

TRAINING STATEMENT

COCATS 4 Task Force 3: Training in Electrocardiography, Ambulatory Electrocardiography, and Exercise Testing



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1. INTRODUCTION

1.1. Document Development Process

1.1.1. Writing Committee Organization

The writing committee was selected to represent the American College of Cardiology (ACC) and included a cardiovascular training program director, an early-career cardiologist, highly experienced members representing both academic and community-based practice settings, and physicians experienced in defining and applying training standards according to the core competencies structure promulgated by the Accreditation Council for Graduate Medical Education (ACGME) and American Board of Medical Specialties (ABMS) and endorsed by the American Board of Internal Medicine (ABIM). The ACC determined that relationships with industry or other entities were not relevant to the creation of this general cardiovascular training statement. Employment and affiliation details for the authors and peer reviewers are provided in [Appendixes 1](#) and [2](#), respectively, along with disclosure reporting categories. Comprehensive disclosure information for all authors, including relationships with industry and other entities, is available as an [online supplement](#) to this document.

1.1.2. Document Development and Approval

The writing committee developed the document, approved it for review by individuals selected by the

ACC, and then addressed the peer reviewers' comments. The document was revised and posted for public comment from December 20, 2014, to January 6, 2015. Authors addressed the additional comments from the public to complete the document. The final document was approved by the Task Force, COCATS Steering Committee, and ACC Competency Management Committee as well as ratified by the ACC Board of Trustees in March 2015. This document is considered current until the ACC Competency Management Committee revises or withdraws it.

1.2. Background and Scope

The Task Force was charged with updating previously published standards for training fellows in clinical cardiology enrolled in ACGME-accredited fellowships (1) on the basis of: 1) changes in the field since 2008; and 2) the evolving framework of competency-based medical education described by the ACGME Outcomes Project and the 6 general competencies endorsed by ACGME and ABMS. The updating effort was also convened as part of a broader effort to establish consistent training criteria across all aspects of cardiology. The background and overarching principles governing fellowship training are provided in the COCATS 4 Introduction, and readers should become familiar with this foundation before considering the details of training in a subspecialty such as electrocardiography (ECG), ambulatory ECG, and exercise ECG testing. The Steering Committee and Task Force recognize that implementation of these changes in training requirements will occur incrementally.

1.3. Training Levels

For most areas of cardiovascular medicine, 3 levels of training are delineated:

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- **Level I training**, which is the basic training required to become a competent cardiovascular consultant, is required of all cardiovascular fellows and can be accomplished as part of a standard 3-year training program in cardiovascular medicine. All cardiologists should attain Level I training in ECG, ambulatory ECG, and exercise ECG testing, as these skills are fundamental to the practice of clinical cardiology. Although many of the skills and competencies for each of these procedures can be acquired within the first 12 months of training, it is expected that such skills will be further developed and refined over the 3-year training period.
- **Level II training** refers to the additional training in 1 or more areas that enables some cardiovascular specialists to perform or interpret specific diagnostic tests and procedures or to render more specialized care for patients and conditions. This level of training is recognized for those areas in which an accepted instrument or benchmark, such as a qualifying examination, is available to measure specific knowledge, skills, or competence. Level II training in selected areas may be achieved by some trainees during the standard 3-year cardiovascular fellowship, depending on the trainees' career goals and use of elective rotations. There is no Level II training for ECG, ambulatory ECG, and exercise ECG testing.
- **Level III training** requires additional training and experience beyond the cardiovascular fellowship to acquire specialized knowledge and competencies in performing, interpreting, and training others to perform specific procedures or render advanced, specialized care at a high level of skill. There is no Level III training in ECG, ambulatory ECG, and exercise ECG testing.

2. ELECTROCARDIOGRAPHY

ECG is the most commonly used diagnostic test in cardiology. When properly interpreted, it contributes substantially to the diagnosis and management of patients with cardiac disorders, and it is essential to diagnosing cardiac arrhythmias and acute myocardial ischemic syndromes, which account for the majority of cardiac catastrophes. ECG is appropriately used as a screening test in many circumstances.

2.1. General Standards

Three organizations—the ACC, American Heart Association (AHA), and Heart Rhythm Society—have together provided recommendations for standardizing and interpreting the electrocardiogram (2-7) and have provided training requirements and guideline standards for ECG training as well as educational objectives for the ECG component of

training in cardiovascular diseases (8). The recommendations from the different organizations are congruent and address faculty, facility requirements, emerging technologies, and practice applications. We recommend strongly that candidates for the ABIM examination for certification in cardiovascular diseases review the ABIM's requirements with specific attention to the ECG components, which include special question formats for ECG interpretation (9). The following recommendations are aimed at trainees in cardiovascular training programs.

Cardiovascular fellowship programs should satisfy the requirements regarding facilities and faculty for training in ECG. Eligibility for the ABIM cardiovascular diseases examination requires that training take place in a program accredited by the ACGME.

2.1.1. Faculty

Faculty should include specialists skilled in ECG interpretation. This should include specialists in both clinical cardiac electrophysiology and cardiology. Faculty should be board-certified in cardiovascular diseases or possess equivalent qualifications. A physician is considered to have equivalent qualifications if he or she trained in a similar environment for a similar duration of time and performed the required number of procedures.

2.1.2. Facilities

Facilities should provide adequate training in multiple clinical settings, including inpatient, outpatient, emergent, and invasive (catheterization and/or electrophysiology laboratory). Facilities should also be available for didactic teaching.

