Occupational Medicine 2013;**63**:103–108
Advance Access publication 8 November 2012 doi:10.1093/occmed/kqs192

Energy expenditure in US automotive technicians and occupation-specific cardiac rehabilitation

J. Adams[1], S. Jordan[2], K. Spencer[2], J. Belanger[2], D. Cheng[3,4], T. Shock[1] and J. Karcher[2]

[1]Cardiac Rehabilitation, Baylor Jack and Jane Hamilton Heart and Vascular Hospital, Dallas, TX, USA, [2]Department of Kinesiology, Texas Woman's University, Denton, TX, USA, [3]Institute for Health Care Research and Improvement, Baylor Health Care System, Dallas, TX, USA.

[4]Present address: Department of Biostatistics, The University of Texas School of Public Health Dallas Regional Campus, Dallas, TX, USA.

Correspondence to: J. Adams, Cardiac Rehabilitation, 411 N. Washington Street, Suite 3100, Dallas, TX 75246 USA. Tel: +1 214 820 1395; fax: +1 214 820 1412; e-mail: jennya@BaylorHealth.edu

Background The standard exercise protocol for patients in a traditional cardiac rehabilitation (rehab) programme may not be adequate for preparing manual workers for a safe return to work, as these activities bear little resemblance to the physical movements and force exertion required in most industrial jobs.

Aims To measure the energy expenditure as metabolic equivalents (METs) required for automotive technicians, to compare this MET level with that normally attained in traditional cardiac rehab programmes and to suggest cardiac rehab exercises for automotive technicians based on specificity of training.

Methods Automotive technicians who volunteered to participate had their MET levels measured while they performed a defined series of work tasks in the service department of an automobile dealership. Their daily walking distance was also determined.

Results Thirty-six of 95 eligible subjects participated; a response rate of 38%. Mean peak MET level was 7.1, less than the 8 METs target training goal often used in traditional cardiac rehab programmes. However, patients' outcome MET levels in cardiac rehab are usually measured by a treadmill stress test, whereas the subjects reached 7.1 METs while performing work tasks. The subjects walked an average of 5 km during a normal workday.

Conclusions Because MET level measurements are work specific, automotive technicians in a cardiac rehab programme should strive to reach and maintain a level of >7 METs while performing specific training exercises that mimic the work tasks they must do throughout the day. They can also benefit from traditional endurance training such as treadmill walking.

Key words Cardiac disease; exercise capacity; metabolic equivalents; physical training; rehabilitation; work.

Introduction

Manual workers who experience a cardiac event may be encouraged to attend an outpatient cardiac rehabilitation (rehab) programme, which is intended to reduce the risk of subsequent cardiac problems and promote the patient's safe return to a full and normal life. Cardiac rehab programmes are multidisciplinary and include baseline patient evaluation, cardiac risk factor management, counselling, education and prescribed exercise training. Cardiac rehab, by definition, is designed to enhance patients' psychosocial and vocational status [1]; however, discussions about occupation-specific exercise training for a safe return to work are typically omitted [2]. It is recognized that medically related withdrawal from normal social roles, including work, is destabilizing and may be detrimental to a patient's mental, physical and social well-being [3,4]. The earliest possible return to work or re-employment should be a primary objective of cardiac rehab training programmes [5].

Exercise intensity is often expressed as metabolic equivalents (METs), a value that is commonly used as a goal for exercise training [6]. The activity of sitting requires 1 MET (defined as the average seated resting energy cost of an adult [7]), whereas heavy work requires 6 to 8 METs [8]. Comprehensive tables of MET levels for common household, occupational and recreational tasks, such as the Compendium of Physical Activities [9], are available and used to determine the fitness levels required for graduation from a cardiac rehab programme. Even so, it has been suggested that the MET levels for the activities listed in the compendium are too low [10]. If this is true, measured MET levels for specific work tasks should be verified and reported so that the graduation training goals prescribed in cardiac rehab might be more appropriate for an efficacious return to work.

