Heel-rise reference	n	4		24		156		543		1069		823	
	Mean	30.1		27.4		24.6		21.9		19.2		16.4	
Heel-rise test – heel-rise reference	n	4		24		156		543		1069		823	
	Mean (SD)	−17.4 (4.1)	0.004	−15.4 (6.0)	<0.0001	−8.5 (8.4)	<0.0001	−8.0 (8.2)	<0.0001	−7.2 (8.1)	<0.0001	−6.7 (8.1)	<0.0001

The p value reflects the test of whether the difference between the performed and reference heel rises was statistically significant.

the early post MI period such as fatigue, fear of exertion and depressive symptoms.[37–39]

While cardiopulmonary exercise testing (CPET) is the gold standard, symptom-limited cycle ergometry and simple tests for muscular endurance provide clinically useful information in routine care.[19]

Strengths and limitations

This is a nationwide, registry-based, real-world study, spanning all Swedish regions with high coverage, enabling precise estimates and reliable age-stratified and sex-stratified analyses and enhancing its generalisability. However, several limitations should be considered. First, the observational design limits the interpretation to descriptive comparisons. Second, the study population was restricted to patients who attended EBCR and completed baseline physiotherapy testing. As non-attendance after MI is associated with older age, higher risk burden and socioeconomic factors,[40] our estimates may underestimate deficits in the broader post-MI population. Third, reasons for non-attendance at the physiotherapy visit were largely unavailable in the registry, limiting further assessment of potential selection mechanisms.

In addition, some patients with spontaneous coronary artery dissection might have been included, especially among younger women, potentially lowering performance at entry. Differences in the time from discharge to the first physiotherapy visit may also have influenced baseline performance. Both factors could have biased levels in either direction. Socio-demographic patterns among attenders (eg, higher education/income) also warrant caution when extrapolating to disadvantaged groups.

Additional limitations relate to the comparison with the exercise capacity reference values. Although the reference material was based on a standardised Swedish ramp-cycle protocol, improving alignment with our testing, the reference cohort was not a random population-based sample of healthy individuals but a clinically referred population with normal test outcomes. Comparability may also have been affected by differences between cohorts in medication use and exertion or termination

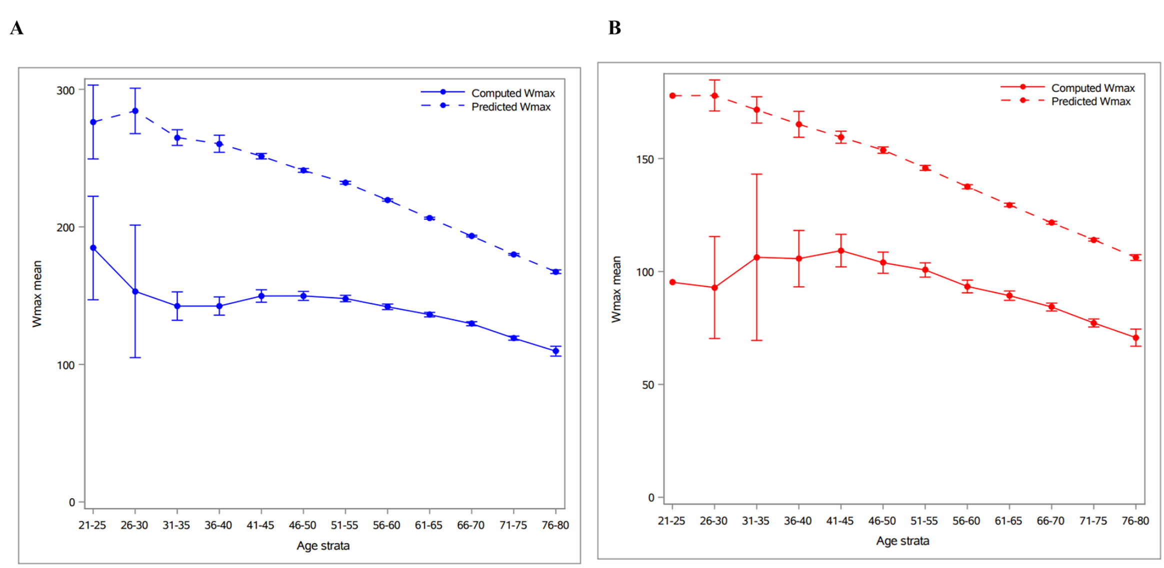

Figure 3 (A) Comparison of computed Wmax and predicted Wmax in men. (B) Comparison of computed Wmax and predicted Wmax in women.

