ORIGINAL ARTICLE

EVALUATION OF HUMAN PERFORMANCE IN DAILY ACTIVITIES UNDER CONTROLLED ENVIRONMENT BASED ON HEART RATE MEASUREMENT: A REVIEW

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ABSTRACT

Performance and efficiency impairment is a critical issue particularly in the workplace. It may lead to undesirable consequences such as injury, accident and profit loss if this issue was not controlled properly in the organisation. Therefore, the three main objectives of this review are: to assess the current status of human performance research by using heart rate (HR) as physiological measures; to find relationship between HR measures and individual performance; and to identify pertinent issues related to human fatigue. A systematic literature search was performed using the following key words and synonyms: Heart rate, human, individual, occupational, worker, performance, and fatigue. Twenty two relevant laboratory studies were discussed in this review paper, chosen from electronic databases. Numerous human performance detection methods and techniques were found in the past studies. Based on this review, HR can assist researchers to determine performance according to a task demand, condition and its complexity. Overall, this review equips interested research groups, occupational health physicians, and employers with an overview of the HR measures to determine human performance in daily work practices. Future studies are needed to deal with performance and efficiency issues in daily work practices should be based on these concerns and factors found in this review.

Keywords: Heart rate, Human, Worker, Performance, Fatigue, Laboratory

INTRODUCTION

Different work practices will lead to different fatigue condition. Some activities may stimulate more fatigue than other practices (Williamson et al., 1996). Performance and efficiency can be impaired during fatigue when an individual continues to perform the current activity as normal (Brown, 1994). For example, in term of driving, fatigue will increase with the time spent when driving (Williamson et al., 1996; Fuller, 1984). The result of fatigue toward drivers could be affecting their awareness to drive more safely (Wang & Pei, 2014). In fact, there is the link between fatigue, human performance impairment and safety, particularly in transport and occupational setting (Williamson et al., 2011).

Based on past studies, mental fatigue has a connection with efficiency and alertness impairment, prolongation of cognitive information processing, and concentration difficulty (Zhao et al., 2012). The increase in reaction time to stimuli after the driving task should be associated with driving mental fatigue, which is evident by subjective self-report measures. Driving can be a complex and risky activity that needed a good physical and mental (Alonso et al., 2016). In addition, fatigue level will change, according to specific mental workload state and can be reflected with performance fluctuations. Decreasing muscular strength and coordination is a physical fatigue (Ahn et al., 2016).

Mental workload is the interaction between the task's properties with person's properties (de Waard & Lewis-Evans, 2014). Different person would do different ways to perform a task. During driving, mental task was being used to understand the dynamics of vehicle and making a decision that depend on some situation (Marquart et al., 2015). Numerous researches on physiological measures of mental workload were reported in studies, focusing on measurement techniques (Kramer, 1990; Wierwille & Eggemeier, 1993). There were electroencephalograms (ECG), event-related potentials, magneto encephalograms (MEG), positron emission tomography, electrooculograms (EOG), cardiovascular measures, pupillometry, respiratory measures, and electrodermal measures. Among all these physiological parameters, ECG can be measured in a less intrusive manner (Arun et al., 2012). In this paper, ECG measures related to cardiac and heart activity will be explained.

In the past, cardiac measure has been the most popular physiological techniques to assess the mental workload, including ECG, blood pressures (BP) measures and blood volume measures (Kramer, 1990; Wierwille & Eggemeier, 1993; Rowe et al., 1998). Several relevant indicators were used in mental workload evaluation related to heart activity, such as: Heart Rate (HR), Heart Rate Variability

(HRV) and the Root Mean Square (RMS) of the difference between successive rhythm-to-rhythm intervals (Orsila et al., 2008; Fu et al., 2011). In addition, Fu et al. mentioned the most commonly used heart parameters in past studies were HR, spectral parameters such as: low frequency (LF) power components of the HRV spectrum, high-frequency (HF) power and LF/HF ratio (Fu et al., 2011). HR is the most important factor in cardiovascular system of human (Mallick & Patro, 2016). HR and HRV signals that are normally derived from Electrocardiogram (ECG) signals, is also found to vary significantly during the different states of the individual (Arun et al., 2012). Variation of HR represents variation of emotional state of the individual (Borghini et al., 2012). In addition, Hartley et al. mentioned that HR is associated with extreme physical demands and fitness of the person (Hartley et al., 1994). About forty years ago, Bishop investigated an ability of HR measures to indicate fatigue. As reported by Hefner et al., in 1985, Bishop found that during extended periods of low workload under monotonous conditions, HR in beats per minute (bpm) decreased while HRV increased (Hefner et al., 2009). Hence, it is believed that heart activity and alertness are related, such that increased alertness is associated with shorter and less variable inter-beat intervals (Williamson et al., 1996; Mascord & Heath, 1992; Brookhuis & De Waard et al., 2001). As mentioned by Jorna , HR is confirmed to be a very reliable workload indicator (Jorna et al., 1993). Based on Wilcoxon statistical analysis, it showed that HR increases significantly each time task demands are increased.