The standard exercise protocol for a patient in a cardiac rehab programme involves walking on a treadmill, pedalling a stationary exercise bicycle, and lifting 0.45–2.3 kg hand weights [6,11] and is generally recommended for all participants, regardless of their occupation or individual fitness requirements. This standard protocol may be adequate and appropriate for patients who lead essentially sedentary lives or have occupations that are not physically demanding. However, it may not be adequate for preparing manual workers to return to work safely and efficaciously because the activities bear little resemblance to the combinations of physical movement, load handling and force exertion that are required of workers in most industrial jobs [5]. By contrast, an exercise prescription based on specificity of training, i.e. one that includes exercises that simulate the mode and intensity of the patient's job tasks is likely to necessitate the use of selected resistance exercises.

The American College of Sports Medicine (ACSM) recognizes that specificity of training is important for preparing patients to return to work after a cardiac event, but a conundrum arises when patients need to perform resistance exercises to simulate their job tasks. The ACSM guidelines recommend a delay in resistance training (lifting weights ≥50% of one repetition maximum), for a minimum of 5 weeks after myocardial infarction (MI) or cardiac surgery, 'including' 4 weeks of consistent participation in a supervised cardiac rehabilitation endurance training programme [6]. Therefore, patients whose jobs require heavy lifting and force exertion cannot begin the specific training they need until at least week 5 of a typical 6–8 week [11] cardiac rehab programme. This delay may notably hinder their ability to return to work. The results of a Danish study support a focus on cardiac rehab for manual workers, as well as individuals younger than 60 years, who have coronary heart disease. The investigators found that these two groups had a significantly higher risk of withdrawing early from the labour market than individuals without coronary heart disease [12].

The current study was one in a series designed to assess the physical demands of various manual occupations; the overall goal is to develop more effective cardiac rehab training that enables patients to return to such occupations safely and confidently after a cardiac event. The aims of the study were to measure the MET level required for automotive technicians, to compare this MET level with that normally attained in traditional cardiac rehab programmes and to suggest cardiac rehab exercises for automotive technicians that are based on specificity of training.

Methods

The Baylor Research Institute Institutional Review Board approved the study, and consent was obtained from all subjects, who were recruited from the workforce at a vehicle repair centre in Dallas, Texas. This has 140 bays and employs 95 automotive technicians, who were all told about the study and invited to participate. Those who volunteered completed an 'obstacle course' of typical work tasks while wearing a portable metabolic system (K4 b^2, Cosmed USA Inc., Chicago, IL). The K4 b^2 software and a laptop computer were used to create a data profile for each subject at the testing site; the date of birth, height, weight and percentage body fat (obtained by the skinfold method [13]) were included in this profile. For safety, blood pressure and heart rate were measured before and after the individual subjects completed the obstacle course. On the days of testing, the K4 b^2 system and the 28 mm turbine flowmeter were calibrated according to the manufacturer's instructions and recalibrated after every subject to ensure accurate collection of oxygen consumption (VO_2) data. In addition to capturing and recording the data, the K4 b^2 software automatically calculated the subjects' MET levels.

The subjects wore their usual uniform (trousers, shirt and athletic shoes or work boots). Before starting the obstacle course, each subject was fitted with a data collection mask that sealed tightly around the mouth and nose and was secured by a head cap. The optoelectronic reader containing the turbine, wind cover and sampling plug was attached to the front of the mask. The obstacle course was explained and demonstrated to all subjects to ensure consistent performance of the five activities: pushing a car, compressing a strut spring, removing and replacing a power seat, raising and lowering a V8 engine and rotating and balancing tyres. These activities were chosen as the most common physically demanding tasks that automotive technicians perform. To simulate normal workday activity, subjects walked for 1 min between stations in the aisle of the automotive shop. Two study team members walked the course with the subjects to ensure task compliance at each station and to time the walk between stations.

The details of the obstacle course are summarized in Table 1. After completing the obstacle course, each subject removed the K4 b^2 equipment and harness. The subject was escorted back to the rest area where water, healthy snacks and a chair were available. Recovery blood pressure and heart rate were measured.

