Original Article

Revisiting the clinical utilization of cardiopulmonary exercise testing in Saudi Arabia after 2 decades

A cross-sectional study

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ABSTRACT

الأهداف: لمعرفة مدى شيوع الاستخدامات سريرية لاختبار الجهد مع قياس الوظائف القلبية الرئوية ومعوقات تطبيقه بالمنشآت الطبية في السعودية مقارنة بدراسة سابقة أجريت قبل عقدين.

المنهجية: أُجريت دراسة مستعرضة، حيث تم إرسال استبانة إلى 70 منشأة طبية بالقطاعين العام والخاص، واستجاب منهم 52 (74.2%). تكوّن الاستبيان من 21 فقرة حول مدى شيوع اختبار الجهد مع قياس الوظائف القلبية الرئوية ومعوقات تطبيقه بالمنشآت الطبية في السعودية، بالإضافة لأسئلة تتعلق بوسيلة الجهد والبروتوكول المستخدمين، ونوعية الأشخاص الخاضعين للاختبار. وتم مقارنة النتائج مع نتائج دراسة سابقة أُجريت قبل عقدين.

النتائج: معظم المنشآت الطبية ((37 **منشأة** (71.9%)) لا تستعمل اختبار الجهد مع قياس الوظائف القلبية الرئوية. ومن ضمن 15 منشأة يستخدمونه، هناك 11 منشأة فقط يستخدمونه بشكل منتظم. ونصف (6) تلك المنشآت يستخدمون الاختبار بقسم القلب للكبار. بلغ مدى الاستخدام من 1 إلى 10 مرات بالأسبوع (المتوسط=3)، وأهم أغراض الاستعمال مرتبط بالقلب (7 مراكز). أما الوسيلة الشائعة لإجهاد المفحوص أثناء الاختبار فكانت جهاز السير المتحرك. أهم معوقات استخدام الاختبار عدم وجود الأجهزة اللازمة وعدم توفر الفنيين المتدربين. واتضح ازدياد استخدام الاختبار بنسبة 14.1% واستعمال السير المتحرك بنسبة 10.1% مقارنة بدراسة أُجريت قبل عقدين.

الخلاصة: هناك زيادة إيجابية مقدارها 14.1% في استخدام اختبار الجهد مع قياس الوظائف القلبية الرئوية على مدى عقدين، لكنها تبدو أقل من النسب المأمولة، مما يدعو لجهد منسق من متخذي القرار والمنشآت الطبية للتعاون والتغلب على معوقات استخدام هذا النوع من الاختبار كإجراء متبع من اجراءات الممارسة السريرية بالمنشآت الطبية.

Objectives: To assess the prevalence of cardiopulmonary exercise testing (CPET) usage and identify barriers among major hospitals and medical centers in Saudi Arabia. We also aim to compare these findings with data from nearly 2 decades ago.

Methods: In this cross-sectional study, 70 major hospitals and medical centers were contacted, and 52 (74.2%) responded. The participants involved in this study were healthcare providers proficient in carrying out CPET from different specialties. The survey comprised 21 items covering CPET utilization, exercise mode characteristics, common protocols, types of patients or disorders, and barriers to not carrying out CPET.

Results: The majority (n=37; 71.9%) of the centers reported a lack of CPET utilization. Of the 15 centers that used CPET, only 11 carried out regular CPET. Cardiac-related conditions were the most commonly referred clinical cases (n=7), followed by pulmonary conditions and cardiopulmonary fitness. The common barriers to carrying out CPET have remained unchanged compared to 2 decades ago - that is, the lack of equipment or trained technicians. However, there has been a 14.1% increase in the utilization of CPET and a 10.1% increase in the use of treadmill mode compared to a survey carried out 2 decades ago.

Conclusion: Although CPET utilization has increased over 2 decades, this still falls below the desired benchmark. This highlights the need for collaborative efforts among policymakers, and healthcare institutions to address barriers and improve CPET integration into clinical practice.