Generally, based on all these reviews, HR change is a sign for individual alertness and performance impairment. However, this issue needs further investigation before any firm conclusion can be drawn about its potential to indicate fatigue. Therefore, research related to HR measures, including its setting, analysis and findings has been reported and discussed in this paper.

METHODS

A list of English language articles dating as far back as 1992 were compiled from Science Direct, Springer and Google Scholar websites. In addition, a secondary search was performed by using bibliography of retrieved articles in order to support the first retrieved paper. A literature search was performed using the following key words and synonyms: Heart rate, human, individual, occupational, worker, performance, and fatigue. Table 1 depicts the detailed descriptions on selecting the past research to be discussed in this study.

Table 1 Descriptions on each stage regarding selection of the past research for this study

Stages	Explanation
Electronic search	-The search was limited to English articles only. -Sources were collected from Science Direct, Springer and Google Scholar. -A secondary search was performed by using references of the first article if necessary.
Keyword	Keywords for all retrieved articles were heart rate, human, worker, performance, fatigue.
Retrieved article	-Abstract had been retrieved and reviewed. -Only article with laboratory or controlled setting was taken for this paper. -Then, full paper had been retrieved and reviewed.
Final selection	Twenty two papers were selected based on the suitability of the papers, within the keywords context, focusing in the controlled setting, and with different case studies.

RESULTS

Table 2 shows a summary of fatigue evaluation from 22 past studies. This literature is organised in the following orders: authors, study design, HR setting and analysis as well as HR findings and concerns. Table 2 shows areas or applications that had been investigated by past researchers. Generally, there are four applications that had been explored by past researchers, entertainment, food or caffeine consumption, sleep or wake cycle and new tools for HR.

Table 2 Heart rate measures application

Parameters	Previous Studies
Entertainment	- Park et al. (2014) - Rowe et al. (1998) -Mascord & Heath (1992) -Bevilacqua et al. (2018) - Suganuma et al. (2018)
Food/Caffeine consumption	- Gibson et al. (1995) -Hajsadeghi et al. (2016) - Segerstrom & Nes (2007) -Spitoni et al. (2017)
Sleep/wake cycle	-Herzig et al. (2017) - Heinze et al. (2012) -Vicente et al. [33] -Gouin et al. [34] -Aeschbacher et al. (2016) -van Leeuwen et al. (2018) - Sessa et al. (2018)
New integrated system or device	- Fairclough et al. (2006) - Sutarto et al. (2010) - Hashem et al. (2010) -Cadmus et al. (2017) -Wang et a,l. (2017) -Hernando et al. (2018)

HR Measures in the Laboratory Setting

Laboratory setting is common in this type of research, particularly when dealing with variety of equipment in the study. Park et al. (2014) had compared the 3D and 2D visual to human fatigue and motion sickness among 30 subjects that were equally divided into two groups. Their findings indicated the HR value of 3D group was higher compared to 2D group. Heinze et al. (2012) had conducted an experiment consists of alternations between 10 minutes attempted sleep and 20 minutes wake for the duration of 50 hours. During sleep episodes, subjects were instructed to lie down in bed and attempt to fall asleep as quickly as possible; the wake-up after 10 minutes was ensured by an alarm sound. During the wake episodes, subjects performed several tasks while standing or sitting in front of a computer.

Meanwhile, Sutarto et al, (2010) proposed HRV-biofeedback as a possible tool to enhance cognitive performance among operators. HRV-biofeedback is designed to control oscillatory variability in HR, henceforth directly targeting and exercising the body's own physiological control mechanisms. This study was divided into two phases. In the preliminary phase, nine female volunteers to perform as simulated operators and were evaluated under three cognitive tasks: Stroop Color-Word Test (cognitive flexibility), memory (verbal memory), and arithmetic test (decision making). A replication of this study was performed with real operators that were assigned to the intervention and control group.

A New Integrated System and Device to Record HR Data

Hashem et al, (2010) had proposed a new integrated low powered device for measuring HR using fingertip, name as Heart Rate Measuring (HRM). The proposed HRM device is claimed to be economical, user friendly and uses optical technology to detect the flow of blood through index finger. It comprise of the optical technology using standard LED and photo-sensor to measure the heart rate within seconds using index finger. A microcontroller is programmed to count the pulse. The HR is digitally displayed on an LCD controlled by the same microcontroller which counts the pulse.