2.1.3. Equipment

Equipment should be sufficient to provide reliable and reproducible ECGs and should include computerized devices that record and store a graphic display and automatically generate a preliminary interpretation.

2.1.4. Ancillary Support

Ancillary support staff should be well trained and available to administer high-quality ECG testing and collect the appropriate data, preferably in an electronic format.

2.2. Training Components

2.2.1. Didactic Program

Didactic instruction may take place in a variety of formats, including, but not limited to, lectures, conferences, journal clubs, grand rounds, clinical case presentations, and patient safety or quality improvement conferences. Fellows must be trained to interpret a large number of ECGs and review all interpretations with experienced

faculty. Programs should encourage the trainee to interpret a majority of ECGs side by side with faculty for immediate review and feedback. Formal, correlative conferences in ECG are highly recommended as part of the fellowship curriculum and should be held regularly during training. In addition, the role of ECG in clinical practice should be thoroughly reviewed.

2.2.2. Clinical Experience

Training in ECG interpretation should include clinical correlation in patients from a wide range of clinical settings, such as intensive care units, emergency rooms, and pacemaker/defibrillator clinics, as well as exposure to all forms of clinically-encountered arrhythmias, normal variants, and electrocardiographic patterns associated with acquired and congenital heart disease. Trainees should be trained to review, edit, and amend ECGs generated by computerized systems that provide a preliminary interpretation.

2.2.3. Hands-On Experience

Hands-on experience is essential for training in ECG interpretation. Additionally, trainees are expected to acquire the technical skills necessary to competently perform and record high-quality, standard 12-lead ECG tracings.

2.3. Summary of Training Requirements

2.3.1. Development and Evaluation of Core Competencies

Training and requirements for ECG and ambulatory ECG address the 6 general competencies promulgated by the ACGME/ABMS and endorsed by the ABIM. These competency domains are: medical knowledge, patient care and procedural skills, practice-based learning and improvement, systems-based practice, interpersonal and communication skills, and professionalism. The ACC has used this structure to define and depict the components of the core clinical competencies for cardiology. The curricular milestones for each competency and domain also provide a developmental roadmap for fellows as they progress through various levels of training and serve as an underpinning for the ACGME/ABIM reporting milestones. The ACC has adopted this format for its competency and training statements, career milestones, lifelong learning, and educational programs. Additionally, it has developed tools to assist physicians in assessing, enhancing, and documenting these competencies.

Table 1 delineates each of the 6 competency domains, as well as their associated curricular milestones for training in ECG and ambulatory ECG. The milestones indicate the stage of fellowship training (12, 24, or 36 months, and additional time points) by which the typical cardiovascular trainee should achieve the designated level. Given that programs may vary with respect to the

sequence of clinical experiences provided to trainees, the milestones at which various competencies are reached may also vary. Level I competencies may be achieved at earlier or later time points. The table also describes examples of evaluation tools suitable for assessing competence in each domain.

2.3.2. Training Requirements

All trainees should achieve Level I training in ECG interpretation. Attainment of skills and competencies during the training program is paramount and must be emphasized. There is no established threshold number of studies that can serve as a training landmark; however, interpreting approximately 3,000 to 3,500 ECGs within 36 months should provide ample experience to acquire such competencies. This represents the procedural volume typically required to obtain competency, but the trainee must also demonstrate that competence is achieved, as assessed by the outcomes evaluation measures. Acquisition of competence may be accomplished by 1 or more training periods assigned specifically for ECG interpretation or as a continuous experience through clinical rotations. The cardiovascular subspecialist should be familiar with nearly all clinically encountered arrhythmias (normal variants) and electrocardiographic patterns associated with acquired and congenital heart disease and those that may accompany high-level exercise and athletic conditioning (10). This knowledge should include an understanding of the physiological mechanisms for arrhythmias and ECG waveforms, rather than simple recognition of patterns. The trainee should understand the clinical implications, sensitivity, and specificity of the ECG. Training in ECG interpretation requires additional experience with interpreting complex arrhythmias and those normal and abnormal rhythms associated with pacemaker and implantable defibrillator devices. As such rhythms can be quite complex, trainees should be able to recognize when to seek consultation and assistance from an experienced electrophysiologist. The ECG knowledge base is included in [Appendixes 1 and 2](#), and contains minimum requirements for each trainee.

The trainee should also be familiar with the instrumentation necessary to acquire, process, and store ECGs in both analog and digital formats; understand the effect of acquisition rates and filter settings; and recognize electronic artifacts. In addition, they should be able to accurately measure basic ECG intervals in both analog and digital systems.

There is no Level II or III training in ECG. The interpretive skills for highly complex arrhythmia diagnosis, signal-averaged ECG interpretation, and those normal and abnormal rhythms associated with pacemaker and implantable defibrillator devices would be acquired

TABLE 1 Core Competency Components and Curricular Milestones for Training in ECG/Ambulatory ECG