Keywords: peak oxygen uptake, cardiopulmonary exercise testing, physical fitness, ventilation, anaerobic threshold

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Cardiopulmonary exercise testing (CPET) has emerged as a pivotal diagnostic tool in the assessment of cardiovascular and respiratory function, as well as overall physical performance.[1,2] It can be implemented for the purpose of performance optimization of training program, assessing functional performance, or for clinical purposes to diagnose symptoms suggestive of cardiopulmonary pathology.[3]

Over the past few decades, the significance of CPET has grown considerably, providing valuable insights into various medical fields. Previous studies have highlighted the potential benefits of CPET in diagnosing, treating, and managing a range of cardiopulmonary disorders.[4-6] The utilization of CPET in clinical decision-making, treatment planning, and prognosis evaluation is highly valuable because of its ability to provide real-time data on an individual's cardiovascular and respiratory responses to exercise. Hospitals and clinics worldwide have successfully used CPET to monitor the prognosis of various diseases, including heart failure, coronary artery diseases, heart valve diseases, pulmonary hypertension, and lung diseases.[4-6] The results obtained from CPET can yield significant functional and prognostic insights relating to individuals afflicted with pulmonary diseases.[7]

As healthcare practices continue to advance, it is crucial to reassess the utilization of diagnostic methodologies regularly to ensure optimal patient care and treatment strategies. In the context of the ever-evolving landscape of healthcare, the proper utilization of advanced diagnostic techniques such as CPET is of paramount importance. In Saudi Arabia, where healthcare advances have rapidly shaped the medical landscape, it is imperative to ensure that such tools are optimally integrated into clinical practices, thereby guaranteeing the delivery of evidence-based care. The kingdom's commitment to elevating healthcare standards necessitates periodic evaluation of existing practices.

In Saudi Arabia, a study published in 2004 showed that CPET was extremely underused as a diagnostic or prognostic tool for assessing cardiopulmonary disorders in the majority of local healthcare facilities.[8] The dynamic nature of healthcare mandates that practices consistently align with current evidence and best practices.[9] Hence, a periodic assessment of CPET utilization is not merely a formality but rather a responsible approach to ensure its effectiveness in the contemporary healthcare context. Therefore, the objective of this study was to investigate the utilization trends of CPET over time. By systematically analyzing the utilization patterns across different medical specialties, patient populations, and clinical scenarios, we aimed to offer insights into the prevalence of CPET utilization. Moreover, by comparing these patterns with data from previous years, we intend to identify any shifts, trends, or improvements in their incorporation into medical practice.

The present study aimed to provide a comprehensive assessment of the clinical utilization of CPET in Saudi Arabia in comparison with utilization patterns reported 20 years ago. By comparing these findings with data obtained nearly 2 decades ago, we can shed light on the extent to which this valuable diagnostic tool has been integrated into clinical practice. By revisiting and comparing the utilization of CPET over time, we aimed to uncover potential gaps, barriers, and successes in its implementation. A comprehensive understanding of CPET utilization can empower healthcare providers to make informed decisions and optimize patient care. Furthermore, it serves as an essential resource for policymakers, medical educators, and healthcare administrators in Saudi Arabia.

Methods. In this cross-sectional study, a self-reported structured survey was adapted from a previous study[8] and distributed among all major public and private hospitals and medical centers in Saudi Arabia from April 2022 to April 2023. The participants in this study consisted of healthcare providers who were skilled in carrying out CPET across various specialized fields. The survey was distributed to department heads in the areas of cardiology, pulmonary medicine, internal medicine, and nuclear medicine. The selected hospitals are classified as general hospitals or regional medical centers that offer tertiary medical care. After 8 weeks, a subsequent correspondence, accompanied by a copy of the questionnaire, was once again dispatched to those centers that did not submit their responses to the preliminary survey. The sample size was based on a previous study that investigated the utilization of CPET in Saudi Arabia, with a sample size of 34 clinicians responding to the survey.[8] G* Power estimate of the sample size was used and statistical power consideration included: effect size (ES)=0.4, 2-sided 5% significance level, and an estimated 80% power. A target of at least 40 medical centers were estimated to be included in this study.

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The study was reviewed and carried out according to the principles of the Declaration of Helsinki. Approval was granted by the institutional review board (IRB: 21-0005) at Princess Nourah bint Abdulrahman University in Riyadh, Saudi Arabia. A consent question was added to ensure the approval of the respondents to participate in the study. All participants were given a full explanation of the study methodology and goals.

