The cost of using Stress ECG as a tool to Determine Rescue Team Fitness to Work – a large chemical production site in China experience.

Jefferelli SB,[a,*] Zhu Q,[b] Surreshan S,[a] Trauth B,[c] Beschmann R,[c] Oberlinner C[c]

[a] Corporate Health Management, EHS Services Asia Pacific, BASF Asia-Pacific Service Centre Sdn. Bhd., Level 26, Mercu Aspire, No. 3, Jalan Bangsar, KL Eco City, 59200 Kuala Lumpur, Malaysia
[b] Central Medical Facility, BASF-YPC Co. Ltd, 210048 Nanjing, China
[c] Corporate Health Management, BASF SE, Carl-Bosch-Strasse 38, 67056 Ludwigshafen am Rhein, Germany

*Corresponding author: jeff.bahrin@basf.com

ABSTRACT: *Rescue Teams (RT)s perform physically demanding tasks. Ensuring they are medically fit to perform related tasks reduces risk of danger to self and others. Stress ECG is a key component of RT Fitness to Work (FTW) assessment in BASF. From 2019 to 2024, 1900 stress ECGs were conducted in a large chemical production site associated with BASF in China to determine RT FTW. One thousand eight hundred and thirty-six (96.6%) were fit and sixty-four (3.4%) were unfit. The detection rate of unfit for RT from stress ECG was 3.4% (64/1900) The total cost for conducting the stress ECGs was USD 64,600. The cost of detecting unfit case by Stress ECG was 1,009 USD per case (USD64,600/64). There were no medical complications among RT (who were certified fit) during training or responses. There are significant risks (severe medical complications including fatality, safety compromise) including potential costs (medical, litigation, moral etc.) if an unfit person performs RT tasks. The authors' view is that the cost of using Stress ECG as a tool to determine Rescue Team Fitness to Work is reasonable.*

Keywords: *Stress ECG, Fitness to Work, Rescue Team*

1.0 INTRODUCTION

The chemical production site where study was conducted is associated with BASF, located in China, established in 2001, and currently employs approximately 2150 employees.

The roles of the emergency services are challenging and often physically demanding. Readiness to meet these challenges and demands is a fundamental requirement for staff to deliver their roles safely and effectively (Nevola VR et. al., 2019). At this site, Rescue Team (RT) which are also known as HAZMAT (Hazardous Materials Emergency Handling) Team are expected to retrieve victims and perform strenuous physical activities such as climbing vertical ladders often using heavy equipment such as

self-contained Breathing Apparatus (SCBA) and Personal Protective Equipment such as chemical protection suit. Rescue team workers face several cardiovascular vulnerabilities due to their demanding jobs. High-stress situations tend to elevate stress hormones like adrenaline and cortisol, increasing cardiovascular risk. Physical exertion, such as lifting heavy equipment and prolonged activity, strains the heart. In addition, inhaling smoke, chemicals, and other hazardous substances harms cardiovascular health and irregular, long working hours often lead to chronic sleep deprivation, a significant heart disease risk factor. Frequent exposure to traumatic events can also cause mental health issues like Post Traumatic Stress Disorder (PTSD) and depression, which are closely linked to cardiovascular health. Additionally, the demanding nature of their work makes it difficult to maintain healthy eating and exercise habits, contributing to poor cardiovascular health (American Heart Association, 2023).

Fitness to Work (FTW) serves as a preventive strategy within a workplace. Assessments of an employee's fitness for work, which evaluate their capability to perform job duties safely without posing risks to themselves or others, are typically carried out during the hiring process, when there are modifications to job responsibilities, or following health-related issues. These evaluations are essential for ensuring that employees can meet the physical and psychological demands of their roles, thereby safeguarding workplace safety and productivity (Hobson et.al, 2019). During this process, the functional capability of assessee is determined and compared with the tasks required by job. The examining doctor needs to determine current ability of assessee to perform job physically and psychologically without significant risk to self or others. For RT in BASF, the assessment includes history taking and physical examination including visual acuity and otoscopy, full blood count, fasting blood sugar, Alanine transaminase (ALT), Gama-glutamyltransferase (GGT), urinalysis air conduction audiometry, chest x-ray, spirometry, resting and stress ECG. Special concerns would include cardiopulmonary and musculoskeletal system, metabolic disorders, claustrophobia and ability to achieve a full seal when using masks (BASF, 2024).