Table 4 Computed and predicted Wmax (men)

		Age categories (years)											
Parameter	Statistic	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–75	76–80
Computed Wmax	n	4	9	46	117	334	675	1190	1506	1949	2137	1792	295
	Mean (SD)	184.6 (23.7)	143.1 (45.9)	142.4 (34.7)	141.8 (34.5)	148.1 (38.9)	148.0 (40.0)	146.0 (37.9)	140.9 (37.9)	135.6 (35.6)	129.2 (33.4)	119.0 (31.3)	109.5 (30.9)
	Upper 95th percentile	206.6	225	207.8	200.1	214.7	218	209.8	206.6	196.5	190.1	177.4	158.9
	Lower 5th percentile	161.1	78.7	94.7	83.7	86.4	81.4	87.6	78.7	73.9	71.2	68.4	60.7
Predicted Wmax	n	4	9	44	110	327	657	1152	1469	1894	2069	1736	291
	Mean (SD)	276.3 (16.9)	284.3 (21.5)	264.9 (18.8)	260.4 (33.0)	251.4 (18.1)	241.0 (17.9)	232.1 (18.3)	219.5 (15.9)	206.3 (15.4)	193.3 (14.3)	180.0 (12.5)	167.4 (11.3)
	Upper 95th percentile	299	315.7	292.9	294.1	280.7	270.7	260.3	246.1	231	214.9	200.8	186.7
	Lower 5th percentile	262.1	242.6	238.5	229.2	222.2	213.2	205	196	184.2	170.8	160.4	150.4
Computed Wmax/ predicted Wmax (%)	n	4	9	44	110	327	656	1151	1468	1893	2066	1736	291
	Mean (SD)	66.9 (8.2)	50.4 (15.8)	54.7 (12.3)	47.7 (69.0)	58.9 (14.7)	61.3 (16.1)	61.5 (49.9)	64.2 (16.8)	65.4 (22.2)	66.4 (26.6)	66.1 (16.9)	65.3 (18.4)
	Upper 95th percentile	78	80.5	79	76	81.6	88.1	89.6	93	94.8	96.8	94.7	91
	Lower 5th percentile	60	27.3	37.4	28.7	35	33.5	38.7	36.8	39.4	38	38.1	37.5

Wmax, maximal Watts.

Table 5 Computed and predicted Wmax (women)

		Age categories (years)											
Parameter	Statistic	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–75	76–80
Computed Wmax	n	1	4	11	18	59	151	278	354	545	644	592	108
	Mean (SD)	95.2 (0.00)	92.9 (14.2)	103.0 (47.8)	105.7 (25.1)	109.2 (27.7)	103.7 (28.4)	100.7 (26.7)	93.4 (27.0)	89.3 (24.6)	84.3 (22.7)	77.2 (21.9)	70.7 (19.9)
	Upper 95th percentile	–	111.9	183.7	150.6	165.8	155.2	150.6	142.8	131.9	120.9	114.3	108.5
	Lower 5th percentile	–	78.2	37.2	37.5	65.4	60.6	58.5	52.7	52.7	50.6	42.0	36.1
Predicted Wmax	n	1	4	11	17	59	144	270	343	526	637	575	104
	Mean (SD)	177.9 (0.00)	178.0 (4.3)	171.6 (8.7)	165.2 (11.2)	159.5 (10.2)	153.8 (8.6)	145.9 (9.1)	137.5 (8.7)	129.5 (8.9)	121.6 (8.2)	114.0 (7.3)	106.2 (6.6)
	Upper 95th percentile	–	181.4	186.7	187.4	175.0	167.3	161.0	152.0	143.1	134.0	126.5	113.8
	Lower 5th percentile	–	171.7	159.4	144.4	143.2	141.9	131.1	124.2	114.6	109.1	103.3	95.1
Computed Wmax/ predicted Wmax (%)	n	1	4	11	17	59	144	270	343	526	635	573	104
	Mean (SD)	53.5 (0.00)	52.3 (8.3)	60.1 (27.9)	63.7 (16.0)	68.7 (17.5)	66.8 (17.5)	68.7 (17.6)	67.9 (19.3)	68.9 (19.0)	69.4 (19.2)	67.7 (19.0)	67.2 (17.7)
	Upper 95th percentile	–	62.7	107.5	87.3	104.0	92.8	99.1	99.5	100.1	99.0	100.0	97.5
	Lower 5th percentile	–	43.4	21.6	22.8	38.8	39.5	41.8	37.9	40.0	42.5	35.8	34.7

Wmax, maximal Watts.