To comprehensively investigate the clinical utilization of CPET and its associated factors, a structured questionnaire was developed based on a previous survey.[8] This survey was designed to address various facets of CPET implementation and utilization within the identified healthcare facilities. The questionnaire consisted of 21 constructed items, each tailored to gather specific insights into the prevailing practices and challenges related to CPET. The survey items underwent a process of face validity assessment. In this process, one of the researchers developed the questionnaire items. Additionally, 2 researchers and experts in the field examined the questions' suitability and appropriateness, including evaluating item clarity and the arrangement of items to ensure that they appeared to measure what they were intended to measure.

The questionnaire aimed to stratify respondents into 3 distinct groups based on their CPET practices within their facilities: I) facilities with CPET (a group encompassing institutions that have fully integrated CPET into their clinical practices); II) facilities without CPET (representing healthcare institutions that have yet to incorporate CPET into their clinical practice); and III) facilities that attempted but did not adopt CPET healthcare facilities that initiated efforts to implement CPET but faced challenges leading to its discontinuation. The questionnaire items were designed to comprehensively cover various dimensions of CPET utilization, such as the availability of CPET within the facility, the specific clinical cases for which it was employed, the exercise modes and protocols most frequently used and the parameters, and the perceived benefits and challenges associated with CPET utilization. Additionally, the questionnaire inquired on the presence of trained personnel, such as trained technicians, as well as the barriers contributing to the lack of CPET implementation.

Statistical analysis. The data were examined to detect any missing data and evaluated for normality using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Continuous variables were presented as median and interquartile range (IQR) when the data were not normally distributed, while categorical values were reported as numbers and percentages (%). The Chi-squared test was used to compare categorical variables. To enable a comparison with the CPET data from 2003, the data from that year was extracted and acquired with the necessary permissions from the principal investigator of the published paper in 2004.[8] The level of statistical significance was set at $p<0.05$. All statistical analyses were carried out using Stata version 16 (StataCorp LLC, College Station, TX).

Results. A total 70 major public and private hospitals and medical centers in Saudi Arabia were contacted to participate in this study. The response rate in the present study was 74.2% (n=52). As shown in Table 1, 15 (28.85%) reported that they utilized CPET, while the majority, comprising 37 (71.15%) hospitals or medical centers, did not use CPET. Of the 15 centers that reported employing CPET, only 11 (73.3%) stated that CPET testing is carried out regularly for perioperative assessment or any other indication. When compared to 2 decades ago, only 5 (14.7%) out of the 34 hospitals and medical centers indicated that they carried out CPET.

In the present study, the majority (n=6; 54.54%) indicated that CPET was carried out in the adult cardiology department. Other departments carrying out CPET included exercise physiology (2 respondents,

Table 1 - Implementation of cardiopulmonary exercise testing in Saudi Arabia (N=52).

Variables	n (%)
Availability of CPET	
Yes	15 (28.8)
No	37 (71.1)
Apply CPET in hospital or medical Center (n=15)	
Regularly	11 (73.3)
Not regular	4 (26.7)
Department applying the CPET testing (n=11)	
Adult cardiology	6 (54.5)
Exercise physiology	2 (18.2)
Physical therapy	1 (9.1)
Research center	1 (9.1)
Respiratory therapy	1 (9.1)
Healthcare provider supervises the exercise testing(n=11)	
Cardiologist	6 (54.5)
Exercise physiologist	4 (36.4)
Pulmonologist	1 (9.1)
Number of technicians being involved in CPET in the unit (n=11)	
One technician	3 (27.3)
2 technicians	4 (36.4)
3 or more technicians	4 (36.4)
Frequency of test per week for assessment	3 (1-10)

Values are presented as numbers and precentages (%) or median and interquartile range (IQR). CPET: cardiopulmonary exercise testing

18.18%), physical therapy (one respondent, 9.09%), research centers (one respondent, 9.09%), and respiratory therapy (one respondent, 9.09%).