SUMMARY OF THE PAST STUDIES IN THIS PAPER

Overall, majority of the past studies combines HR measures with other measures tools, either by using subjective method such as, KSS, questionnaire, and workload assessment or objective method such as EEG and EOG. In addition, there is correlation between HR and multiple measures as determined in a few studies. Moreover, in term of performance impairment, it was highlighted by the significant increase in mean reaction time, increase in heart rate inter-beat interval and HRV, suggesting physiological and behavioral measures provide complementary evidence for the detection of fatigue effects (Mascord & Heath 1992).

Other than that, HR will be different with different setting parameters and subject s' experience, for instance:

- Entertainment: HR was stable when watching 2D video, as compared to 3D (Park et al. 2014).

- Entertainment: The user, who has an experience in playing certain games, will be more relaxed compared to inexperience user (Rowe et al,. 1998)

- Food control: HRV of the subject was elevated when under high self-regulatory (eat carrot, resist cookies) compared to low self-regulatory (eat cookies, resist carrot), cookies is more desirable than carrot (Spitoni et al. 2017).

- Caffeine control: Caffeine had no effect on HR during the last two hours of the fatigue trial. HRV increased significantly after the placebo (calm drug) but decreased after caffeine (Gibson et al,. 1995).

- Sleep/wake cycle: the mean HR during attempted sleep correlated best with body temperature and subjective sleepiness (Heinze et al, 2012).

- New system: Training by compiling several HRV value, as mentioned by Sutarto et al showed the potential to be an inexpensive approach to improve autonomic and respiratory control (Sutarto et al,. 2010)

In general, laboratory setting is the best option if the researcher wants to control all related parameters to the study. It is easy, can save the travelling cost, save energy and might helpful to produce the good findings. Details on each study have been documented in Appendix.

CONCLUSION

This review systematically discovered relevant literature related to HR as physiological measures methods to determine human performance impairment in daily work practices and activities. Majority of the past studies combined HR measures with other physiological measures methods such as EEG, EOG and EMG and also subjective methods such as self-administered questionnaire. In addition, most of the past studies reviewed in this paper were conducted by European (3 papers), Australia (2 papers) and USA (1 paper), Asian researchers, including Malaysia, Korea, and Bangladesh (3 papers). It clearly indicated that HR research in daily work practices and activities particularly in Malaysia is still at budding stage.

Based on past studies, there is evidence that HR can determine the individual physiological level of workload. HR generally increases with arousal and workload. Nevertheless, the HR may fluctuate either increase or decrease based on how attention is directed or allocated. For example, when the person does not normally familiar with the surrounding or the work, the HR will be slightly different and unstable compared to normal activity. In this case, the HR of the person becomes irregular when viewing 3D videos, as opposed to 2D videos. In addition, as fatigue developed over the journey or the shift works it reduced persons' capacity to control mental effort and that this was greater in the more demanding task. Normally, there is highly significant reduction in HR over time.

This review deals with monitoring techniques and analysis, focusing on HR measures to determine human performance. While high majority of the past studies have concentrated on the use of ECG and the wrist monitor to record HR data, it may also be promising if there is another solution to scan and compile the HR data. Hence, in this review paper, there were two studies that have developed new system and device to measure HR. According to these studies, these new integrated systems and devices is more economical compared to the standard ECG.

In order to understand the human performance impairment when performing daily work practices, it is important to investigate the reason behind it and implement the appropriate intervention programs. A detailed review on these measures will provide insight for future studies and enhancements can be performed to find the best parameters to determine the human performance in daily work practices.

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COMPETING INTERESTS

There is no conflict of interest.

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APPENDIX

Summary of recent studies by using HR to determine individual performance impairment

Abbreviations: BL=Baseline, CHF =Chronic Heart Failure, FA=Facial Actions, FFT=Fast Fourier Transform, HF=High frequency, HF-HRV=High Frequency Power HRV, HR=Heart Rate, ISI=Insomnia Severity Index, LF=Low frequency, HRM= Heart Rate Mean, MF=Mid frequency, Multivariate statistical process control=MSPC, PSQI=Pittsburgh Sleep Quality Index, RES=Recovery Nights, RF=Respiratory frequency, RMSSD= Root Mean Square Successive Difference, RR=Rhythm to rhythm, RT=Reaction time, SD=Standard deviation, SDNNi=Mean of standard deviation of all NN intervals for all 5 min segments of the entire recording (in milliseconds), SR=Sleep Restriction, TD=Time domain, Total power=TP,VAS=Visual analogue scale

