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EDITORIAL

Wearables for cardiac monitoring in athletes: precious metal or fool's gold?

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Introduction

Wearable and 'smart' medical technologies continue to proliferate at rapid rates, reaching millions of consumers worldwide. These devices now carry the capacity to measure biologic signals previously only possible in medical settings. Monitoring of heart rate and electrocardiograms (ECGs) (and other physiologic or environmental variables) can now be performed by a range of smart gadgets including smartphones, watches, and textiles.[1] Within the medical and sports community, these devices have garnered much attention with the promise of playing a role in the cardiovascular health of athletes. While the clinical use of these powerful tools may appear self-evident, there exist some limitations and potentially unintended risks with their widespread use. It is important to note that the potential clinical benefits of these wearables have not been established in well-conducted trials, and their use can be potentially associated with harms from overuse, misinterpretation of the data generated, or lead to unnecessary further investigations.

An athlete and the physician caring for the athlete should be aware of the nuances involved in evaluating the suitability and utility of these devices in clinical practice. The term 'wearable technology' is a catch-all phrase and can mistakenly impress upon a consumer the ubiquitous applicability of the device. Seven dichotomies need to be considered when selecting a device or interpreting its findings, as their functionality and limitations are largely context specific. For the purposes of this discussion, we will primarily refer to that information contained in the ECG and or heart rate profile. Many other variables can potentially be measured, but their practical usefulness is not established, and we will consider them in this review.

Firstly, consider whether the device is being used for optimizing sport performance or intended as a clinical tool (including screening, diagnosing, and monitoring pathophysiological states).

Second, if intended as a medical tool, it is important to differentiate whether it is being employed for diagnosing disease or for monitoring known pathology.

Third, if used as a diagnostic tool, identify if the device is being applied to an asymptomatic or to a symptomatic athlete.

Fourth, if the device is being used as a diagnostic tool on an asymptomatic athlete, what is the pretest probability of a relevant abnormality (low vs. high)?

Fifth, as medical tool, is the device being used for the ascertainment of heart rate, or for an ECG tracing?

Sixth, are the parameters being recorded on an intermittent or a continuous basis?

Seventh, for devices with ECG capacity, is the device outputting single or multi-lead tracings?

Attempting to navigate these dichotomies can help the physician and the athlete select the appropriate device for its intended purpose and guide their degree of confidences in the tool's 'finding'.

Asymptomatic athlete—wearables for screening

The use of these devices for investigating or monitoring asymptomatic events in otherwise healthy athletes, including for the purposes of pre-participation screening, may be associated with more harm than benefit. Bayes' Theorem asserts that the predictive power of a diagnostic tool is largely dictated by the prevalence of the disorder being examined within the population. Amongst athletes, a relevant

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disorder, sudden cardiac arrest (SCA), occurs at a rate of ~1 in 100 000 per athlete year,[2] while abnormal ECGs are identified at a rate of 2–10%, yielding a small or trivial positive predictive value (0.001–0.05%).[3] The incidence of abnormalities indicating potential sudden death risk, discovered from wearable devices, is not known. Atrial fibrillation is often considered to be a relevant screening diagnosis. However, discovering asymptomatic atrial fibrillation in a person at low risk of stroke (the majority of athletes under age 65) is of unproven usefulness.[1] The reliance on the ECG as a screening tool may also result in a large number of false positives. The rate of false positives is likely further increased by the use of limited-lead wearable ECG devices and photoplethysmographic technology. An athlete identified as abnormal by heart rate or ECG screening may endure unnecessary invasive testing and therapy that may be of limited or no benefit to their outcomes. The physical and psychological harms sustained may range from anxiety to depression amongst disqualified athletes, and harms from unnecessary investigations and treatments. Even amongst athletes identified as 'true positive', the disorders diagnosed may not be associated with an increased risk of SCA or the risks may not be modifiable by intervention. It is important to recognize that the vast majority of arrhythmias in healthy asymptomatic athletes are benign in nature and over-investigating them may result in unwanted and unwarranted complications.

In asymptomatic athletes deemed at high risk of SCA, as identified by a personal or family history, or a physical exam, 12-lead ECG screening is the standard of care.[4] The utility of wearable ECG devices in this context is limited by their single-lead nature and the challenges in monitoring the ECG continuously during exercise (only some wearable technologies permit this).

Symptomatic athlete

In monitoring symptomatic athletes, these devices may be considered for symptom-rhythm correlation to identify underlying arrhythmic events.[1] The reliability of the heart rate (HR) monitoring (using PPG technology) in detecting abrupt rate changes, such as in the case of paroxysmal supraventricular tachycardia or ventricular tachycardia, is variable depending on the device being used and may result in false reassurance, by missing rapid or brief transitions in HR.[5] These devices may miss up to 60% of such brief arrhythmias.[4] With ECG monitoring, many marketed devices require the athlete to activate the device by placing their hands on an electrode (imbedded within the primarily device or as an add-on), with ~30 s contact time, before an ECG is recorded. This limits the utility of these technologies to arrhythmias that last 1 min or longer. The majority of arrhythmias occurring in athletes are short-lived, lasting <30 s. Moreover, not all sports are conducive to the use of these devices. An athlete on a bike, rowing or swimming would not be able to readily use these devices to 'check' their underlying rhythm. Additionally, these devices may require the athlete to be still to capture an ECG tracing of diagnostic quality, which may either not be possible or would further increase the time from symptoms onset to ECG tracing. Wearable technologies that allow for continuous ECG monitoring, do exist, but are usually also restricted to single-lead tracings. While these continuous devices may be easier to use and increase the frequency of detected arrhythmias, they increase the rate of detection of both relevant (those that increase the risk of SCA, and the outcome is modifiable) and non-relevant (clinically inconsequential or impose a non-modifiable risk) arrhythmias—increasing sensitivity at the expense of specificity. Exercise-induced ischaemic ECG changes may be appreciated in patients with coronary artery disease, but the limited lead nature of these devices precludes their reliable and accurate use.

Monitoring for SCA

Wearable devices may potentially play a role in 'real time' monitoring for life-threatening arrhythmia during sport competitions to allow for targeted, rapid deployment of resuscitative efforts. A proof-of-concept study has shown this to be feasible.[6] Given the extreme rarity of such events, (1 in 100–200 000 marathon participants for example), the economic sustainability and practicality of such an approach (i.e. equipping all athletes with the device) versus the pre-emptive placement of automatic external defibrillators (AEDs) and personnel in sporting venues is yet to be established and will likely continue to be modified as price and availability of these devices change.[7]

Risk assessment and decision-making

In the event that a 'positive' finding is suggested by the use of these devices, both the athlete (user of the device) and the clinician need to appropriately estimate the risk associated with such a finding on an individual level. The potential likelihood of false versus true positive need to be considered in the context of the athlete's medical history and pertinent physical examination, to guide subsequent investigations if any. A model of shared-decision making is central to navigating the associated uncertainty.

Conclusion

Wearable devices encompass an array of technologies with different potential applications within the athletic population. Their availability, accuracy, and reliability are suggested to be salient features in support of their use. However, limitations and unintended consequences associated with their use are not solely the result of their diagnostic performance but relate also to mathematical constraints imposed by basic probability theory. The underlying technology will continue to progress, and the utility of these devices therefore remains dynamic. Current technologies have not been shown to be useful in clinical monitoring of individuals with known cardiac disease. An athlete-centred approach is needed when considering the individual benefits and risks associated with the use of wearables for the purpose of cardiac monitoring.

Conflict of interest: none declared.

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