Cardiopulmonary exercise testing

An underutilized diagnostic tool in Saudi Arabia

Hazzaa M. Al-Hazzaa, PhD, FACSM, *Abdullah F. Al-Mobeireek,* FRCP, *Abdurrahman M. Al-Howaikan,* MSc.

ABSTRACT

Objective: To assess the use of cardiopulmonary exercise testing (CPET) in major hospitals and medical centers throughout the Kingdom of Saudi Arabia (KSA) and to seek information on the way CPET is conducted.

Methods: Self-reported questionnaires on the use of CPET were mailed during the fall of 2002 to 54 major public and private hospitals and medical centers throughout the KSA. The response rate was 64.2%. The returned questionnaires were coded and data were analyzed.

Results: The findings indicated that more than 85% of the sample was not employing CPET in their medical centers. However, all of the surveyed centers were regularly performing stress electrocardiogram tests. Approximately 21% of those medical centers who did not have CPET are planning to have it in the near future. The most frequent reasons for not conducting CPET were lack of equipment, lack of trained technicians and lack of training in interpreting test results. Moreover, the most important reasons for conducting the CPET were pulmonary problems, followed by cardiac disorders. Treadmill and leg ergometer were used most as an exercise mode. Bruce protocol as well as institution specific protocols were equally used during CPET. Finally, there appears a lack of local cardiorespiratory data, especially for healthy Saudi females at all ages as well as older male group.

Conclusion: Cardiopulmonary exercise testing as a diagnostic tool for cardiopulmonary diseases was extremely underutilized in Saudi hospitals and medical centers. Much greater efforts are needed to raise the awareness among physicians on the usefulness of CPET.

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Cardiopulmonary exercise testing (CPET) involves the simultaneous evaluation of the cardiovascular and pulmonary functions during exercise.[1-7] In CPET, gas exchange variables, electrocardiogram (ECG), blood pressure and exercise capacity are all continuously monitored and recorded. In recent years, integrated CPET has become a common procedures in major hospitals and medical centers around the world.[1-7] It objectively assesses the cardiac and respiratory responses of individuals to constant or graded exercise stress.[2,3] These responses can then be compared to previously established "normal" values, so inferences regarding limitation of exercise due to cardiac, respiratory, metabolic, endocrine, neuromuscular, or other factors may be made.[1-11] Furthermore, CPET offers a unique opportunity not only to diagnose specific pathophysiology involving the cardiovascular or ventilatory systems but also to quantify the severity of dysfunction.[2] Indeed, recent joint guidelines from the American College of Cardiology and the

From the Exercise Physiology Laboratory (Al-Hazzaa, Al-Howaikan) King Saud University and the Pulmonary Section, Department of Medicine (Al-Mobeireek), King Faisal Specialist Hospital and Research Centre, Riyadh, *Kingdom of Saudi Arabia*.

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Address correspondence and reprint request to: Prof. Hazzaa M. Al-Hazzaa, Director, Exercise Physiology Laboratory, King Saud University, PO Box 9792, Riyadh 11423, *Kingdom of Saudi Arabia*. Fax. +966 (1) 4684121. E-mail: halhazzaa@hotmail.com

American Heart Association[6] stated that exercise testing with measurement of gas exchange can (1) provide the best estimate of functional capacity; (2) grade the severity of functional impairment; (3) objectively evaluate the response to interventions that may affect exercise capacity; (4) objectively track the progression of disease that may limit exercise capacity; and (5) assist in differentiating cardiac from pulmonary limitations in exercise capacity". Moreover, exercise capacity was recently shown to be a strong predictor of the risk of death in patients referred for exercise testing for medical reasons.[12]

Both treadmill and cycle ergometer are commonly used as a mode of CPET. However, cycle ergometer is widely utilized in clinical practice, because of its safety and accuracy in quantifying work load.[1-4] Furthermore, with the development of rapidly responding electronic analyzers and precise flow meters, today CPET has evolved into fully computerized graphic display of numerous physiologic responses. The use of this CPET has truly expanded around the world, and physicians are now provided with a powerful diagnostic tool to help guiding decisions, regarding medical management in broad spectrum of patients. Despite its worldwide use as a diagnostic tool for the assessment of cardiovascular and pulmonary diseases, personal observation indicated that CPET appears underutilized in the Kingdom of Saudi Arabia (KSA). Therefore, we carried out a national survey to document the use of CPET in major hospitals and medical centers throughout the KSA. It was also the aim of the survey to seek information on how CPET is performed in term of protocols and methods. Finally, we were especially interested in knowing the reasons why many medical centers around KSA are currently not conducting CPET, and possible capacity for such centers to conduct CPET in the future.