Competency Component		Milestones (Months)			
MEDICAL KNOWLEDGE		12	24	36	Add
1	Know the basic principles of ECG and the operation/use of the instruments to acquire, display, and store ECGs (see Appendix 3).	I			
2	Know the underlying cellular and ionic mechanisms in the genesis of surface ECGs and the effects of the autonomic nervous system (see Appendix 3).		I		
3	Know the normal values for electrical axis and ECG intervals, durations, and voltage.	I			
4	Know the anatomy of the specialized conducting tissue and the spread of excitation in conduction system and myocardium.	I			
5	Know re-entry, automaticity, and triggered activity mechanisms for cardiac arrhythmias.		I		
6	Know the types and mechanisms of aberrancy.		I		
7	Know capture and fusion complexes and the ECG pattern criteria for distinguishing supraventricular arrhythmias with aberrancy, accessory pathway conduction, pacing, and artifact from ventricular arrhythmias.			I	
8	Know the concepts of concealed conduction and exit block and their manifestation on the ECG.			I	
9	Know the characteristic ECG patterns of key clinical diagnoses (see Appendix 4).			I	
10	Know the ECG changes that are commonly seen in highly trained athletes and the challenges in distinguishing normal from abnormal findings.		I		
11	Know the indications for, and limitations of, continuous (Holter) and intermittent (event) ambulatory ECG recording.	I			
EVALUATION TOOLS: direct observation, ECG and rhythm interpretation during simulation training (e.g., mock codes), global evaluation, and in-training examination.					
PATIENT CARE AND PROCEDURAL SKILLS		12	24	36	Add
1	Technical skills to perform and record high-quality, standard 12-lead ECG tracings.	I			
2	Skill to identify normal ECG patterns, normal variants, and artifacts (including incorrect lead placement).		I		
3	Skill to identify ECG signs of atrial abnormalities and right and left ventricular hypertrophy or enlargement.		I		
4	Skill to identify types and significance of intraventricular conduction delay or block (including functional or aberrant conduction abnormalities).			I	
5	Skill to identify types of atrioventricular dissociation.			I	
6	Skill to identify first-degree, second-degree (types I, II, 2:1, and high-degree), and third-degree atrioventricular blocks.			I	
7	Skill to identify the ECG patterns and localization of cardiac ischemia and infarction.		I		
8	Skill to identify the ECG changes of electrolyte and metabolic abnormalities and drug effects.			I	
9	Skill to identify nonspecific QRS and ST-T wave changes.		I		
10	Skill to identify atrial, atrioventricular, nodal, and ventricular arrhythmias.			I	
11	Skill to identify each of the specific patterns and rhythms in Appendix 4 .			I	
12	Skill to integrate ECG findings into clinical and risk assessments and the management of patients.		I		
13	Skill to select and interpret ambulatory ECG recording studies.			I	
14	Skill to identify normal and abnormal pacemaker rhythms/functions, and when to seek consultation from an electrophysiologist for advanced interpretation.			I	
EVALUATION TOOLS: direct observation, ECG examination, and in-training examination.					
SYSTEMS-BASED PRACTICE		12	24	36	Add
1	Skill to retrieve and utilize ECG tracings in electronic data systems.	I			
EVALUATION TOOLS: conference presentation and direct observation.					

TABLE 1 Core Competency Components, continued

Competency Component		Milestones (Months)			
		12	24	36	Add
PRACTICE-BASED LEARNING AND IMPROVEMENT					
1	Identify knowledge and performance gaps and engage in opportunities to achieve focused education and performance improvement.			I	
EVALUATION TOOLS: conference presentation and ECG examination.					
PROFESSIONALISM					
1	Practice within the scope of expertise and technical skills.	I			
2	Know and adhere to evidence-based and appropriate use criteria for ECG testing.			I	
EVALUATION TOOLS: conference presentation, direct observation, multisource evaluation, and reflection and self-assessment.					
INTERPERSONAL AND COMMUNICATION SKILLS					
1	Communicate testing results to physicians and patients in an effective and timely manner.			I	
EVALUATION TOOL: multisource evaluation.					

Add = additional months beyond the 3-year cardiovascular fellowship; ECG = electrocardiography/electrocardiogram.

during specialized training in electrophysiology (see COCATS 4 Task Force 11 report).

3. AMBULATORY ECG MONITORING

Observation and documentation of cardiac rhythm during daily activities and of the relation between the rhythm disturbances and patient symptoms are important factors for clinical decision making and should be a focus for training in cardiovascular medicine. Major indications for ambulatory ECG monitoring include the following: detection of—or ruling out—rhythm disturbances as a cause of symptoms, detection and assessment of arrhythmias believed to be associated with an increased risk for cardiovascular events, identification and accurate interpretation of ambulatory ST-T wave changes, assessment of the efficacy of antiarrhythmic and anti-ischemic therapy, and investigation of the effects of therapeutic devices (e.g., pacemakers, implantable cardioverter-defibrillators).

Multiple methods of ambulatory ECG recording and analysis are available for clinical use, including continuous short-term recorders (e.g., Holter monitors) and intermittent longer-term recorders (e.g., patient-activated event and loop recorders, auto-triggered recorders, patch-type extended Holter monitoring, and ambulatory telemetry monitoring) (11). The trainee should understand the similarities and differences between these devices; the indications, advantages, and disadvantages of each device; and the potential pitfalls inherent in the technology. In addition, the trainee should have current knowledge about what may represent a “normal” finding for various age groups during

sleeping and waking hours and what should be considered “abnormal,” realizing that the clinical significance of some findings on ambulatory monitoring remains unresolved.

3.1. General Standards

The ACC and the AHA have addressed competency, training requirements, and guidelines for ambulatory ECG (8). The following recommendations are aimed at trainees in cardiovascular training programs.

3.1.1. Faculty

The trainee should participate in interpretation sessions with a staff cardiologist knowledgeable in the indications for the test, the techniques of recording, and the clinical significance and correlations of findings. Faculty should be board-certified in cardiovascular diseases or possess equivalent qualifications. A physician is considered to have equivalent qualifications if he or she trained in a similar environment for a similar duration of time and performed the required number of procedures. If dedicated electrophysiology faculty are available, the trainee should take advantage of this knowledge for evaluating and managing complex arrhythmias. Faculty should be available to discuss individual cases and provide formal educational experiences.