From their workspace, automotive technicians walk outside to get vehicles and walk to the parts counter and the service aisle multiple times each day. To measure the

Table 1. Details of the obstacle course

Obstacle course task	Task details
Pushing a car (approximately 1624 kg)	The subject walked to a parking lot adjacent to the automotive shop to push a car positioned between two sets of cones placed 9 m apart. A study team member put the car in neutral and steered while the subject, on command, began to push the car at the back bumper. The task was complete when the back bumper passed the second set of cones. To ensure uniformity throughout the study, the same team member steered the car during each trial.
Compressing a strut spring	The subject picked up a strut and spring from the floor and positioned them in a wall-mounted compressor (mid-point height, 140 cm). Using both hands, he manually turned a crank until the spring was compressed enough to remove the strut. This activity required the subjects to reach overhead as they worked.
Removing and replacing a power seat	To simulate lifting a front seat with heater/motor assembly out of a sport utility vehicle (SUV), the subject performed a bent-knee squat to grasp a power seat that was positioned on the floor. He tilted the seat from side to side to simulate removing it and then placed the seat on a workbench that was 89 cm tall. To simulate replacing the seat in the vehicle, he lifted the seat from the workbench and placed it back on the floor.
Raising a V8 engine (approximately 318 kg)	The subject used a standard, manually operated (hand pump) engine hoist to raise a V8 engine high enough to clear the front of an SUV as if he were going to remove the engine from a vehicle. Once the engine was lifted, he pulled the engine/hoist assembly back 4.5 m, then pushed the engine/hoist assembly forward 4.5 m to an engine stand where he lowered the engine and mounted it on the stand. After securing the engine to the stand with a bolt, he reversed the process; he lifted the engine from the stand and lowered it back down to the starting position.
Rotating and balancing tyres (four wheel/tyre assemblies, each weighing 28.6 kg)	The subject first squatted down and adjusted the automotive lift height so he could raise a full-size SUV approximately chest high. After raising the vehicle to the proper height, he removed the lug nuts from all four wheels with a pneumatic impact gun, then removed the tyres and placed them on a cart. He pushed the cart across the shop to a tyre-balancing machine (spindle height, 76 cm from the floor), where he mounted, spun and unmounted each tyre. He stacked the tyres back on the cart, pushed the cart to the SUV and put the tyres back on, tightening the lug nuts with the impact gun. He lowered the SUV and removed the lift.

distance they walk during a typical workday, subjects were given pedometers (W4LElite, Walk4Life, Plainfield, IL) and were asked to record their steps from 8:30 a.m. to 5:30 p.m. for 3 days. A study team member calibrated each pedometer by counting the number of steps that the subject took to walk 9 m. The stride length was calculated from this number and used to determine the total distance reflected by the pedometer step counts.

Results

Thirty-six male career automotive technicians volunteered to participate in this study (38% of those working at the repair centre and invited to participate). The age range was from 21 to 60 years. The subjects were screened for hypertension, and none were taking medication that might have affected physiological variables during testing. All subjects completed the obstacle course, and no adverse events were noted. Demographic characteristics are summarized in Table 2.

Table 3 lists the MET and VO_2 data, along with the average daily distance walked. The subjects' mean peak MET level of 7.1 (95% confidence interval [CI]: 6.8–7.5) was lower than 8 the goal MET level commonly used in traditional cardiac rehab ($t_{35} = -4.51$; $P < 0.001$). The mean peak VO_2 was 25.0 ml/kg/min (95% CI: 23.7–26.3), and the mean daily distance walked during the 3 day monitoring period was 5 km (95% CI: 4.5–5.5).

Discussion

The automotive technicians in this study walked an average of 5 km per workday. Because patients in traditional cardiac rehab programmes walk on a treadmill an average

Table 2. Characteristics of the study subjects (*n* = 36)

Variable	Value
Age and anthropometric data, mean (standard deviation)	
Age in years	36 (10)
Height in cm	170 (2)
Weight in kg	91 (15)
Per cent body fat	22 (5)
Race/ethnicity, *n* (%)	
Asian	3 (8)
Black	1 (3)
Caucasian	22 (61)
Hispanic	10 (28)