Methods. Self-reported questionnaire along with covering letters were mailed during the fall of 2002 to 54 major public and private hospitals and medical centers throughout KSA. The questionnaire consisted of 16 items related to the use of CPET in the kingdom, and the way it is conducted in term of protocols and methods. The chosen hospitals were all considered general hospitals or regional medical centers offering tertiary medical cares. The list of hospitals and medical centers were obtained from the office of the Postgraduate Medical Education of the College of Medicine at King Saud University, Riyadh, KSA. All general hospital and specialized medical centers in the list were included in the survey. After 8-weeks, another letter along with a copy of the questionnaire was again mailed to each one of those centers who did not respond to the first questionnaires. Later, 2 questionnaires were returned due to undelivered. One questionnaire was returned with no response because the hospital was closed (was not opened yet by that time). The total number of the complete returned responses was 34. This gave a response rate of 64.2%. The questionnaires were then coded and the data were entered on the computer and analyzed using Statistical Package for Social Sciences (version 10).

Results. The findings of this study indicated that only 14.7% (5 out of 34) of the surveyed hospitals and medical centers in KSA were conducting CPET, while more than 85% (29 out of 34) were not performing this important diagnostic test at all. However, all hospitals and medical centers in our sample were regularly performing stress ECG tests. For those centers who are currently not conducting CPET, approximately 21% (6 out of 29) were planning to have CPET in the near future, while 32% were not. The remaining 47% of the sample were not sure. **Table 1** shows the name of the departments conducting CPET as well as those departments performing stress ECG only. Pulmonary and exercise physiology departments were the only departments currently involved in CPET in KSA. For the stress ECG, cardiology department was the most to conduct the test, followed by medicine and pulmonary. When centers were asked about the most important reason for conducting CPET, pulmonary disorders ranked first followed by cardiac and metabolic abnormalities. Other important reasons for performing this non-invasive procedure include assessments of cardiorespiratory function for healthy people, and measurements of aerobic fitness for athletes and military pilots. Regarding CPET supervision, it appeared that pulmonologists and

Table 1 - Name of the department conducting exercise testing in Saudi hospitals.

Department name	**N**	**(%)**
Cardiopulmonary exercise testing		
Pulmonary	3	(60)
Exercise physiology	2	(40)
Total	**5**	**(100)**
Stress electrocardiogram testing (only)		
Cardiology	15	(51.2)
Medicine	8	(27.6)
Pulmonary	3	(10.3)
Pediatrics	1	(3.4)
Rehabilitation	1	(3.4)
Anesthesiology	1	(3.4)
Total	**29**	**(100)**

Table 2 - Exercise mode mostly used in cardiopulmonary exercise testing.

Exercise mode	N	(%)
Treadmill	4	(80)*
Leg ergometer	3	(60)*
Arm ergometer	2	(40)*

*more than one mode was used in some centers.

Table 3 - Treadmill protocol used most in cardiopulmonary exercise testing.

Exercise protocol*	N	(%)
Bruce	2	(40)
Institution specifi protocol	2	(40)
Naughton/Balke	1	(20)
Total	**5**	**(100)**

*more than one protocol was used in the same center.

Table 4 - Physiological parameters assessed most in cardiopulmonary exercise testing.

Parameter	N	(%)
Respiratory frequency	5	(100)*
Minute ventilation	5	(100)*
Oxygen uptake	5	(100)*
Carbon dioxide production	5	(100)*
Heart rate	5	(100)*
Oxygen pulse	5	(100)*
Blood pressure	5	(100)*
Respiratory exchange ratio	5	(100)*
Tidal volume	4	(80)*
Ventilatory threshold	3	(60)*
Blood lactate	1	(20)*

*More than one parameter was used by each center.

exercise physiologists are currently supervising the tests. Results also showed that there were usually 2-3 technicians involved in CPET in each centers. For those medical centers doing only stress ECG testing, cardiologists were supervising the most (82%), followed by internists (12.5%) and the remaining percentage was supervised by medical residents or technicians.

