

Field Study

Usefulness of a Portable Internet-enabled ECG Recording System for Monitoring Heart Health among Japanese Workers Residing Abroad

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Abstract: Usefulness of a Portable Internet-enabled ECG Recording System for Monitoring Heart Health among Japanese Workers Residing Abroad: Isamu KABE, et al. Health Administration Department, Furukawa Electric Co., Ltd.—Objective: The aim of this study was to examine the usefulness of a portable Internet-enabled ECG recording system (iECG) in monitoring the heart health of Japanese individuals working abroad. **Methods:** This study included 24 male Japanese individuals working abroad, who had been found to have risks of cardiovascular diseases (CVDs) at periodic health checkups. The subjects were instructed to send ECG recordings obtained by the iECG via a personal computer from their countries of residence. Interpretations of the ECG results were shared with the participant and the participant's occupational physician via e-mail. Further, a questionnaire survey was conducted among the subjects to determine the usefulness of the iECG. **Results:** Only 21 subjects (53.7 ± 5.2 years) could send their ECG recordings from their countries of residence. During the monitoring period (average, 0.7 ± 0.3 years), 504 ECG recordings were obtained using the iECG. No new CVD events were observed. The iECG monitoring recorded ST-T abnormality in 4 subjects (19%), ST-T abnormality plus left bundle branch block in 1 subject (5%), bradycardia in 1 subject (5%), atrial fibrillation in 1 subject (5%), short PR interval in 1 subject (5%) and normal findings in 13 subjects (61%). The questionnaire results showed

a 68% rating for satisfaction, 58% rating for comfort, 68% rating for device utility and 37% rating for lifestyle improvements brought about by device use. **Conclusions:** The iECG could serve as a useful support tool for monitoring heart health in Japanese workers residing abroad with risk factors of CVDs. (J Occup Health 2014; 56: 387–392)

Key words: Cardiovascular disease, Internet, Portable ECG

In recent times, the immense stress that most individuals suffer due to work and life pressure has been a significant social problem. Although the relationship between work-related stress and death has not been firmly established, previous studies have found that individuals with considerable work-related stress have a 5–20% higher probability of suffering from cardiovascular diseases (CVDs) than those with low work-related stress^{1,2}, and this association between CVDs and work stress has been corroborated by several other studies. In 2008, the World Health Organization (WHO) claimed that CVDs alone were responsible for 30% of the total deaths globally, and this value has been increasing annually³. The WHO also reported that over 50% of CVD-related deaths can be prevented by proper patient monitoring⁴.

In 2012, 18,490,667 Japanese individuals emigrated from Japan, and over 537 Japanese individuals died abroad, mainly because of cerebrovascular diseases or CVDs⁵. Individuals who reside abroad are unable to undergo routine health checkups, which greatly increases the probability of sudden death. One solution for this problem is a portable system for monitoring health status. Transtelephonic electrocardiographic event monitors (TTMs) have proved useful and cost effective for evaluation of adults with palpitations, syncope, or presyncope^{6–9}. Thus, a portable capacitive electrocardiogram (ECG) may be suitable for the diagnosis of myocardial infarction¹⁰. In fact, an

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Abbreviations

AF: atrial fibrillation, BP: blood pressure, BMI: body mass index, CVD: cardiovascular disease, HbA1c: glycated hemoglobin, HDL: high-density lipoprotein, iECG: Internet-enabled electrocardiogram recording system, LDL: low-density lipoprotein, TTM: transtelephonic electrocardiographic event monitor

Internet-based ECG system offers the potential to monitor many patients simultaneously from local and remote locations where Internet access is available¹¹.

The present study examined the usefulness of a portable Internet-enabled ECG recording system (iECG) in monitoring the heart health of Japanese individuals working abroad.

Materials and Methods

Subjects

Twenty-four Japanese men working abroad who were found to have risk factors of CVDs (age \geq 40 years, smoking, hypertension, dyslipidemia, diabetes, obesity, ECG abnormalities or a current history of CVDs) at periodic health checkups were enrolled. All participants provided written informed consent, and the study protocol was approved by the Ethics Committee of the National Center for Global Health and Medicine, Japan.