3.1.2. Facilities

Cardiovascular departments (heart stations) should have staff and space available for collecting and organizing ambulatory ECG data, preferably using digital technology. These data should be readily accessible for faculty and fellows in a timely fashion. In addition, access to patients’

medical information, preferably via an electronic health record, is important to correlate findings with clinical status. The reviewer of the ambulatory ECG should be able to locate and communicate with the treating physician to convey critical information.

3.1.3. Equipment

The trainee should be familiar with the various devices that are available for both continuous and intermittent recording of cardiac rhythms (11). Trainees should understand how to place the equipment to collect cardiac monitoring data accurately.

3.1.4. Ancillary Support

Ancillary support should be available to administer ambulatory ECG testing and collect the appropriate data, preferably in an electronic format.

3.2. Training Components

3.2.1. Didactic Program

A comprehensive educational program should be provided to trainees to complement hands-on interpretation of ambulatory ECG recordings. The training program shall include didactic lectures, interactive case presentations, and self-directed learning. The educational offerings for ambulatory ECG should be combined with teaching about ECG and other topics in electrophysiology. Over the course of cardiovascular fellowship training, trainees should understand how to interpret and report ambulatory ECG information and should be taught about advances in ECG technology and the importance of this type of testing in evaluating patients with cardiovascular disease.

3.2.2. Clinical Experience

Trainees should be exposed to a wide array of ambulatory ECG monitors from a mix of patient populations, including those with complex rhythm disturbances and congenital and acquired structural heart disease. Trainees should be responsible for analyzing and interpreting all aspects of the ambulatory ECG study. When appropriate, the trainee should have knowledge of the patient's medical background and rationale for testing. An experienced attending cardiologist in ambulatory ECG should oversee the trainee and be responsible for evaluating and documenting the trainee's progress and skill level. In addition, expert consultation should be sought for complex arrhythmias from faculty with advanced training in electrophysiology, if available.

3.2.3. Hands-On Experience

Trainees should be provided with the opportunity to learn all aspects of ambulatory ECG monitoring, including

understanding available technologies, advising the patient, ordering the test, placing the monitor on or in the patient, and downloading the information. Analysis and interpretation of the data are critical to developing competency in this area. Trainees should also understand how to relay critical findings to the patients and other healthcare team members. Each of these steps should be overseen by an attending cardiologist comfortable with this testing modality.

3.3. Summary of Training Requirements

Refer to [Table 1](#) for a list of ambulatory ECG core competencies.

3.3.1. Training Requirements

Attainment of skills and competencies during the training program is paramount and must be emphasized. There is no established threshold number of studies that can serve as a training landmark. However, interpreting approximately 100 to 200 ambulatory ECGs within 36 months should provide ample experience to acquire such competencies. This volume of procedures is typically required to obtain competency, but there must also be demonstration of achievement of competence, as assessed by the outcomes evaluation measures. Acquisition of competence may be accomplished by 1 or more training periods assigned specifically for interpretation of ambulatory ECGs or as a continuous experience through clinical rotations. Trainees should be exposed to both full-disclosure (complete printout) and computer-assisted ambulatory ECG systems. In addition, trainees should be exposed to transtelephonic and event-recorder devices for prolonged ambulatory ECG. Furthermore, trainees should be exposed to recordings such as artifact, pacemaker, and implantable cardioverter-defibrillator patterns; heart rate variability studies; and repolarization abnormalities. Trainees should demonstrate knowledge of the operation and limitations of a variety of types of ambulatory ECG instrumentation. In addition, all trainees should be skilled in interpreting in-hospital telemetry ECGs. Trainees should understand the indications and limitations of testing from structured training by experienced cardiologists with specific expertise in ambulatory ECG. Such training will provide knowledge to satisfy clinical competence in ambulatory ECG as indicated by the ACC/AHA/American College of Physicians-American Society of Internal Medicine Task Force on Clinical Competence (8).

There is no Level II or III training in ambulatory ECG. The interpretive skills for highly complex arrhythmia diagnosis, insertion and management of implantable loop recorders, and those normal and abnormal rhythms associated with pacemaker and implantable defibrillator

devices would be acquired during specialized training in electrophysiology (see COCATS 4 Task Force 11 report).

4. EXERCISE ECG TESTING

Exercise ECG testing is among the most fundamental and widely-used tests in the evaluation of patients with cardiovascular disease. It is easy to administer, perform, and interpret and is readily available in hospital or practice settings. Initially developed to detect the presence of myocardial ischemia due to coronary artery disease, the exercise ECG is now widely recognized for its utility in predicting prognosis. Exercise test variables beyond the ST segment, especially when used in combination with clinical information, yield important information to predict outcomes and guide therapy in a broad range of individuals. Exercise ECG testing can be applied in the evaluation and management of patients with a wide variety of cardiovascular conditions, including coronary artery disease, valvular heart disease, congenital heart disease, genetic cardiovascular conditions, arrhythmias, and peripheral arterial disease. When appropriately used with adjunctive modalities to measure gas exchange and ventilation, or imaging techniques such as echocardiography or nuclear perfusion imaging, the power of the exercise ECG test is further enhanced. This section provides training and competency requirements specific to exercise ECG testing. Other COCATS 4 Task Force reports will address training and competency requirements for exercise and pharmacological stress testing when combined with imaging techniques.