Table 2 shows the exercise mode used most for CPET. Treadmill came first with 80% of the centers using it. Leg and arm ergometer were ranked second and third. As to those hospitals and medical centers who were performing only stress ECG tests, treadmill was also the first choice for the majority of them (87%) followed by cycle ergometer (13%), with no one using arm ergometer at all. The type of exercise protocol used during CPET is shown in **Table 3**. Bruce protocol as well as institution specific protocols were equally used during testing. Naughton and Balke protocols, however, were used less often. For those centers conducting stress ECG tests only, Bruce protocol was the most popular one with over 80% of the centers were using it. Naughton and modified Balke protocols made up the reminder. **Table 4** indicates the physiological parameters assessed most in CPET. All of those conducting the test were measuring important cardiovascular and respiratory indices, including respiratory frequency, minute ventilation, oxygen uptake, carbon dioxide production, oxygen pulse, respiratory exchange ratio, heart rate and blood pressure. Tidal volume and ventilatory anaerobic threshold were used by the majority of the centers, while only one center was routinely measuring blood lactate. Furthermore, 60% of the centers conducting CPET were assessing perceived effort using Borg sensory scale. Concerning local normative data, especially for maximal oxygen uptake, 2 centers were having

Table 5 - The most frequent reasons for not conducting cardiopulmonary exercise testing.

Reason	N	(%)
Lack of equipment	12	(41.4)*
Lack of trained technicians	10	(34.5)*
Lack of training in interpreting results	9	(31)*
Not totally convinced of its value	1	(3.4)*
Time consuming	1	(3.4)*

*more than one reason was possible.

norms for healthy young males as well as young athletes (18-29 years). However, only one center was having normative data for children and adolescent boys, and another was having norms for healthy young and middle age males (20-50 years). None was having any normal data for Saudi women at any age group.

The most important reasons for not conducting CPET are shown in **Table 5**. Lack of proper equipments, lack of trained technicians and lack of formal training in interpreting test results were considered the most important reasons for not having CPET in most major hospitals and medical centers in Saudi Arabia. Small percentage of the respondents were either not totally convinced or considered the test time consuming. Finally, when we asked the needs for a training course or workshop in CPET to be organized in KSA, 90% of the centers said it was needed, while only 10% answered no.

Discussion. The present study is the first to report on the use of CPET in KSA. Our findings clearly indicate that contrary to what is happening in major hospitals and medical centers in many developed countries,[2-4,8-12] CPET is definitely underutilized in KSA. Despite this low rate of application in KSA, non-invasive CPET has proven useful in the assessment of heart and lung diseases elsewhere.[2,10] Indeed, CPET offers the investigators the unique opportunity to study simultaneously the cellular, cardiovascular and ventilatory responses under conditions of precisely controlled metabolic stress.[2] There are many diagnoses uniquely made by CPET. Detailed description of such cases is beyond the scope of this paper, but can be found elsewhere.[2,13] Our survey showed that physicians, notably cardiologists and pulmonologists, generally supervise exercise testing. Back in 1980, exercise tests in the United States of America (USA) were directly supervised by physicians more than 90% of the time.[14] However, recent trend indicates that more extensive use of exercise physiologists, physician assistants, physical therapists and nurses in conducting exercise tests, with a physician immediately available for consultation and emergency management.[15] Current guidelines for exercise testing state that supervision can be assigned to a properly trained non-physician when testing apparently healthy young persons (<40 years of age) and those with stable chest pain syndromes.[5,7] Nevertheless, risk of acute myocardial infarction during exercise or soon after strenuous exercise was shown to be greater than the risk during periods of light activity or rest.[16]

Over the past 3 decades, there has been a significant development of both laboratory-based and portable metabolic gas analyzers. This has greatly decreased the time and efforts to perform gas exchange measurements during exercise testing. Currently, many well-known manufacturers are producing a wide range of fully computerized system of gas exchange analyses. Our survey revealed that all of medical centers conducting CPET in KSA did utilize gas exchange parameters effectively, along with cardiac load indices, such as cardiac frequency and blood pressure. However, ventilatory anaerobic threshold was used by some but not all centers. Ventilatory threshold is considered a very useful parameter when interpreting CPET results in healthy and diseased persons.[2,4,10] The findings of the present study indicated that 60% of the centers conducting CPET in KSA were using Borg scale of perceived effort. The subjective rating of intensity perceived by the subjects performing exercise is related to physiological markers of efforts.[17] In general, Borg scale above 18 indicates that the person has reached maximal effort.[5,17] Exercise guidelines from American Heart Association[5] and American College of Sports Medicine[1] recommend using perceived exertion scale. It should be mounted on the wall in clear view of the patient. Descriptions of cardiopulmonary responses of normal healthy subjects to exercise testing are widely published for many populations.[18-20] Maximal cardiorespiratory references for healthy Saudis are currently available for children and adolescents, middle-aged males, and athletes.[24-27] However, there is a lack of normative data for Saudi females of all ages as well as older Saudi males. Such normal standards are needed during both treadmill and leg ergometer, since previous research has shown that maximal cardiorespiratory data for healthy sedentary males during cycle ergometer testing are lower by about 20% compared to those obtained during treadmill testing.[23]