Monitoring devices and protocols

The iECG is diagrammatically shown in Fig. 1. A portable home ECG monitoring device, a CG-2100 Personal 1-Lead ECG Monitor (Card Guard, Israel) (Fig. 2), was developed for evaluation of patients with suspected arrhythmias. This device is a pocket-sized event monitor powered by two 3 V batteries. It has a bipolar lead between the right hand and V5. The recording time is approximately 30 s.

The study subjects were instructed to send ECGs recordings obtained by the iECG via a personal computer (PC) in their countries of residence to a call center in Japan (MJG Cardiovascular Institute, Saitama, Japan) at least once a week. The ECG recordings were analyzed automatically, and the results were confirmed and assessed by a cardiovascular specialist. The ECG findings were shared with the participant and an occupational physician via e-mail.

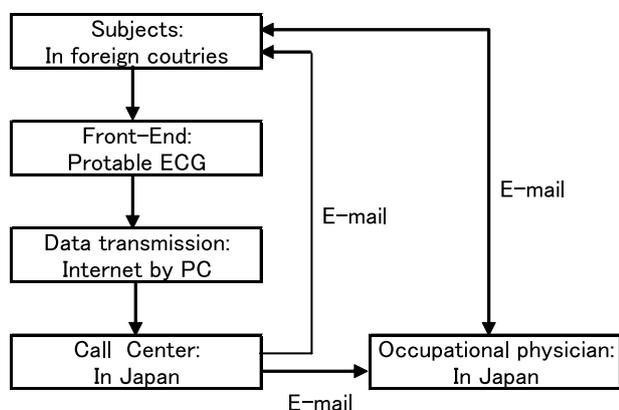


Fig. 1. System block diagram showing Internet transmission of ECG data.

The trial period was October 2010 to March 2012.

In March 2012, a questionnaire survey was conducted among the study subjects to determine subject satisfaction and comfort with respect to use of the portable iECG system, their opinion of its utility and improvements in daily life resulting from its use.

The survey item concerning about the satisfaction they felt concerning use of a portable iECG, “Please rate on the following scale your satisfaction concerning use of the portable iECG”, was to be answered with “5 Very satisfied”, “4 Satisfied”, “3 Neutral”, “2 Unsatisfied” or “1 Very unsatisfied”. The item regarding the comfort to undergo the device, “Please rate on the following scale your comfort with respect to use of the portable iECG”, was to be answered with “5 Very comfortable”, “4 Comfortable”, “3 Neutral”, “2 Uncomfortable” or “1 Very uncomfortable”. The item concerning the utility of using the device, “Please rate on the following scale the utility of the portable iECG for individuals in foreign countries”, was answered as “5

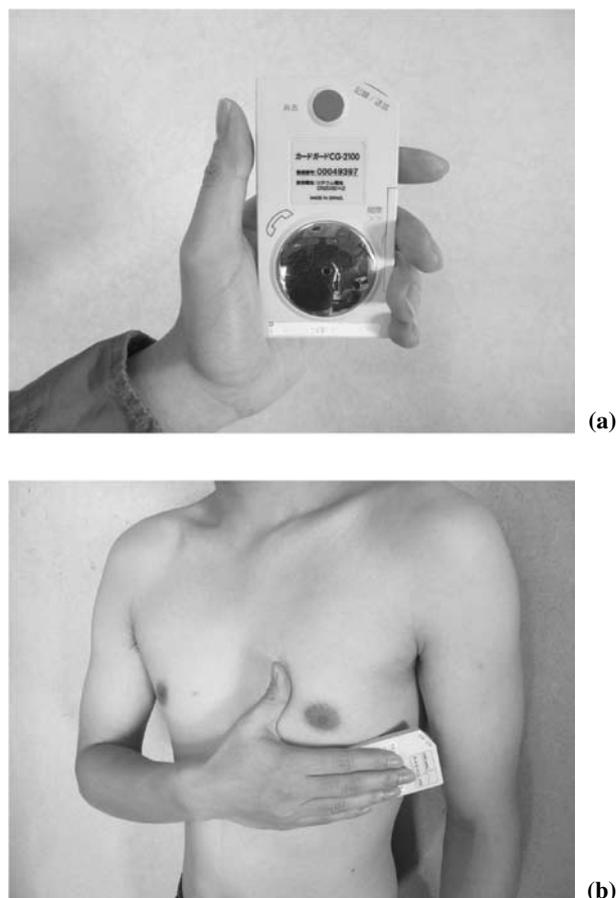


Fig. 2. The CG-2100 portable ECG system (a). Participants applied one of the electrodes to the chest and the other to the right hand (b). The device records 30-s epochs. The ECG recordings can be transferred to a call center in Japan via the telephone or Internet.