4.1. General Standards

The ACC and AHA have addressed competency, training requirements, and guidelines for exercise testing and testing laboratories (12-15). The recommendations are congruent and address faculty, facility requirements, emerging technologies, and practice. The trainee should become familiar with each of these standards and recommendations.

4.1.1. Faculty

Faculty should be effective teachers who are experts in the clinical use and interpretation of exercise ECG testing and who perform these tests on a regular basis. Such faculty should be supervised by the physician medical director of the exercise testing laboratory, such that the specifics of exercise test performance, protocols, and interpretation are consistent with the laboratory's policies and standards. The faculty should be board-certified in cardiovascular disease or possess equivalent qualifications. A physician is considered to have equivalent qualifications if he or she trained in a similar environment for

a similar duration of time and performed the required number of procedures.

4.1.2. Facilities

The laboratory should regularly perform exercise tests that involve a broad spectrum of both inpatients and outpatients with a variety of known and suspected cardiovascular disorders. Specific standards regarding the exercise testing environment are outlined by the AHA (14).

4.1.3. Equipment

The laboratory should contain exercise testing equipment for testing and monitoring, as well as emergency medications and equipment as outlined by the AHA (14).

4.1.4. Ancillary Support

The exercise testing laboratory staff generally consists of a variety of personnel that may include exercise physiologists, nurses, nurse practitioners, physicians' assistants, and medical technicians. These individuals often perform several duties, including assessing and preparing patients for the test; conducting the technical aspects of the test, including protocol selection and patient monitoring; and assisting the physician staff with patient management and medical emergencies should the need arise. Appropriate training requirements and information about the cognitive and performance skills necessary to competently supervise exercise tests are available in published guidelines (8,14).

4.2. Training Components

4.2.1. Didactic Program

Didactic instruction may take place in a variety of formats, including, but not limited to, individual instruction during exercise test performance and interpretation sessions, lectures, conferences, journal clubs, grand rounds, and clinical case and correlative conferences. In addition, self-learning—through required reading material that includes relevant guidelines, textbooks, seminal papers, and emerging literature regarding exercise testing—is essential. Such learning material should be provided, updated, and monitored by the exercise laboratory director or other faculty.

4.2.2. Clinical Experience

The trainee must become proficient in the interpretation of commonly used measurements available from the exercise test that are performed in a wide variety of patients with various cardiovascular conditions and other comorbidities. The trainee must acquire a working knowledge of cardiovascular exercise physiology and a keen understanding of appropriate and inappropriate physiological responses to exercise. Understanding all of the technical aspects of testing is essential to ensure proper test

performance and interpretation of results. The trainee must be thoroughly familiar with methods used in determining exercise capacity and its importance in prognostic evaluation and activity prescription. The trainee should become proficient in integrating data such as hemodynamic measurements, exercise ECG analyses, and non-ST-segment variables in both the diagnostic and prognostic assessment of the patient. This training will provide knowledge to satisfy clinical competence in exercise testing, as indicated by the ACC/AHA/American College of Physicians-American Society of Internal Medicine Task Force on Clinical Competence (15).

4.2.3. Hands-On Experience

The training program should be structured so that the trainee is guided in the laboratory by a specially trained exercise professional until the trainee has become proficient at conducting and personally monitoring exercise tests under a variety of clinical circumstances. The trainee must be given the responsibility of initially interpreting all phases of the exercise study, as well as providing that detailed interpretation to, and reviewing it with, the attending cardiologist who is responsible and experienced in exercise testing.

4.3. Summary of Training Requirements

4.3.1. Development and Evaluation of Core Competencies

The training and requirements for exercise testing address the 6 general competencies promulgated by the ACGME/ABMS and endorsed by the ABIM. These competency domains are: medical knowledge, patient care and procedural skills, practice-based learning and improvement, systems-based practice, interpersonal and communication skills, and professionalism. The ACC has used this structure to define and depict the components of the core clinical competencies for cardiology. The curricular milestones for each competency and domain also provide a developmental roadmap for fellows as they progress through various levels of training and serve as an underpinning for the ACGME/ABIM reporting milestones. The ACC has adopted this format for its competency and training statements, career milestones, lifelong learning, and educational programs. Additionally, it has developed tools to assist physicians in assessing, enhancing, and documenting these competencies.

Table 2 delineates each of the 6 competency domains, as well as their associated curricular milestones for training in exercise-ECG testing. The milestones indicate the stage of fellowship training (12, 24, or 36 months, and additional time points) by which the typical cardiovascular trainee should achieve the designated level. Recognizing that programs may vary with respect to the sequence of clinical experiences provided to trainees, the milestones at which various competencies are reached

may vary as well. Level I competencies may be achieved at earlier or later time points. The table also describes examples of evaluation tools suitable for assessment of competence in each domain.

4.3.2. Training Requirements

The committee recommends that all trainees achieve Level I training in exercise ECG interpretation. The training of a cardiovascular fellow should include active participation in a fully equipped exercise testing laboratory. Attainment of skills and competencies during the training program is paramount and must be emphasized. Level I trainees will gain competency in supervision and interpretation of the standard exercise ECG test. There is no established threshold number of studies that can serve as a training landmark; however, personally supervising and interpreting approximately 200 to 300 exercise tests within 36 months should provide ample experience to acquire such competencies. This volume of procedures is typically required to develop competency, but the trainee must also demonstrate competence, as assessed by the outcomes evaluation measures. Acquisition of competence may be accomplished by 1 or more training periods assigned specifically for interpretation of exercise ECG testing; competence may be acquired concurrently with training in an exercise imaging laboratory as part of the training requirements in nuclear cardiology or echocardiography.