Stress electrocardiography (ECG), commonly referred to as an exercise electrocardiogram or treadmill test, is a valuable, cost-effective, and non-invasive diagnostic tool that provides critical cardiopulmonary insights for both healthy individuals and those with underlying health conditions. This assessment involves monitoring the heart's electrical activity during physical exertion, allowing for the evaluation of cardiovascular responses to stress (Chai et al., 2020). The main purposes of stress ECG are to detect irregular heart rhythms (arrhythmias) that may only occur during physical exertion, to diagnose coronary artery disease by identifying inadequate blood flow to the heart muscles, evaluate a patient's exercise capacity, and to assess the effectiveness of treatments for heart-related conditions and guide the selection of appropriate treatment options. There are many advantages of Stress ECG such as it being non-invasive, that does not require invasive procedures or injections, making it a safe and comfortable option for most patients. It is also widely available, and are commonly performed in medical facilities, making them easily accessible for patients and healthcare providers. Stress ECG is also more cost effective compared to other types of stress tests, such as stress echocardiograms or nuclear stress tests, making it generally more affordable. However, it is important to note that this method has several limitations, particularly concerning its sensitivity. Research indicates that the diagnostic accuracy of stress ECG can be compromised, especially in patients with pre-existing ECG abnormalities, which may lead to false-negative results (Bjørnstad et al., 1995). Stress ECG has a lower accuracy rate in detecting coronary artery disease than stress echocardiogram and nuclear stress test. False positives and negatives can occur, potentially leading to unnecessary further testing or missed diagnoses. There are also possibilities of inconclusive results. Certain factors, such as a pre-existing ECG abnormality, obesity, or specific medications, can make it difficult to interpret the results of a stress ECG, leading to inconclusive findings. Stress ECG can also be unsuitable for some patients because they are unable to perform the required exercise, necessitating medication-induced stress testing or alternative diagnostic methods. There is also no direct visualization of heart structure. Unlike stress echocardiogram and nuclear stress

test, stress ECG does not provide direct visualization of the heart's structure, limiting its ability to detect certain heart conditions (Cardiac Stress Tests - Stress ECG, Stress Echo and Nuclear Stress, 2024). Stress ECG can also be used to evaluate reaction of blood pressure during the exercise and for early detection of hypertension and other malfunction of circulatory system. Before proceeding with stress ECG test this site contraindications were evaluated and considered.

There are various types of economic evaluations in healthcare. Cost effective analysis (CEA) is one the most used type of economic evaluation in healthcare. It involves identifying all relevant costs such as treatment, hospitalization, lost productivity and the health outcomes associated with each intervention. The results are often expressed as an incremental cost-effectiveness ratio, which represents the additional cost per unit of health outcome gained by choosing one intervention over another (Drummond et. al, 2023). There are other related evaluations as well such as Cost Utility Analysis, that follows a similar methodology to CEA but incorporating quality of life weights, or utilities, into the evaluation framework. This allows for a more comprehensive assessment of health interventions by translating clinical outcomes into quality-adjusted life years (QALYs) (Chatterjee et al., 2015). Cost Benefit Analysis, which involves identifying and quantifying all relevant costs and benefits, including those not directly related to health such as education and environmental impact (Boardman, A. E et. al., 2018), Cost Minimization Analysis, which focuses solely on identifying the least costly option (Deborah Caldwell et. al., 2007), and Cost Consequence Analysis, which is a form of comparative economic analysis that evaluates two or more policy alternatives in terms of their relative costs and outcomes (Turner HC et. al., 2021).