Table 3. Metabolic equivalent, oxygen consumption, and walking distance data

Subject	Peak METs	Peak VO_2	Average daily distance (km)[a]
1	9.4	32.9	5.9
2	6.9	24.2	7.7
3	7.6	26.6	5.7
4	7.7	27.0	5.4
5	6.3	22.1	3.9
6	6.7	23.5	3.7
7	6.1	21.4	4.0
8	6.7	23.5	6.7
9	5.6	19.6	7.6
10	7.6	26.6	3.8
11	7.4	25.9	3.1
12	6.4	22.4	3.9
13	7.6	26.6	5.2
14	9.9	34.7	5.2
15	4.2	14.7	4.0
16	6.7	23.5	4.5
17	7.8	27.3	1.4
18	7.9	27.7	3.6
19	7.2	25.2	5.0
20	7.4	25.9	4.0
21	7.2	25.2	6.2
22	8.8	30.8	5.0
23	8.2	28.7	4.7
24	6.5	22.8	2.5
25	6.1	21.4	7.2
26	8.2	28.7	5.3
27	7.0	24.5	3.5
28	7.7	27.0	3.7
29	7.7	27.0	1.6
30	6.2	21.7	6.2
31	6.3	22.1	6.5
32	7.9	27.7	6.2
33	6.1	21.4	7.7
34	6.7	23.5	7.3
35	4.9	17.2	4.8
36	8.4	29.4	6.4

METs indicates metabolic equivalents; VO_2, oxygen consumption (ml/kg/min).
[a]Average of distances calculated from pedometer step counts for three consecutive workdays.

of 1.5–3 km per exercise session, cardiac rehab training would, in theory, adequately prepare automotive technicians for the amount of walking required by their job. Moreover, a primary goal in traditional cardiac rehab is to train patients to an intensity of 8 METs, which correlates with a fitness level that serves as the minimum requirement for graduation from the programme [14].

The study subjects reached a mean peak MET level of 7.1; however, they did so while simulating the specific automotive tasks that they must perform on the job. Thus, in addition to walking approximately 5 km, the automotive technicians in this study must be able to perform work tasks at >7 METs (not 3 METs, as indicated in the Compendium of Physical Activities [9]) for extended periods throughout an 8 hour workday.

Three aspects of the study potentially limit the generalizability of the findings and therefore must be noted. First, the possibility of participation bias exists because volunteer subjects were used. The differences between the automotive technicians who participated and those who did not are unknown, as are their potential effects on the MET levels reached. Second, the sample size, though recommended by the statistician, was relatively small. Third, the study was conducted in a modern, well-equipped service centre with moderate to cool temperatures, a setting that is unlikely to represent the working environment of all automotive technicians. Those who work in higher temperatures or who lack the benefit of ergonomic equipment may reach higher MET levels.

In similar studies of firefighters [15] and police officers [16], the subjects reached mean peak MET levels that were much higher than the traditional cardiac rehab goal of 8 METs (firefighters, 17; police officers, 14.7), indicating that traditional cardiac rehab training would clearly be inadequate for patients in those occupations. The mean peak MET level of the automotive technicians, however, was comparable to the traditional cardiac rehab goal. Taken together, these findings illustrate considerable variation in the physical demands of manual labour jobs. Although it would be impractical to measure the MET levels required for every occupation, it is hoped that these initial studies will demonstrate the need for task-specific cardiac rehab training of appropriate candidates and, ideally, lead to better outcomes in return to work.

The most effective way to increase specific work performance is to train in a manner that mimics that task [6]. Although the standard cardiac rehab protocol (treadmill walking, stationary cycling, and lifting light hand weights) may be satisfactory for patients in many occupations, it cannot meet the needs of all, particularly those whose jobs require heavy lifting. Automotive technicians, for example, must lift wheel/tyre assemblies that can weigh 20–35 kg, depending on vehicle size, and seats that can range from 10 (manual seat) to 35 kg (motorized seat). According to the American Heart Association, supervised resistance training, in addition to aerobic training,

Table 4. Suggested task-specific exercises for cardiac rehabilitation training of automotive technicians

Task	Exercise selection
Pushing a car	Standing chest press Isometric forward press (wall) Lunge (physioball against wall)
Compressing a strut spring	Overhead band/dumbbell press Seated dumbbell flys
Removing and replacing a power seat	Wood chop (low to high with band) Deadlift (dumbbell)
Raising a V8 engine	Squat + row with dumbbells Squat + row with resistance machine Tricep dips (bench or chair)
Rotating and balancing tyres	Standing chest press holding a dumbbell or weight plate Squat + standing chest press
Walking to retrieve parts and supplies	Treadmill walking, interval training, and walking with a load; work up to at least 5 km

can be safely prescribed in phase II cardiac rehab [17]. Table 4 lists examples of exercises that could be used to train automotive technicians in the cardiac rehab setting, which is a safe clinical environment in which to assess patients' physiological limits.