The trainee should become knowledgeable in performing both heart rate-limited and maximal or near-maximal treadmill testing and, when available, stationary cycle exercise tests. The training program should provide the opportunity for the trainee to know and understand cardiovascular exercise physiology and pathophysiology. The trainee should also be taught the technical aspects of exercise testing, such as skin preparation, electrode selection and application, choice of exercise testing protocols, blood pressure monitoring during exercise, and monitoring of the patient for adverse signs or symptoms. The trainee should be exposed to the technical aspects and interpretation of cardiopulmonary exercise testing, when available. The trainee should be thoroughly familiar with evidence-based indications and contraindications to exercise testing.

Level I trainees will become proficient in the supervision and interpretation of exercise tests in a wide variety of complex patients for a variety of indications, including the evaluation of coronary artery disease, valvular heart disease, congenital heart disease, genetic cardiovascular conditions, arrhythmias, and peripheral arterial disease. All trainees are expected to know the indications for ordering and the utility of the information provided by cardiopulmonary exercise testing, exercise testing for measurement of ankle-brachial indices in patients with

TABLE 2 Core Competency Components and Curricular Milestones for Training in Exercise ECG Testing

Competency Component		Milestones (Months)			
		12	24	36	Add
MEDICAL KNOWLEDGE					
1	Know the indications, risks, limitations, and contraindications for exercise stress testing both for diagnosis and risk stratification in patients with suspected or known coronary heart disease.		I		
2	Know the principles and details of exercise testing, including the standard requirements of a safe testing laboratory, and technical requirements of proper lead placement and skin preparation.		I		
3	Know the application of Bayes' theorem to interpret exercise test results.		I		
4	Know the common exercise test protocols and targets.		I		
5	Know the concept of metabolic equivalent (MET) and estimation of exercise intensity in different modes of exercise.		I		
6	Know the ECG criteria for a positive test.		I		
7	Know the normal and abnormal heart rhythm and blood pressure responses to graded exercise and in recovery.		I		
8	Know the ECG, exercise capacity, and/or hemodynamic findings indicating a strongly-positive test or adverse prognosis.		I		
9	Know the changes in the ECG that may result from exercise, hyperventilation, ischemia, hypertrophy, conduction disorders, electrolytes, and drugs.			I	
10	Know the criteria and indications for stopping a test before reaching the target heart rate.		I		
11	Know the significance of exercise-associated arrhythmias.			I	
12	Know the use of exercise testing in special groups (women, asymptomatic subjects, post-myocardial infarction, or patients with recent acute coronary syndrome).			I	
13	Know the use, precautions, and contraindications of exercise testing in patients with valvular and myocardial diseases.			I	
14	Know the effects of baseline ECG abnormalities and medications on exercise testing.		I		
15	Know clinical and baseline ECG findings that warrant the addition of imaging to the exercise ECG.		I		
16	Know the indications for the selection of pharmacologic rather than exercise testing.		I		
17	Know the indications for, and the sensitivity and specificity of, adding echocardiographic or nuclear perfusion imaging to stress ECG testing.			I	
18	Known the indications for myocardial perfusion imaging and the appropriate selection of exercise versus pharmacologic stress testing.		I		
19	Know the role of stress testing in assessment of valvular heart disease.			I	
20	Know the role of exercise ECG testing in the evaluation of arrhythmias.			I	
21	Know the role of exercise ECG testing in the evaluation of genetic cardiovascular conditions (e.g., long QT syndrome), including hypertrophic cardiomyopathy.			I	
22	Know the role of cardiopulmonary exercise testing in the evaluation of dyspnea.		I		
23	Know the role of exercise testing in physical activity and exercise prescription in patients with cardiovascular disease.		I		
24	Know the role of exercise testing with measurement of ankle-brachial indices in the evaluation of patients with known or suspected peripheral arterial disease.			I	

EVALUATION TOOLS: chart-stimulated recall, direct observation, and in-training examination.

PATIENT CARE AND PROCEDURAL SKILLS		12	24	36	Add
1	Skill to select clinically appropriate exercise test type and protocol for diverse patient types and clinical settings.			I	
2	Skill to safely perform appropriate heart rate–limited and maximal or near-maximal treadmill exercise tests.		I		
3	Skill to identify and effectively treat complications during and following stress testing.			I	
4	Skill to utilize exercise symptoms and capacity, ECG findings, and hemodynamic response in the risk assessment and management of patients.			I	
5	Skill to interpret limb segmental blood pressure measurements, pulse volume recordings, and treadmill vascular exercise tests.			I	
6	Skill to utilize data from the exercise test in deriving an exercise prescription for patients with cardiovascular disease.			I	

EVALUATION TOOLS: chart-stimulated recall, conference presentation, direct observation, and logbook.