A study among RT in BASF Indonesia found that the cost to identify one unfit case was USD 12,721 and this cost was deemed reasonable (Jefferelli SB et al., 2024). To the best of author's knowledge there is no other publication on economic evaluation of stress ECG as a tool to determine FTW as RT. This study will answer what is the detection rate of unfit RT and cost based on experience in at this site. Further in-depth studies are required to shed more light on this subject.

2.0 METHOD

This study was based on data over a six-year period (2019-2024). Potential RT members at this site were selected after initial assessment (pre-stress ECG) which were part of annual health check. Assessment included medical history, physical examination, basic blood investigations including renal function, basic cardiology assessments (risk factors), resting ECG, and lung function test. All potential RT members at this site who were included in study population. Participants who were certified fit after Stress ECG were classified as fit whereas those who required further assessment were declared unfit. Stress ECG results including costs were analysed and summarised. No pilot studies or statistical analysis was done.

3.0 RESULTS

When compared to the general site population, the study sample had higher percentage of males (98% compared to 80%), were younger (average age-36.68 compared to 41, range, 20-59 compared to 22-63) and were mostly performed non-office work (98% compared to 63%) (Table 1).

Table 1 Comparison of overall site employees and study sample (2024)

Gender	Overall Site Employees 2024		Study population (potential RT)	
	Number	Percent	Number	Percent
Male	1740	80	565	98
Female	454	20	10	2
Total	2194	100	575	100

Age	Average		Average	
	41		36.68	
	Range		Range	
	22-63		20-59	

Work Type	Number	Percent	Number	Percent
Non-office	1393	63	562	98
Office	801	37	13	2
Total	2194	100	575	100

During this study period, a total of 1900 Stress ECGs (1846-male, 54-female) were done for potential RT members in this site (Table 2).

Number or percentage of cases certified fit based on Stress ECG were: 548 or 98.56% in 2019-2020, 47 or 97.92% in 2021, 529 or 96.18% in 2022, 171 or 100% in 2023, 541 or 94.09% in 2024. Number or percentage of cases certified unfit were: 8 or 1.44% in 2019/2020, 1 or 2.08% in 2021, 21 or 3.82% in 2022, 0 or 0% in 2023 and 34 or 5.91% in 2024. Total number of cases or percentage certified fit from 2019-2024 were 1836 or 96.6% whereas 64 or 3.4% were certified unfit (Table 2).

Table 2 FTW for RT test results by year

Year	Result	Number	Percentage
2019-2020	Fit	548	98.56
	Unfit	8	1.44
	Total	556	100.00
2021	Fit	47	97.92
	Unfit	1	2.08
	Total	48	100.00
2022	Fit	529	96.18
	Unfit	21	3.82
	Total	550	100.00
2023	Fit	171	100.00
	Unfit	0	0
	Total	171	100.00
2024	Fit	541	94.09
	Unfit	34	5.91
	Total	575	100.00

Stress ECG Assessment Cost
Total direct cost of each Stress ECG was USD 34. Total direct cost for 1900 tests were 64,600 USD.
Direct cost of detecting each unfit case by Stress ECG was USD 64,600/64 = 1,009 USD per case
Direct cost of determining each fit case based on Stress ECG was USD 64,600/1836 = 35.2 USD per case

Pre-Stress ECG Assessment Cost
Direct cost of conducting initial check (annual medical) = 41 USD per person

Total assessment Direct Cost
Direct cost of Pre-Stress ECG and Stress ECG assessment to detect each unfit case = USD 1,050 (USD41+USD1,009)
Direct cost of Pre-Stress ECG and Stress ECG assessment to determine each fit case = USD 76.2 (USD41+USD35.2)

During the study period, none of the RT members developed medical issues during training or rescue activities.