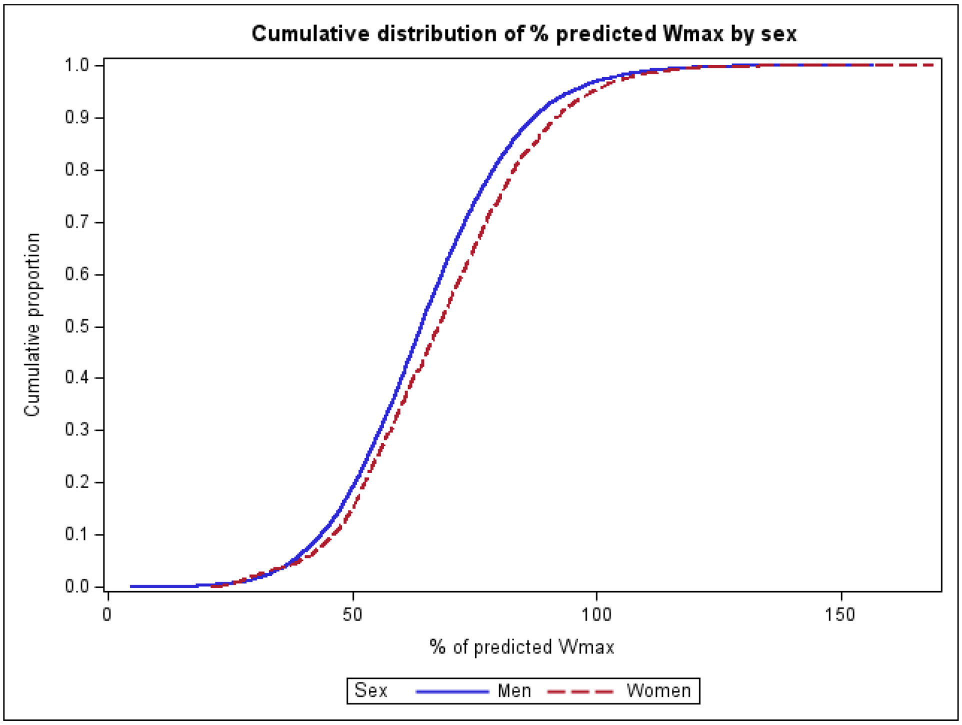

Figure 4 Cumulative distribution of % predicted Wmax by sex. Wmax, maximal Watts.

criteria. In particular, cardioactive medication, such as β-blockers, may influence absolute exercise capacity values, although prior data suggest that this effect may vary by setting and protocol.[41 42]

Furthermore, the comparison required recalculation across test protocols. Although this was done to improve comparability, its validity in symptom-limited testing and in post-MI populations has not been fully established and may have affected the absolute values of computed Wmax. However, the recalculated values were as expected consistently higher than the originally measured values across age groups, with no obvious age-dependent systematic deviation (online supplemental S3a and b).

Finally, although SWEDEHEART-CR has shown high overall completeness and accuracy in published nationwide audits, the physiotherapy variables used in this study were not specifically included in that validation, and some degree of misclassification or measurement error cannot therefore be excluded.

Clinical implications

The findings of this study support clinical practice by providing a benchmark of physical fitness at entry to EBCR after MI and by highlighting substantial deficits and wide variation in both exercise capacity and muscular endurance. Routine symptom-limited cycle ergometry test and the heel-rise test can help clinicians tailor exercise prescription and identify patients with greater limitations who may need closer support. While (CPET) is the gold standard, these routine assessments are feasible and provide clinically useful information when gas exchange measurements are not available.[25] Expressing results relative to clinical reference values can also make findings easier to explain to patients and make progress easier to follow, which may support patient engagement and motivation.

CONCLUSION

At EBCR entry after first-time MI, both exercise capacity and muscular endurance are markedly reduced relative to reference expectations across age and sex. These findings support comprehensive baseline assessment and tailored EBCR that target both aerobic capacity and muscular endurance, using feasible tests suitable for everyday practice.

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Data availability statement Data are available upon reasonable request. SWEDEHEART does not allow individual data sharing to a third party. Access to aggregated data might be granted after review by the SWEDEHEART steering committee.

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