It is well known that in order to stress the cardiorespiratory gas system, exercise testing must involve large muscle groups.[1,6] The most common ergometer that involve large muscle mass are treadmill and leg ergometer. Our survey showed that both treadmill and cycle ergometer were the most often used mode of testing in CPET. For stress ECG tests, treadmill was naturally found the preferred mode of testing. A survey conducted in the USA during 1980, ranked treadmill as number one as the mode of stress testing followed by cycle ergometer.[14] Treadmill is involved walking or running, something almost every one can do. On the other hand, the cycle ergometer is usually less expensive, occupies less space and produces less noise than the treadmill does. In addition, if used during CPET, cycle ergometer permits precise measurements of work load and allows much easier ancillary assessments, such as blood pressure and blood sampling.[2,5] However, a major limitation to cycle ergometer is incoordination and leg fatigue, especially at high work load. This may cause the subject to stop before reaching a true maximal oxygen uptake. Peak oxygen uptake was indeed shown to be higher during treadmill compared with cycle ergometer in case of both healthy persons and patients.[1,3,5,28] American Heart Association guidelines for clinical testing laboratories stipulate that a treadmill should be electrically driven and should accommodate body weight up to at least 157.5 kg.[7] Treadmill should have a wide range of speeds (from 1.6 km to at least 12.8 km) and a variety of elevation settings (from 0-20% elevation).[7] In addition, treadmill platform should be at least 127 cm long and 40.6 cm wide.[7]

The present study showed that Bruce protocol came first as the protocol of choice for exercise testing in the majority of the surveyed centers. Bruce protocol was ranked number one as stress test protocol in the USA.[14] The advantage of Bruce protocol is its universal use and therefore there is extensive published data for it. The protocol with its 3 minute stages allow collecting submaximal data. Its disadvantages are larger inter stage increments in work load that can compromise oxygen uptake estimation. Moreover, the fourth stage in Bruce protocol can be either walk or run, which results in different oxygen costs.[5] However, when comparing maximal heart rate or maximal oxygen uptake, there seems to be no significant difference between protocols as long as the same mode of testing is used.[29] In recent years, the ramp protocol has been increasingly used in exercise testing.[5,30] The protocol starts with a relatively low treadmill speed and increases it until the person's comfortable stride. The inclination is then progressively increased at fixed intervals, starting with zero.[5] Nevertheless, irrespective of the type of protocol, the optimal protocol for any exercise test should last between 6 and 12 minutes, with adjustment for the subject need.[1,5] Our study demonstrated that a large proportion of the centers attributed not having CPET in their institutions to lack of equipments. This was interesting since all the surveyed hospitals and medical centers were already performing stress ECG tests, and all they really need is a good gas exchange analyses system. The added cost of such system with one-year supplies is approximately less than 400,000 Saudi Riyals. This is much less costly than many other diagnostic types of equipment typically found in hospitals. Therefore, it seems that the other 2 reasons combined, namely the lack of training on performing the CPET and the lack of interpreting test results, are the real obstacles for not conducting the test in Saudi hospitals and medical centers. Indeed, 90% of the surveyed centers admitted that there is a real need for a training course in CPET. Such a training course should be considered a priority as part of postgraduate training for physicians in KSA.

Finally, the present study may have one limitation. Not all medical centers who received our questionnaires had responded to us. This has occurred despite follow-up attempts to get the survey back. Ultimately, almost 36% of the hospitals and medical centers did not respond. However, it is our impression that the characteristics of the nonrespondent medical centers were unlikely to differ much from those responding to our survey. Further, it appears no regional bias in the returned questionnaires. Adding to that is the fact that medical care in KSA is seemingly unified.

In conclusion, our survey showed that CPET was extremely underutilized as a diagnostic tool for cardiopulmonary diseases in KSA. Therefore, it is recommended that much greater efforts must be exerted to raise the awareness among the physicians in KSA concerning the utility of CPET in health and diseases.

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