TABLE 2 Core Competency Components, continued

Competency Component		Milestones (Months)			
SYSTEMS-BASED PRACTICE		12	24	36	Add
1	Effectively lead and coordinate the exercise test interprofessional team (including nurses and technicians) to ensure safe and efficient care.			I	
2	Incorporate risk/benefit analysis and cost considerations in test selection.			I	
EVALUATION TOOLS: conference presentation, direct observation, and multisource evaluation.					
PRACTICE-BASED LEARNING AND IMPROVEMENT		12	24	36	Add
1	Identify knowledge and performance gaps and engage in opportunities to achieve focused education and performance improvement.			I	
2	Review practice alignment with guidelines.			I	
EVALUATION TOOLS: conference presentation, direct observation, and reflection and self-assessment.					
PROFESSIONALISM		12	24	36	Add
1	Demonstrate sensitivity and responsiveness to diverse patient populations.			I	
2	Know and adhere to evidence-based and appropriate use criteria for utilizing stress testing.			I	
EVALUATION TOOLS: conference presentation, direct observation, multisource evaluation, and reflection and self-assessment.					
INTERPERSONAL AND COMMUNICATION SKILLS		12	24	36	Add
1	Communicate with and educate patients and families across a broad range of cultural, ethnic, and socioeconomic backgrounds.			I	
2	Communicate testing results to physicians and patients in an effective and timely manner.			I	
EVALUATION TOOL: multisource evaluation.					

Abbreviations as in [Table 1](#).

peripheral arterial disease, and exercise testing performed to evaluate complex arrhythmia and genetic cardiovascular conditions; however, additional time would be needed to acquire the skills to perform and interpret these tests. Level I trainees should be proficient in proper test selection (exercise ECG, exercise imaging, pharmacological imaging) for a given indication tailored to the physical and medical conditions of a given patient (see COCATS 4 Task Force 5 and 6 reports). This includes the use of exercise testing in special populations such as athletes and patients with valvular heart disease or hypertrophic cardiomyopathy.

There is no Level II or III training in exercise ECG testing.

5. EVALUATION OF COMPETENCY

Evaluation tools in ECG, ambulatory ECG, and exercise ECG testing include direct observation by instructors, in-training examinations, case logbooks, conference and case presentations, multisource evaluations, trainee portfolios, simulation, and reflection and self-assessment. Case management, judgment, interpretive,

and bedside skills must be evaluated in every trainee. Quality of care and follow-up; reliability; judgment, decisions, or actions that result in complications; interaction with other physicians, patients, and laboratory support staff; initiative; and the ability to make appropriate decisions independently should be considered. Trainees should maintain records of participation and advancement in the form of a Health Insurance Portability and Accountability Act (HIPAA)-compliant electronic database or logbook that meets ACGME reporting standards and summarizes pertinent clinical information (e.g., number of cases, diversity of referral sources, diagnoses, disease severity, outcomes, and disposition).

The ACC, AHA, and Heart Rhythm Society have formulated a clinical competence statement on ECG (8), and the ACC/AHA have jointly formulated a competence statement on stress testing (15). Self-assessment programs and competence examinations in ECG are available through the ACC and other organizations. Training directors and trainees are encouraged to incorporate these resources into their curriculum in order to document the trainee's competency. In addition, on a regular basis,

faculty should assess and document the trainee's progress, including technical performance and ability to interpret results. The program director is responsible for confirming experience and competence and for reviewing

the overall progress of individual trainees with the Clinical Competency Committee to ensure achievement of selected training milestones and identify areas in which additional focused training may be required.

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KEY WORDS ACC Training Statement, ambulatory electrocardiography, COCATS, electrocardiography, exercise electrocardiography, exercise treadmill test, stress test

**APPENDIX 1. AUTHOR RELATIONSHIPS WITH INDUSTRY AND OTHER ENTITIES (RELEVANT)—
COCATS 4 TASK FORCE 3: TRAINING IN ELECTROCARDIOGRAPHY, AMBULATORY
ELECTROCARDIOGRAPHY, AND EXERCISE TESTING**

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For the purpose of developing a general cardiology training statement, the ACC determined that no relationships with industry or other entities were relevant. This table reflects authors' employment and reporting categories. To ensure complete transparency, authors' comprehensive healthcare-related disclosure information—including relationships with industry not pertinent to this document—is available in an [online data supplement](#). Please refer to <http://www.acc.org/guidelines/about-guidelines-and-clinical-documents/relationships-with-industry-policy> for definitions of disclosure categories, relevance, or additional information about the ACC Disclosure Policy for Writing Committees.

ACC = American College of Cardiology.

**APPENDIX 2. PEER REVIEWER RELATIONSHIPS WITH INDUSTRY AND OTHER ENTITIES (RELEVANT)—
COCATS 4 TASK FORCE 3: TRAINING IN ELECTROCARDIOGRAPHY, AMBULATORY
ELECTROCARDIOGRAPHY, AND EXERCISE TESTING**

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ACC = American College of Cardiology; AHA = American Heart Association; VCU = Virginia Commonwealth University.

APPENDIX 3. ELECTROCARDIOGRAPHIC CORE COMPETENCIES: TECHNICAL ASPECTS AND ELECTROPHYSIOLOGY

Anatomy and Electrophysiology

- Anatomy of the specialized conducting system (sinoatrial node, atrioventricular node, His bundle, bundle branches), concept of the trifascicular conduction system
 - Spread of excitation in the ventricles
 - Difference between unipolar and bipolar leads
 - Einthoven triangle; frontal and horizontal lead reference system
 - Vectorial concepts
 - Significance of a positive and negative deflection in relation to lead axis
 - Relation between electrical and mechanical activity
-