Among the healthcare professionals carrying out CPET most frequently, cardiologists were frequently involved with 6 (54.6%) respondents. Exercise physiologists were also significantly involved in supervising the test, with 4 (36.4%) respondents. The majority of the CPET units engaged more than 2-3 technicians. In terms of the frequency of CPET tests carried out per week for various assessment purposes, the median was reported to be 3 tests per week, ranging from 1-10. This finding suggests wide variation in the utilization of CPET across different healthcare settings.

The clinical cases referred for CPET and the most common conditions are shown in Table 2. Among the referred clinical cases, cardiac-related conditions were the most frequent (n=7, 63.63%), followed by the pulmonary cases, and cardiopulmonary fitness. Both symptomatic and symptomatic individuals comprised the most common clinical presentation, accounting for 45.45%, followed by asymptomatic cases (36.36%).

Table 2 - Description of the cardiopulmonary exercise testing and referred clinical cases (n=11).

Characteristics	n (%)
Exercise mode	
Treadmill	10 (90.9)
Leg ergometer	2 (18.2)
Arm ergometer	1 (9.1)
CPET protocol	
Modified Bruce protocol	10 (90.9)
Balke protocol	2 (18.2)
Naughton protocol	1 (9.1)
Type of the workload	
Ramp protocol	3 (27.3)
Standard incremental protocol	8 (72.8)
Use of sensory scale for measuring exercise intensity	
Yes	6 (54.5)
No	5 (45.4)
Type of sensory scale used	
Rate of perceived exertion scale (RPE)	3 (50.0)
Parameters usually used as the main predictor of the outcome during CPET	
Peak VO_2	2 (18.2)
Anaerobic threshold	4 (36.4)
Heart rate threshold	2 (18.2)
All	3 (27.3)
Referred cases	
Metabolic	2 (18.2)
Cardiac	7 (63.6)
Pulmonary	3 (27.3)
Cardiorespiratory fitness	3 (27.3)
Most common cases	
Asymptomatic people	4 (36.4)
Symptomatic people	2 (18.2)
Both	5 (45.4)

Values are presented as numbers and precentages (%).
CPET: cardiopulmonary exercise testing, VO_2: maximal oxygen uptake

The description of the CPET parameters and protocols utilized in the study revealed varying practices among the participating medical centers (Table 2). Among the different exercise modes, the treadmill was predominantly used (n=10, 90.9%). Most of the treadmill mode was preferred by the cardiologists followed by the exercise physiologist. The CPET protocols employed exhibited diversity. The most common protocol was the modified Bruce protocol, utilized in 90.9% of cases, followed by the Balke protocol (18.2%), and the Naughton protocols (9.1%). Concerning the type of workload increments utilized, both the ramp protocol (27.3%) and the standard incremental protocol (72.7%) were employed during CPET assessments. The parameters used as the main predictors of CPET outcomes varied. Submaximal tests at the anaerobic threshold level were selected in 36.4% of cases, and 27.3% used a combination of peak maximal oxygen uptake (VO_2), anaerobic threshold, and heart rate threshold. Such diverse approaches to exercise modes, protocols, workload types, and outcome predictors highlight the range of CPET practices across the medical centers surveyed.

As shown in Table 3, comparisons between protocols commonly used by the cardiologists and the exercise physiologists showed that all the cardiologists (n=6, 100%) reported employing the standard incremental protocol, whereas exercise physiologists equally used both protocols, with a significant difference between the 2 groups (p=0.05). Additionally, cardiologists used the CPET mainly for cardiac function, while exercise physiologists employed the exercise test for various reasons, including cardiorespiratory fitness (p=0.04).

Table 4 presents the physiological parameters assessed most frequently used is: heart rate (90.9%), oxygen pulse (81.8%), blood pressure (72.7%), respiratory frequency (54.5), and oxygen uptake (45.4%). Respiratory quotient, anaerobic threshold, ventilatory equivalent of carbon dioxide (VE/VCO_2), and ventilatory equivalent of oxygen (VE/VO_2) were used less frequently.

Various normative data are used by medical centers that employ CPET, spanning from pediatric to adult standards (Table 5). However, there is a paucity of normative cardiorespiratory data for older individuals of both genders (60+ years) and healthy female young adults (18-39 years). However, it is worth mentioning that the availability of normative data has improved over the past 2 decades, during which no normative data for Saudi women of any age group were available.