Very usable”, “4 Usable”, “3 Neutral”, “2 Unusable” or “1 Very unusable”. Finally the item concerning the improvement in the daily life resulting from using the device, “Please rate the changes in your daily lifestyle resulting from portable iECG use”, was to be answered with “5 Better”, “4 Slightly better”, “3 No change”, “2 Slightly worse” or “1 Worse”.

General health examination

In Japan, employees are obliged to undergo general health checkups at least once a year under the Occupational Safety and Health Law. These checkups follow standardized protocols^{12, 13)} and included the results of anthropometric and biochemical measurements, such as height; body weight; waist circumference; blood pressure (BP); and levels of high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, fasting plasma glucose, glycated hemoglobin (HbA1c), aspartate aminotransferase, alanine aminotransferase and γ -glutamyl transpeptidase, as well as any information on disease history. The data also include chest X-ray and ECG scans taken at rest. Body mass index (BMI) is calculated as weight in kilograms divided by the square of height in meters. HbA1c is measured according to a method used by the Japan Diabetes Society (JDS), wherein it is converted to the National Glycohemoglobin Standardization Program (NGSP) equivalent value (%) using the formula: $\text{HbA1c}(\%) = 1.02 \times \text{HbA1c}(\text{JDS})(\%) + 0.25\%$ ¹⁴⁾.

In the present study, hypertension was defined as a systolic BP ≥ 140 mmHg, diastolic BP ≥ 90 mmHg or ongoing medication for hypertension. Dyslipidemia was defined as a HDL-cholesterol level ≤ 40 mg/dl, LDL-cholesterol level ≥ 140 mg/dl, triglyceride level ≥ 150 mg/dl, or ongoing medication for dyslipidemia. Diabetes was defined as a fasting plasma glucose level ≥ 126 mg/dl, HbA1c level $\geq 6.5\%$ or ongoing antidiabetic therapy. Lastly, obesity was defined as a BMI ≥ 25 .

The hypertension standard was based on the Japanese Society of Hypertension Guidelines for the Management of Hypertension 2014. The dyslipidemia standard was based on the Japan Atherosclerosis Society Guidelines for Prevention of Atherosclerotic Cardiovascular Diseases 2012. The diabetes standard was based on the Japan Diabetes Society Guideline for the Diagnosis of Diabetes Mellitus. The obesity standard was based on the Japan Society for the Study of Obesity Criteria for Obesity Disease 2011.

Statistical analysis

Continuous variables and categorical variables are expressed as mean values with the standard deviation or as numbers (%). The Fisher exact test and

chi-square test were applied for comparisons of categorical variables. All statistical calculations were performed using Statcel2 (OMS Publishing Inc., Tokyo, Japan).

Results

Subject characteristics

Twenty-four male Japanese professionals were enrolled (age, 53.7 ± 4.8 years). Of them, 17 lived in Asian countries other than Japan, 3 lived in North America, 2 lived in Europe, 1 lived in South America, and 1 lived in Africa. Three participants were unable to send the ECG recordings from the countries they resided in because of problems with PC setup. The baseline demographics of the remaining 21 participants (age, 53.7 ± 5.2 years) are shown in Table 1. Four subjects had structural CVDs (hypertrophic cardiomyopathy (HCM), 1 subject; angina, 1 subject; atrial fibrillation (AF), 1 subject; and arterial thrombosis, 1 subject). These 4 subjects were already treated in hospitals. All subjects were ≥ 40 years old. Three

Table 1. Subject demographics

Characteristics	Values
Number of subjects	21
Age (years)	53.7 ± 5.2
Health checkup	
Body mass index (BMI) (kg/m ²)	25.2 ± 2.9
Systolic blood pressure (mmHg)	121 ± 17
Diastolic blood pressure (mmHg)	77 ± 10
AST (IU/dl)	26 ± 12
ALT (IU/dl)	30 ± 19
rGT (IU/dl)	49 ± 31
LDL-cholesterol (mg/dl)	120 ± 34
HDL-cholesterol (mg/dl)	51 ± 12
Triglyceride (mg/dl)	207 ± 139
Fasting plasma glucose (mg/dl)	107 ± 26
HbA1c (n=19) (%)	5.9 ± 0.7
Current smoker	5 (21)
Hypertension	7 (33)
Dyslipidemia	12 (57)
Diabetes	6 (29)
Obesity	9 (43)
History of CVDs	4 (19)
Frequency of CVD risk factors	5.2 ± 2.2
Three	2 (10)
Four	5 (24)
Five	7 (33)
Six	3 (14)
Seven	3 (14)
Eight	1 (5)

Values are given as mean \pm SD or n (%).