4.0 DISCUSSION

Medical screening for rescue team members is crucial to ensure they can perform their duties safely and effectively. The screening involves evaluating overall physical health, including cardiovascular, respiratory, and musculoskeletal systems, through general health assessments, physical fitness tests to assess strength, endurance, and agility, and vision and hearing tests to ensure adequate capabilities. Additionally, psychological evaluations are conducted to identify any conditions that could affect performance under stress, along with stress management evaluations to assess the ability to handle stressful situations. The screening also includes identifying pre-existing medical conditions that could be worsened by rescue activities and reviewing current medications to ensure they do not affect performance. Ensuring up-to-date vaccinations for diseases like tetanus, hepatitis B, influenza, and others relevant to the deployment area is also part of the process. Specialized screening on past exposure to hazardous materials or environments will also identify any special needs or accommodations required. These criteria help ensure that rescue team members are physically and mentally prepared for the demanding nature of their work (Centres for Disease Control and Prevention, n.d.).

FTW are often conducted and involve different tests and standards. However, publication on the cost of using certain tools such as stress ECG to determine FTW for RT is limited.

A similar study on FTW for RT was conducted and comparison of some key points are as follows (BASF Indonesia) (Table 3). An important difference between both studies is that in BASF Indonesia, further FTW assessment was conducted for those suspected to be unfit after Stress ECG before determining FTW status. However, in this study in China, those suspected as being unfit after Stress ECG were immediately deemed unfit for RT work. Although further assessment was also offered, the findings would not change their FTW status.

The FTW assessment of the RT in this study incorporates checks on medical history, physical examination, basic blood investigations, basic cardiology assessments (risk factors), resting ECG, and lung function tests during their annual health checks which costs 41 USD per person. Those deemed suitable by the company medical team and external hospital will be sent for further assessment which includes resting ECG, blood pressure and stress ECG which costs 34 USD per person.

There are some differences in terms of the type of assessment conducted in Indonesia, whereby RTs undergo initial assessment which includes medical history, physical examination, basic blood investigation, stress ECG, cardiology assessment, which costs USD 31.60 per person. Those who require further assessment will undergo cardiac CT and if necessary further blood tests which costs 235.75 USD per person. Comparison of results of this study are shown in Table 3 (Assuming no further FTW assessment) and Table 4 (With further FTW assessment) below.

Table 3 Comparison with results of this study and BASF Indonesia (BI) study assuming no further FTW assessment

Element	This study	BASF Indonesia
Further FTW assessment done	No	No
Number of cases assessed	1900	313
Percentage of cases Fit	1836 (96.6%)	301 (96.2%)
Percentage of cases Unfit	64 (3.4 %)	12 (3.8%)
Total cost of assessment	USD 64,600	USD 9,892
Cost to determine each unfit case	USD 1,009	USD 824

The percentage of cases that were certified fit and unfit if only based on stress ECG result in this study was similar to study in Indonesia (assuming no further assessment). In this study, the total cost of assessment was about 18% higher to identify each unfit case (Table 3).

Table 4 Comparison with results of this study and BASF Indonesia (BI) study with further FTW assessment

Element	This study	BASF Indonesia
Further FTW assessment done	No	Yes
Number of cases assessed	1900	313
Percentage of cases Fit	1836 (96.6%)	312 (99.7%)
Percentage of cases Unfit	64 (3.4 %)	1 (0.3%)
Total cost of assessment	USD 64,600	USD 12,671
Cost to determine each unfit case	USD 1,009	USD 12,671

The percentage of cases that were certified fit and unfit based on single stress ECG result without further assessment in this study was different when compared to study in Indonesia when additional FTW assessment was conducted. The number of those who were certified as Fit was less in this study compared to study in Indonesia. This is expected because in this study those who could not be certified fit based on single Stress ECG did not have the opportunity to undergo further FTW assessment. Further FTW assessment would have likely to have resulted in more being certified fit. The total cost of assessment to determine unfit case was also higher because more tests were offered after Stress ECG (Table 4).