Table 3 - Comparison between the cardiology and exercise physiology in the utilization of the cardiopulmonary exercise testing.

Characteristics	Healthcare providers		X^2 test	*P*-values
	Cardiologist (n=6)	Exercise physiologist (n=4)		
Mode				
Treadmill	6 (100)	2 (50.0)	3.75	0.15
Leg ergometer	0 (0.0)	1 (25.0)		
Arm ergometer	0 (0.0)	1 (25.0)		
Workload				
Ramp protocol	0 (0.0)	2 (50.0)	3.75	0.05
Standard incremental protocol	6 (100)	2 (50.0)		
Cases				
Metabolic	0 (0.0)	1 (25.0)	7.91	0.04
Cardiac	5 (83.3)	0 (0.0)		
Pulmonary	1 (16.7)	1 (25.0)		
Cardiopulmonary fitness	0 (0.0)	2 (50.0)		
Stress electrocardiogram testing	5 (83.3)	1 (25.0)	6.428	0.011

Values are presented as numbers and precentages (%).

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

Parameters	n (%)
Heart rate	10 (90.9)
O_2 pulse	9 (81.8)
Blood pressure	8 (72.7)
Respiratory frequency	6 (54.5)
Tidal volume	5 (45.4)
O_2 uptake	5 (45.4)
Cardiac output	5 (45.4)
Minute ventilation	4 (36.3)
CO_2 production	4 (36.3)
Anaerobic threshold	3 (27.2)
Blood lactate	3 (27.2)
Respiratory quotient	3 (27.2)
VE/VCO_2 or VE/VO_2	3 (27.2)
Others	1 (9.0)

Values are presented as numbers and precentages (%).
VE/VCO_2: ventilatory equivalent of carbon dioxide,
VE/VO_2: ventilatory equivalent of oxygen

The primary barriers reported among hospitals and medical centers that did not use CPET (n=37) included lack of equipment (91.8 %), followed by lack of trained technicians (83.7 %), and approximately 40.5% (n=12) highlighted the lack of training in interpreting the results of CPET (Table 6). In addition, the majority (76.9%) of the surveyed centers highlighted the need for a training course on CPET. In comparison with the findings of a similar survey carried out 2 decades ago, there has been no change in these barriers, with the major ones being a lack of equipment and trained technicians.[8] Approximately 68.29% of the medical centers not currently carryig out CPET (n=28) expressed their intention to introduce the test in the near future. In comparison to 2 decades ago, there has been an increase of 14.1% in those centers utilizing the CPET, and an increase in the percentage (10.1%) of employing the treadmill mode during the test. In the current survey, the department of cardiology and exercise physiology departments appeared to carry out the testing, prominently, whereas in the previous survey, the department of pulmonary and exercise physiology carried out the testing most often (Table 6).

Discussion. This study revisited the clinical CPET utilization in Saudi Arabia by comparing it with a previous use 2 decades ago. The results revealed that the majority of hospitals and medical centers did not use CPET. A few centers have stated that CPET testing was regularly carried out for perioperative assessments. Most of them indicated that CPET was carried out in the adult cardiology department. The findings also suggest wide variations in the utilization of CPET across different healthcare settings. Cardiologists, followed by physiologists, were most frequently involved in carrying out CPET, with the involvement of more than 2-3 technicians. The reported frequency of CPET tests in terms of the median was 3 tests per week. Cardiac-related conditions were the most frequent clinical cases referred for CPET, followed by pulmonary conditions and cardiopulmonary fitness. The treadmill is the most commonly used CPET parameter in medical centers by most cardiologists using the modified Bruce protocol. The main selected predictor of CPET outcomes was the submaximal test at the anaerobic threshold level.

Table 5 - Normative data, for the types of populations and gender (n=15).

Conditions	Male	Female
Pediatric (6-17 years)	5 (33.3)	5 (33.3)
Young adult (18-39 years)	4 (26.6)	1 (6.6)
Middle age (40-59 years)	7 (46.6)	6 (40.0)
Older people (≥60 years)	1 (6.6)	1 (6.6)

Values are presented as numbers and precentages (%).

Table 6 - Comparison of cardiopulmonary exercise testing findings reported by the current study and a previous survey carried out 2 decades ago.