In summary, the results of the current study suggest that training to a level of 8 METs on the treadmill is not satisfactory for patients who want to return to work as automotive technicians. Although the goal for these patients is still 8 METs, their training should simulate their occupational tasks. With resistance training at an appropriate intensity level, along with treadmill walking, automotive technicians can be prepared for a safe return to work after a cardiac event.

Key points

- The study subjects reached a mean metabolic equivalent level of 7.1 while performing simulated occupational tasks, and they walked an average of 5 km per day.
- Automotive technicians undergoing cardiac rehab are likely to benefit from conventional treadmill training, combined with exercises that mimic the occupational tasks they must do for extended periods during the workday.
- When training patients who want to return to manual labour jobs, cardiac rehab staff should take into account the patients' occupational tasks instead of relying on the standard one-size-fits-all exercise protocol.

Funding

Cardiovascular Research Review Committee in cooperation with the Baylor Heart and Vascular Institute, Dallas, Texas (grant no. 51509).

Acknowledgements

We are grateful to Mason Kessner and the other managers at Sewell Lexus in Dallas, Texas, for allowing us to perform research on their automotive technicians; study team members Kathleen Kennedy, Danielle Strauss, Anne Lawrence, Stephanie McCray, Aster Naffe and Henry Viejo for invaluable help with the obstacle course and data collection; and the Cardiovascular Research Review Committee for encouraging and supporting cardiovascular rehabilitation research projects. Beverly Peters, a freelance medical editor, was compensated for providing editorial assistance.

Conflicts of interest

None declared.

References

1. Thomas RJ, King M, Lui K, Oldridge N, Piña IL, Spertus J; American Association of Cardiovascular and Pulmonary Rehabilitation/American College of Cardiology/American Heart Association Cardiac Rehabilitation/Secondary Prevention Performance Measures Writing Committee. AACVPR/ACC/AHA 2007 performance measures on cardiac rehabilitation for referral to and delivery of cardiac rehabilitation/secondary prevention services. *Circulation* 2007;**116:**1611–1642.
2. Ross J. *Occupational Therapy and Vocational Rehabilitation*. Chichester, West Sussex: John Wiley & Sons, 2007; 184.
3. American College of Occupational and Environmental Medicine. The personal physician's role in helping patients with medical conditions stay at work or return to work [position statement, 2008 December 11]. http://www.acoem.org/PhysiciansRole_ReturntoWork.aspx (16 January 2012, date last accessed).
4. Waddell G, Burton AK. Is Work Good for Your Health and Well-Being? London: TSO, 2006; viii, ix. http://www.dwp.gov.uk/docs/hwwb-is-work-good-for-you.pdf (18 July 2012, date last accessed).
5. Mital A, Shrey DE, Govindaraju M, Broderick TM, Colon-Brown K, Gustin BW. Accelerating the return to work (RTW) chances of coronary heart disease (CHD) patients: part 1—development and validation of a training programme. *Disabil Rehabil* 2000;**22:**604–620.
6. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*. 8th edn. Philadelphia: Lippincott Williams & Wilkins, 2009; 214, 215, 220, 222.
7. Plowman SA, Smith DL. *Exercise Physiology for Health, Fitness, and Performance*. 2nd edn (reprint). Baltimore, MD: Lippincott Williams & Wilkins, 2008; 136.

8. McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Energy, Nutrition, and Human Performance*. 6th edn. Philadelphia: Lippincott Williams & Wilkins, 2007; 203.
9. Ainsworth BE, Haskell WL, Whitt MC *et al.* Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000;**32:**S498–S504.
10. Kozey SL, Lyden K, Howe CA, Staudenmayer JW, Freedson PS. Accelerometer output and MET values of common physical activities. *Med Sci Sports Exerc* 2010;**42:**1776–1784.
11. American Association of Cardiovascular and Pulmonary Rehabilitation. *Guidelines for Cardiac Rehabilitation Programs*. Champaign, IL: Human Kinetics, 2004; 8, 120.
12. Kruse M, Sørensen J, Davidsen M, Gyrd-Hansen D. Short and long-term labour market consequences of coronary heart disease: a register-based follow-up study. *Eur J Cardiovasc Prev Rehabil* 2009;**16:**387–391.
13. Golding LA, Myers CR, Sinning WE. *Y's Way to Physical Fitness: The Complete Guide to Fitness Testing and Instruction*. 3rd edn. Champaign, IL: Human Kinetics, 1989; 77.
14. Brooks GA, Fahey TD, Baldwin KM. *Exercise Physiology: Human Bioenergetics and Its Applications*. 4th edn. Boston, MA: McGraw-Hill, 2005; 464, 596.
15. Adams J, Roberts J, Simms K, Cheng D, Hartman J, Bartlett C. Measurement of functional capacity requirements to aid in development of an occupation-specific rehabilitation training program to help firefighters with cardiac disease safely return to work. *Am J Cardiol* 2009;**103:**762–765.
16. Adams J, Schneider J, Hubbard M *et al.* Measurement of functional capacity requirements of police officers to aid in development of an occupation-specific cardiac rehabilitation training program. *Proc (Bayl Univ Med Cent)* 2010;**23:**7–10.
17. Williams MA, Haskell WL, Ades PA *et al.*; American Heart Association Council on Clinical Cardiology; American Heart Association Council on Nutrition, Physical Activity, and Metabolism. Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation* 2007;**116:**572–584.

doi:10.1093/occmed/kqs045

Mesothelioma

There are three cases of mesothelioma that stand out in my mind during my career as an occupational physician. The first was a lagger I encountered whilst I was a trainee working for a power generation company. I visited him at home to talk about ill health retirement, the cooling towers of the power station he had lagged 20 years beforehand looming over his back garden. Only in his mid-forties, he was bewildered, and I came away feeling hopeless and helpless. I had seen one or two cases whilst working on a chest ward but this was palpably a terrible occupational disease. The second memorable case was 20 years later: a very fit and healthy manager in his late forties who had worked in the same factory as I had for a similar length of time. The majority of his working life had been in offices and not the shop-floor. He hadn't worked in departments where we knew there was an asbestos legacy and where I had been keeping an eye on the toll of mesothelioma cases slowly mounting in long retired workers. It was difficult to understand how this manager had contracted the condition and worrying to think that his relevant exposure was probably the general factory environment.

The ever increasing death rate of mesothelioma in the UK is frightening. In 1968 there were 153 deaths. In 2009 there were 2321 deaths from the condition, only a few hundred more than people claiming disablement benefit. The median time from diagnosis to death remains stubbornly fixed at 18 months. In males, death rates show an almost perfect 10-fold increase with increasing age: one death per 10 million in 30-year-olds, one death per million in 40-year-olds, one death per 100 000 in 50-year-olds, one death per 10 000 in 60-year-olds and approaching one death per 1000 in 70-year-olds. Those who die are those who worked in certain occupations. This has shifted from primary users, such as those who manufactured and made products with asbestos and classical occupations such as shipbuilding, to secondary users or those who come into contact with asbestos as part of their work and specifically those in construction and craft trades, plumbers, carpenters, and electricians. Male deaths are estimated to peak in 2016, but this does not look certain from the graphs.

The third case rang me in 2011. He had heard a scratching noise in his chest when he was in bed. He rang me because he knew my speciality but also because he wanted me to provide a witness statement. Did I remember the underground passageway between the medical school and the hospital 30 years ago? The overhead pipes, the crumbling lagging, the number of times we had used it, the adjacent pigeon holes and seating area where we often met and had a chat and a coffee as medical students. He died aged 50, 7 months after the phone call. I still have the voicemail.

John Hobson
e-mail: hon.editor@som.org.uk