Technique and the Normal ECG

- Effect of improper electrode placement (limb and precordial)
 - Effect of muscle tremor
 - Effect of poor frequency response of the equipment
 - Effect of uneven paper transport
 - Measurement of PR, QRS, QT, normal values/rate correction of QT interval
 - Normal ranges of axis in the frontal plane
 - Effect of age, weight, and body build on the axis in the frontal plane, as well as specific ECG diagnoses (i.e., left ventricular hypertrophy, left ventricular hypertrophy, and strain)
 - Normal QRS/T angle
 - Differential diagnosis of normal ST-T, T-wave variants (e.g., "juvenile" pattern and early repolarization syndrome)
-

Arrhythmias: General Concepts

- Re-entry, automaticity, triggered activity
 - Aberration (various mechanisms)
 - Capture and fusion complexes
 - Escape (passive, accelerated) complexes or rhythms: atrial, junctional, and ventricular
 - Interpolated premature beat
 - Parasystole (atrial, junctional, ventricular), modulated parasystole
 - Vulnerability
 - Exit block
 - Reciprocation
 - Concealed conduction
 - Supernormality
-

ECG = electrocardiogram.

APPENDIX 4. ECG CORE COMPETENCIES: PATTERN AND ARRHYTHMIA RECOGNITION

General Features

- Normal ECG
- Normal variant
- Incorrect electrode placement
- Artifact

Atrial Abnormalities

- Left atrial abnormality
- Right atrial abnormality
- Biatrial abnormality

Sinoatrial Rhythm

- Normal sinus rhythm
- Sinus tachycardia
- Sinus bradycardia
- Sinus arrhythmia
- Sinoatrial pause or arrest
- Sinoatrial exit block

Atrial Rhythms

- Atrial premature complexes (conducted; nonconducted)
- Atrial tachycardia (ectopic)
- Atrial tachycardia with atrioventricular block
- Atrial fibrillation
- Atrial flutter (typical and atypical forms)
- Atrial tachycardia, multifocal

AV Junctional Rhythms

- Premature junctional complexes
- Atrioventricular node re-entrant tachycardia (AVNRT-common and uncommon types)
- Nonparoxysmal junctional tachycardia/accelerated junctional rhythm

- Atrioventricular re-entrant tachycardia (AVRT) with an accessory pathway
- AV junctional escape complex or escape rhythm

Ventricular Rhythms

- Ventricular ectopic complexes
- Accelerated idioventricular rhythm
- Ventricular tachycardia: uniform (monomorphic), multiform (pleomorphic or polymorphic), sustained, nonsustained, bidirectional, and torsades de pointes
- Ventricular flutter, ventricular fibrillation
- Ventricular escape complexes or rhythm

Atrioventricular Relationship and Conduction

- Atrioventricular dissociation due to:
 - Slowing of dominant pacemaker
 - Acceleration of subsidiary pacemaker
- Third-degree atrioventricular block
- Isorhythmic atrioventricular dissociation

Atrioventricular Block

- First degree
- Second degree: 2:1, Mobitz type I (Wenckebach), Mobitz type II, high-degree atrioventricular block
- Third degree (complete)

QRS Voltage and Axis

- Low voltage
- Left axis deviation
- Right axis deviation
- Left ventricular hypertrophy

- Right ventricular hypertrophy
- Biventricular hypertrophy
- Electrical alternans

Intraventricular Conduction Disturbances

- Incomplete and complete left bundle-branch block
- Incomplete and complete right bundle-branch block
- Left anterior and left posterior fascicular blocks
- Indeterminate (nonspecific) intraventricular conduction defects
- Aberrant intraventricular conduction (rate related; Ashman)
- Ventricular pre-excitation syndromes (Wolff-Parkinson-White pattern)

Myocardial Ischemia and Infarction

- ST-T wave changes due to ischemia
- Acute current of injury
- ST-elevation MI
- Q-wave MI
- Abnormal Q waves not associated with infarction
- Time course of ECG changes in MI (acute/recent; age undetermined/old)
- ECG localization of MI

Miscellaneous ST-T, U-Wave Abnormalities

- Nonspecific ST-T wave abnormalities
- Prolonged Q-T interval
- Prominent U waves
- ST-T wave abnormalities secondary to hypertrophy

Pacemaker

- Fixed-rate pacemaker
- Atrial pacing
- Ventricular demand pacing
- Atrial triggered ventricular pacing
- Atrioventricular dual pacing
- Biventricular pacing
- Malfunctioning: demand acting as fixed rate, failure to sense, slowing of rate, acceleration of rate, failure to capture, failure to pace (inappropriate inhibition)

Clinical Diagnoses (Selected)

- Hyperkalemia
- Hypokalemia
- Hypercalcemia
- Hypocalcemia
- Long-QT syndromes (congenital and acquired)
- Atrial septal defect, secundum
- Atrial septal defect, primum
- Dextrocardia
- Mitral stenosis
- Acute cor pulmonale, including pulmonary embolus
- Pericardial effusion
- Acute pericarditis
- Hypertrophic cardiomyopathy
- Brugada disease
- Arrhythmogenic right ventricular dysplasia
- Central nervous system disorder
- Myxedema
- Hypothermia
- Sick sinus syndrome
- Digitalis effect
- Digitalis toxicity
- Effects of other drugs (e.g., tricyclic or antiarrhythmic agents)

ECG = electrocardiogram; MI = myocardial infarction.

APPENDIX 5. ABBREVIATION LIST

ABIM = American Board of Internal Medicine

ABMS = American Board of Medical Specialties

ACC = American College of Cardiology

ACGME = Accreditation Council for Graduate Medical Education

AHA = American Heart Association

COCATS = Core Cardiovascular Training Statement

ECG = electrocardiography/electrocardiogram

HIPAA = Health Insurance Portability and Accountability Act