Variables	Al-Hazzaa et al[8] (N=34)	Current study (N=52)
Availability of CPET		
Yes	5 (14.7)	15 (28.8)
No	29 (85.4)	37 (71.1)
Mode		
Treadmill	4 (80.0)	10 (90.9)
Leg ergometer	3 (60.0)	2 (18.2)
Arm ergometer	2 (40.0)	1 (9.1)
Type of barriers		
Lack of trained technicians	10 (34.5)	31 (83.7)
Lack of equipment	12 (41.4)	34 (91.8)
Lack of training in interpreting the results	9 (31.0)	15 (40.5)
Time consuming	1 (3.4)	1 (2.7)
No cardiologist available	0 (0.0)	1 (2.7)
Not totally convinced of its diagnostic value	1 (3.4)	1 (2.7)
Healthcare provider supervising the exercise testing		
Cardiologist	3 (60.0)	6 (54.5)
Exercise physiologist	2 (40.0)	4 (36.4)
Pulmonologist	0 (0.0)	1 (9.1)

Values are presented as numbers and precentages (%). CPET: cardiopulmonary exercise testing

However, the commonly used CPET protocol differs significantly between cardiologists and physiologists. Cardiologists used the CPET standard incremental protocol mainly for cardiac function, while exercise physiologists employed both standard incremental and ramp protocols for cardiorespiratory fitness. The most common physiological parameters assessed during CPET were heart rate, oxygen pulse, and blood pressure. The lack of equipment and trained technicians was the major barrier among centers that did not use CPET.

Compared to 20 years ago, there has also been an increase in the number of centers using CPET and an increase in the proportion of centers using the treadmill mode during the test. This increase in CPET utilization may reflect, in part, the expansion of the national healthcare transformation program as charted in the Saudi Vision 2030.[10] The lack of equipment and trained experts, as major barriers to the use of CPET, have not changed from the findings of the past survey carried out 20 years ago.[8] However, the majority of medical facilities that do not currently offer CPET stated that they will soon start doing so. The cost of CPET as a barrier to its use may not be as valid as it seems, as the total cost of the equipment represents a fraction of the cost of major diagnostic tools currently used in hospitals, such as CT scans and MRI.

More than half of the respondents (54.6%) in the present study indicated that the test was supervised directly by cardiologists, whereas 36.4% were supervised by exercise physiologists. Nevertheless, the guidelines by the American College of Sports Medicine have evolved over time, allowing well-trained non-physician healthcare professionals to administer the test while supervised by a physician skilled in exercise testing who is immediately available.[11] These non-physician healthcare professionals normally comprise exercise physiologists, nurses, and physician assistants but may include other health professionals.

In a manner similar to the current study, a review published recently offers a useful manual for those involved in the administration and interpretation of CPET, and promotes the use of this specialized reference

examination much more frequently in the appropriate circumstances.[12] Another recent review offered clinical practitioners useful advice on how to apply CPET data to tailor exercise recommendations for individuals who are at risk of or already have cardiovascular disease.[13] Therefore, CPET should be encouraged in the clinical context, and training should be a required element of the medical eduation of cardiologists and respiratory specialists.

Our findings showed that only 27.3% of those using CPET in Saudi Arabia used the ramp protocol during testing. Traditionally, the exercise testing protocol includes increasing treadmill elevation or ergometer load in an incremental fashion. However, with the introduction of the ramp protocol, it was possible to adjust the workload and exercise time individually.[14] Indeed, it was observed that the slope of the relationship between measured and estimated oxygen uptake was higher (closer to the unity line) when using the ramp treadmill protocol than when using the Bruce protocol in patients with heart failure. This is interpreted as over-predicting estimated maximal oxygen uptake in heart disease patients when using Bruce treadmill protocols as opposed to ram protocol.[15]

Assessment of functional capacity during CPET is usually carried out using a motorized treadmill or stationary ergometer. The present survey revealed that the treadmill was used more frequently than cycle ergometry. Historically, the treadmill is the most common exercise testing modality in North America, whereas the cycle ergometer is the preferred mode of testing in most European countries.[15] The treadmill exercise testing is more natural and reflects greater overall major muscle use, thus, yielding more maximal oxygen uptake than cycle ergometers by 10-20%.[11] Upright cycle ergometer testing is usually preferred in subjects with orthopedic limitations, obesity, or balance instability. During exercise, the ventilatory anaerobic threshold is the point of nonlinear increase in pulmonary ventilation and subsequent changes in the VE/VO_2 without immediate change in the VE/CO_2. This is related to the point at which anaerobic metabolism exponentially increases in exercising muscles to sustain energy for work demand. Our findings show that few medical centers in the country utilize this important CPET parameter.