From a FTW assessment cost perspective, it would be cheaper to determine fitness without offering further FTW assessment when assessor is unable to certify person fit from Stress ECG. However, such strategy would also end up excluding some people who may have been able to perform RT work. This can be an issue in sites with inadequate potential RT members.

During study period this site has managed to detect 64 unfit cases. This has managed to reduce risk of severe medical complications while performing RT tasks. There are various potential outcomes when a person with cardiac condition detectable on stress ECG does not undergo assessment and performs physically demanding tasks. There is an increased risk of cardiac events such as myocardial infarction (heart attack) or sudden cardiac arrest. Stress ECG can help identify individuals at risk for

these events during exertion (Maron, B. J., et al., 2003). The costs associated with cardiac events are high worldwide both in direct and subsequent treatment, for example in the Unites States, it ranges from USD $6,699 to USD $56,024 with a mean inpatient cost of USD $16,981 (Chapman et al., 2011). Long-term heart damage resulting from acute cardiac events can lead to chronic health issues and subsequent healthcare costs as well. According to (Martin et al, 2019), the costs associated with arrhythmias, particularly atrial fibrillation, are substantial, as indicated by the systematic review conducted which highlights the direct and indirect costs linked to stroke and bleeding events in patients with atrial fibrillation. One such reference in the study quantifies the total costs $19,989 in Denmark (Jakobsen et al, 2016). Other benefits would include opportunity for early intervention for unfit cases and perception that company cares for employees' safety by ensuring they are FTW before performing physically demanding work.

From the authors' perspective this indicates that stress ECG is a reasonable tool to determine FTW for RT work. This is due to low relative direct cost of detecting a case which is a one-time cost of 1009 USD or 64 cases for USD 64,600 over a period of 6 years in this study, compared to the recurring cost of missing a case which needs further medical attention which can range upwards to approximately 56,000 USD (Chapman et al., 2011). If 64 cases were missed the potential costs would be even higher. In Indonesia, the direct cost of detecting a case was higher at 12,671 USD. This was because further assessment was conducted for those suspected to be unfit after initial Stress ECG before determining FTW status.

Medical fitness to work tests are generally reliable. Standardized tests by skilled and experienced person administering the test enhances reliability. While medical tests including stress ECG are useful for assessing an individual's ability to perform job-related tasks safely and effectively, they should be part of a comprehensive evaluation process (Gagne et al, 2010).

Among the limitations of this study are, it is from only one company in one country and detailed cost analysis was not done. We recommend more comprehensive studies on this subject. There are also possibilities to use alternate cost-effective methods in future studies. For example, recent advancements in AI-based diagnostic tools have shown significant promise in accurately predicting cardiovascular events with greater efficiency and lower costs compared to traditional methods like stress ECG. AI algorithms can analyze vast amounts of data quickly, providing real-time insights and reducing the need for extensive physical testing (Singh, Manasvi et al, 2024).

5.0 CONCLUSION

The total cost of Stress ECG was 64,600 USD while the cost of detecting unfit case for RT by Stress ECG was 1,009 USD per case (USD64,600/64). Those certified fit did not experience any cardiovascular complication during training or response to an incident. The study highlights the importance and financial implications of using stress ECGs as part of the Fitness to Work (FTW) assessment for Rescue Team (RT) members. While the publication on the cost of using such tools is limited, this study provides valuable insights by comparing it with a similar study conducted in BASF Indonesia. The key difference lies in the approach to further FTW assessment, which significantly impacts the cost and outcomes. From a cost perspective, it may seem cheaper to determine fitness without offering further assessments. However, this approach risks excluding individuals who could potentially perform RT work, which can be significant in sites with limited RT members. The study also highlights the benefits of early detection of unfit cases, including reducing the risk of severe medical complications and associated high costs of cardiac events.

The authors' view is that cost of using Stress ECG as a tool to determine Rescue Team Fitness to Work is reasonable compared to the cost of missing a case which needs further medical attention. Larger studies with more sophisticated cost analysis are recommended to confirm this assumption.

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