CVDs, cardiovascular diseases; AST, aspartate aminotransferase; ALT, alanine aminotransferase; rGT, γ -glutamyl transpeptidase; HbA1c, glycated hemoglobin.

subjects had hypertension (33%), 12 subjects had dyslipidemia (57%), 6 subjects had diabetes (29%), and 9 subjects had obesity (43%). The mean frequency of CVD risk factors was 5.2 ± 2.2 .

ECG recordings

During the monitoring period (0.7 ± 0.3 years), 504 ECG recordings were obtained using the iECG. No new CVD events were observed. Table 2 shows the outcomes regarding the diagnostic utility of the iECG monitoring system used in this study. The portable ECG monitor recorded ST-T abnormality in 4 of the 21 subjects (19%), ST-T abnormality plus left bundle branch block in 1 subject (5%), bradycardia in 1 subject (5%), AF in 1 subject (5%), short PR interval

in 1 subject (5%) and normal findings in 13 subjects (61%). Each subject with hypertrophic cardiomyopathy, bradycardia, angina and AF at baseline checkups showed no change in the iECG data obtained from their countries of residence. On the other hand, 4 normal findings from the baseline ECG changed, with 3 ST-T abnormalities and 1 short PR interval in the iECG data, and a cardiovascular specialist judged their observation. Figure 3 shows the tracing acquired using the portable ECG monitor in a subject with HCM residing in Germany. The portable ECG monitor revealed a similar pattern of ST changes as that found at a health checkup conducted before the subject left for Germany.

Table 2. Comparison of ECG findings at baseline checkups and iECG findings in countries of residence

Baseline checkups			In countries of residence		
	n	ECG	iECG	n	Follow-up
Structural CVDs (+)	4			4	
HCM	1	ST-T abnormality	ST-T abnormality	1	Under medical treatment
Angina	1	ST-T abnormality + LBBB	ST-T abnormality + LBBB	1	Under medical treatment
Atrial fibrillation	1	Atrial fibrillation	Atrial fibrillation	1	Under medical treatment
Arterial thrombosis	1	Normal findings	Normal findings	1	Under medical treatment
Structural CVDs (-)	17			17	
	1	Bradycardia	Bradycardia	1	Observation
	16	Normal findings	Normal findings	12	None
			ST-T abnormality	3	Observation
			Short PR interval	1	Observation

CVDs: cardiovascular diseases. HCM: Hypertrophic cardiomyopathy. LBBB: left bundle branch block. iECG: portable Internet-enabled ECG recording system.



Fig. 3. Tracing acquired with the portable iECG monitor from a subject with hypertrophic cardiomyopathy in Germany.

Subject satisfaction and comfort, iECG utility, and lifestyle changes

Nineteen subjects responded to the questionnaire (19/21, 90%). The countries of residence of these subjects were China in 6 cases, Thailand in 2 cases, and the Philippines, Vietnam, Indonesia, India, Sri Lanka, the USA, Mexico, Brazil, Germany, Belgium, and Libya in 1 case each. The results revealed that 68% of the subjects (13/19) were satisfied with the iECG (= (“Very satisfied” + “Satisfied”) / 19 subjects), 58% of the subjects (11/19) found it comfortable (= (“Very comfortable” + “comfortable”) / 19), 68% of the subjects (13/19) thought it was usable (= (“Very usable” + “Usable”) / 19), and 37% of the subjects (7/19) had experienced lifestyle improvements (= (“Better” + “Slightly better”) / 19) (Table 3). Four subjects with structural CVDs responded positively with regard to all parameters (satisfaction, 4/4; comfort, 4/4; device utility, 4/4; lifestyle improvements, 3/4), but these figures were not significantly different from those in subjects without such diseases. The oldest subject (63 years), who had arterial thrombosis, frequently sent his ECG results and rated comfort as 5 and lifestyle improvements as 5, since he started managing his diet and exercising daily after using our iECG system.