A request for concerted action from governments, healthcare organizations, and other key stakeholders is carried out in light of findings from a recent study and recent literature.[19,20,22-27] in an effort to remove remaining barriers and advance the integration of CPET into regular clinical practice and can be adopted in Saudi Arabia, especially in light of a global public health emergency due to the outbreak of pandemics.[22] Cardiopulmonary exercise testing offers an objective and repeatable opportunity to determine the cause of exertional dyspnea and to calculate the degree of exercise capacity limitation.[20,23] In addition to aiding in the distinction between cardiovascular, pulmonary, and pulmonary vascular illnesses, it can also be useful in revealing the underlying, frequently intricate mechanisms. Therefore, CPET should be carried out prior to the patient undergoing a thorough diagnostic workup that looks for an anomaly that occurs while the patient is at rest and during exercise. Cardiopulmonary exercise testing certainly covers a wider range of potential differential diagnoses than any other medical test, and it is also likely to be more affordable because it aids in diagnosis and treatment choices.[24] In addition, many patients find CPET to be a very helpful component of their clinical examination.[25] All of this, points to the need for much more regular use of CPET in Saudi Arabia, especially given that it provides a look at more important parameters compared with only exercise electrocardiogram (ECG). Additionally, CPET offers a significantly higher diagnostic value compared to non-discriminating exercise performance tests such as an exercise ECG, and a 6-minutes walking test, and more, which do not evaluate exercise cardio-metabolic tolerance. This is primarily due to the ability to identify vital prognostic variables through simultaneous measurement of ventilatory gas exchange, even at submaximal exercise levels.26-28

Study strengths & limitations. The main strength of this study is the assessment of the barriers and frequency of CPET use in Saudi Arabia's major hospitals and healthcare facilities. In addition, by using the same questionnaire and methodology as the earlier research 2 decades ago, the study has revealed the trends taking place in CPET utilization over the time. However, it is imperative to acknowledge and address the limitations inherent in this study. First, the research design employed was cross-sectional and descriptive in nature. This design, while invaluable for providing a snapshot of the current situation, inherently lacks the capacity to establish causal relationships or discern behavioral trends over time. Furthermore, the limited numbers of those carrying out the CPET made it challenging to carry out meaningful statistical tests to effectively compare specific answers to some questions within the study between the findings of 2023 and those of 2003. Therefore, the findings should be interpreted within the

constraints of the study design.[29] Variations in resources, practices, and policies across different institutions may affect the extent to which the identified barriers and utilization patterns apply. Also, no pilot study was carried out before the actual study. The methodology and procedures were based on established practices and prior experience in similar research projects that aim to evaluate the use of CPET in clinical practice.

In conclusion, 2 decades ago, CPET was underutilized in Saudi Arabia. The current study was carried out to investigate the current status of CPET utilization in Saudi Arabia taking in consideration the advancement in healthcare services in Saudi Arabia. Most hospitals and medical centers in Saudi Arabia do not use CPET despite the clinical importance of it. The current study revealed that few centers regularly used CPET testing for perioperative assessment, and it is most often carried out in adult cardiology departments. Cardiologists and physiologists are most frequently involved in CPET, with a median frequency of 3 tests per week. Cardiac-related conditions are the most frequent clinical manifestations of CPET. The most common physiological parameters assessed during CPET are heart rate, oxygen pulse, and blood pressure. Barriers include a lack of equipment and trained technicians. The findings have elicited a call for coordinated measures to be obtained by governments, healthcare organizations, and other key stakeholder to eliminate existing barriers and advance the integration of CPET into routine clinical practice in Saudi Arabia, particularly in a global public health emergency brought on by the outbreak of pandemics.

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