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# Managing mass events and competitions with difficult-to-access locations using mobile electrocardiac monitoring

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## ABSTRACT

**Objective:** Using mobile wireless technology to monitor ECG in participants of mass events and sports taking place in difficult-to-access location could both prevent and easier detect arrhythmias as well as provide real-time monitoring for any type of injury. We assessed the effectiveness of mobile wireless monitoring technology and IT in detecting possible emergencies during a skyscraper race.

**Methods:** We attached specially designed wireless surveillance biopatches on 120 individuals participating to monitor their continuous ECG and location during a skyscraper run-up race at Taipei 101 building, Taiwan. The outcomes of interest were detection of abnormal heartbeats and QRS waves indicative of possible cardiac problems and the exact location of participants during the occurrence of emergencies.

**Results:** The devices accurately sent over 50 warnings to our monitoring platform when both, danger limits were reached by competitors (<60 or >195 beats per minute) or competitors stopped moving, proving very effective in quickly detecting abnormalities and alerting staff of possible emergencies at exact locations.

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*Conclusion:* This efficient and inexpensive monitoring method can also prevent arrhythmias in unscreened competitors, the danger of collision among staff and competitors, and preserves oxygen by eliminating additional on-foot monitoring staff. Additionally, it could have multipurpose usage, especially during disasters and accidents occurring in difficult-to-access locations, in military exercises and personal monitoring.

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## 1. Introduction

Advancements of current sophisticated technologies bring constant benefits to human life in general, especially in the area of health status monitoring. Creating better technologies for monitoring health status in competitions, exercise, and other activities has played a crucial role in injury prevention and treatment, and overall health and quality of life optimization. As continuous urbanization brings forth new, unusual and exciting mass competitions and charity sports such as skyscraper running open to the public, new monitoring technologies can overcome traditional inefficient monitoring caused by the nature of such events and/or not enough available personnel, as well as decreasing event costs.

Racing to the top of skyscrapers is one example of a particularly unusual mass competition becoming increasingly popular around the world. This event inherently entails risks to participants and poses new challenges for event hosts and medical staffs (e.g. Taipei 101, Empire state building), because it attracts thousands of competitors every year [1–4]. The greatest challenge in such events is the limited staircase space where participants must compete (Fig. 1) making it difficult for staff to monitor the event on foot and to aid in emergencies. In addition, public and charity competitions in many countries do not usually require health checks prior to events, therefore increasing the risk for cardiac-related injuries [5–13] and other injury types [14–18]. Furthermore, this particular sport is open to individuals of all ages, some having hearing impairments which may cause additional difficulties in communicating during an emergency.

Previous studies have documented that both professional athletes and non-athletes who suffer from arrhythmias are at risk for cardiac and bodily injuries when engaging in strenuous physical activities or competing in strenuous sports [19–22]. Individuals suffering from arrhythmias and other cardiac conditions are exposed to increased risks and complications for two main reasons: (1) they are unaware of having arrhythmias or other cardiac problems and (2) lack of sufficient oxygen when combined with physical activity. Therefore, an accurate, easy to use and inexpensive technology capable of real-time mobile ECG reveals many benefits and possible applications in many situations, particularly a skyscraper competition.

Annual mass competitions taking place at Taipei 101 currently make use of traditional monitoring technology (e.g. video equipment and on-foot personnel). From 2005 to 2008, the Taipei 101 annual mass competitions prepared for emergencies by deploying medical stations on Floors 1, 35, 59, and 91, with each station staffed by one doctor and three nurses. However, the great increase in participants over the years had



**Fig. 1 – Race-up competition in progress inside a skyscraper’s emergency staircase. As seen here, race-up competitions occur in places with limited space and oxygen, making it difficult for monitoring personnel to efficiently monitor these events and also risking colliding with runners.**

an average of 25 health-related incidents at each past event, with dozens unable to complete the event being helped off. Although, the event added 12 on-foot personnel to monitor all 91 floors beginning in 2009, the additional staff is still inadequate as the number of competitors are extremely large for such a limited space (2011 annual race had 6000 [3] and 2012–2014 races had over 4000 competitors from around the world). However, adding more on-foot monitoring personnel can hamper the event as it increases the danger of collision with runners and also uses additional oxygen needed by the participants.

Race-up competitions therefore require a more practical surveillance method that can efficiently monitor participants without using additional space, oxygen and create additional risk of injuries from collisions with monitoring personnel. During recent years, various ECG and physiological monitoring technologies have been developed for acquiring and measuring the heart rate highly efficient and significant in activities requiring extreme physical effort [23–29]. Our goal is to use such technologies in detecting arrhythmias and cardiac incidents [30] before and during the race or competition in order to overcome the lack of preparticipation screening. In addition, by using real-time mobile monitoring we attempt to overcome problems that may be triggered by changes in the health conditions of competitors from the time of preparticipation screening to the time of the competition [26]. Furthermore,

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