Discussion

To our knowledge, this study is the first to report the use of a portable ambulatory Internet-enabled ECG monitor for evaluation of Japanese individuals working abroad. The results of this study showed that the iECG monitor was well accepted, and that the iECG system could serve as a useful support tool for Japanese workers in foreign countries with risk factors of CVDs. It is particularly noteworthy that subjects with structural CVDs responded positively to all aspects of device use. Moreover, 4 subjects with structural CVDs under medical treatment showed no change between baseline ECG and iECG findings. On the other hand, 4 normal findings from the baseline ECG changed, with 3 ST-T abnormalities and 1 short PR interval being found in the iECG data. The ECG findings in the countries of residence compared with those before could be an important decision basis to determine whether to continue working abroad or to consult specialists.

In the present study, data from the portable ECG device were recorded on PCs and sent over the Internet. Cellular phone-based online ECG processing for ambulatory and continuous detection has already been used in the USA and Singapore^{15–18}. Use of portable ECG devices would perhaps be more widespread if cellular ECG systems were put into practical use in Japan as well.

Table 3. Questionnaire regarding subject satisfaction and comfort, iECG utility and lifestyle improvements brought about by iECG use

Questionnaire	Values
Please rate on the following scale your satisfaction concerning use of the portable iECG	
5 Very satisfied	6 (32)
4 Satisfied	7 (37)
3 Neutral	5 (26)
2 Unsatisfied	1 (5)
1 Very unsatisfied	0 (0)
Please rate on the following scale your comfort with respect to use of the portable iECG.	
5 Very comfortable	4 (21)
4 Comfortable	7 (37)
3 Neutral	7 (37)
2 Uncomfortable	1 (5)
1 Very uncomfortable	0 (0)
Please rate on the following scale the utility of the portable iECG for individuals in foreign countries.	
5 Very usable	4 (21)
4 Usable	9 (47)
3 Neutral	5 (26)
2 Unusable	1 (5)
1 Very unusable	0 (0)
Please rate the changes in your daily lifestyle resulting from portable iECG use.	
5 Better	1 (5)
4 Slightly better	6 (32)
3 No change	10 (53)
2 Slightly worse	1 (5)
1 Worse	1 (5)

Values are given as n (%) (total n=19). iECG: portable Internet-enabled ECG recording system.

Traditionally in Japan, CVDs have been detected noninvasively using 24-h ECG recorders (Holter). However, the rate of diagnosis of palpitation is relatively low with Holter monitoring (35–39%), and it is higher with event monitoring (67–83%)^{6,7,9}. In a population of patients who still complained of palpitation despite a negative result in standard 24-h Holter monitoring, cardiac event monitoring using a portable ECG monitor was successful in obtaining high-quality ECG recordings¹⁹.

This study had several limitations that must be acknowledged. First, the number of study subjects was rather small. This may have influenced the questionnaire results, wherein the results of subjects with structural CVDs were not significantly different from those of other subjects. Secondly, the monitoring period (0.7 ± 0.3 years) was short. Many Japanese workers live abroad for longer periods of time. Therefore, the true ratings regarding the iECG may have been misestimated. Future investigations with more thorough long-term follow-up may provide more

reliable estimates of the sensitivity and predictive value of the iECG. Previous studies have evaluated the cost-effectiveness of time-limited TTMs in adult populations with palpitations, syncope or presyncope⁶⁻⁸.

It has been found that most deaths among Japanese individuals abroad occur because of cerebrovascular diseases or CVDs⁵. Moreover, the risk of CVDs among Japanese individuals working abroad may be higher because of the increasing age of this subpopulation²⁰. In the present study, the iECG was rated 68% of the subjects were satisfied with the iECG, 58% of the subjects found it comfortable, 68% of the subjects though it was usable, and 37% of the subjects experienced lifestyle improvements. Thus, a portable ECG device including TTMs seems useful for monitoring the heart health of individuals residing abroad.

Conclusion

The iECG could serve as a useful support tool for monitoring the heart health of Japanese workers residing abroad with risk factors of CVDs.

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