No	Authors / Study design	HR setting & analysis	Other measure	HR findings & concerns
1	Rowe et al. [14] Subject: 13 subjects Country: USA Condition: Subjects were required to play a series of five games while connected via three leads to ECG recording equipment.	ECG equipment consisted of Dataq's WinDaq/200 hardware and software used in conjunction Delphi with a Windows 3.1. Developer 2.0 was used to develop the computer game used in the experimental task. CARSPAN and SAS software packages were used for data analysis.	Subjective workload assessment based on NASA's Task Load Index	User HRV showed significant biased sensitivity to the manipulation of the independent variable on the basis of domain experience. HRV appeared to indicate the point at which user capacity to process targets was exceeded
2	Mascord & Heath [21] Subject: 17 subjects Country: Australia Condition: 140 min	HR and HRV were measured using an infrared finger pulse sensor, which was attached to the thumb. HR monitor pulse signal was processed by the Isaac Lab Control System using a grounded Schmitt Trigger. Mean HR and SD for each of the four time periods were taken. Statistical analysis: Newman-Keuls (NK) post hoc study.	RT, pedal depression	Decrement on performance was highlighted by the significant increase in mean reaction time, increase in heart rate inter-beat interval and HRV, suggesting physiological and behavioral measures provide complementary evidence for the detection of fatigue effects.
3	Park et al. [24] Subject: 30 subjects Country: Korea Condition: 1 hour	ECG signals were measured in a relaxed environment before and after watching the video content (pre- and post-rest for 3 min). Signal was recorded at a 500 samples/s and the R-peak was extracted from this recording using the "QRS detection algorithm". Analyse SDNN, HR	Subjective evaluation	Heart rhythms fairly regular and stable before viewing 2D video, and remained so after viewing. Heart rhythms fairly regular and stable before viewing 3D video, but became irregular and unstable after viewing, and were accompanied by a significantly higher HR.
4	Bevilacqua [25] Subject: 20 subjects Country: Brazil Condition: Play	The participants were each recorded for about 25 min, during which they played three games. Subjects were seated in	FA	Variations of HR and FA on a group and on an individual level are different when comparing boring and stressful parts of the gaming sessions.

		front a computer, alone in the room, while being recorded by a camera and measured by a heart rate sensor.		
	three games, answer a questionnaire after each game and rest			
5	Suganuma et al. [26] Subject: 23 subjects Condition: Country:	Participants rested with their eyes closed in a sitting position for 3 minutes, and then spent another 3 minutes playing Minesweeper.	-	The 'fatigue' responses during play at the highest difficulty level were negatively correlated with the median RRI values (ρ = -0.605, p < 0.05), while the responses of 'regretted' and "the wish to make another try" during play at the standard difficulty level elicited positive correlations with the median RRI values (ρ = 0.558 and ρ = 0.573, p < 0.05, respectively).
6	Gibson, et al. [27] Subject: 20 subjects Country: Australia Condition: 4 hours, tested on 4 occasions	The heart IBI was monitored continuously over the whole 4 hours period.	BP, oral temperature, questionnaire, performance test	Highly significant reduction in HR over time was found. Caffeine had no effect on HR during the last two hours of the fatigue trial. HRV increased significantly after the placebo but decreased after caffeine. Older subjects had significantly lower HRV than the younger subjects. Highly significant reduction in mean HR was found for all subjects after the fatigue trial.
7	Hajsadeghi [28] Subject: 44 subjects Country:Iran Condition: Adult participants aged between 15 and 30 years	Participants were advised not to take alcohol within 48 h prior to the study date and not consume any caffeine at least 12 h before the study	BP (systolic and diastolic) ECG recordings	HR is decreasing when the caffeine doses are lower and HR would increase when the doses are higher.
8	Segerstrom & Nes [29] Subject: 41-42 subjects Country: USA Condition: 2 conditions manipulation of self-regulation effort (eating carrots or cookies): (1st: high and 2nd: low)	ECG sampled at 1000 samples/s. HR and HRV were measured continuously.	Skin conductance	HRV was elevated during 1st test (eat carrots, resist cookies) compared with 2nd test (eat cookies, resist carrots).
9	Spitoni et al. [30] Subject: 24 (obesity subjects) and 49 (healthy control subjects) Country: Italy Condition: Subjects who are admitted in a clinic specialized	ECG was continuously monitored with the Firstbeat Bodyguard 2 (Firstbeat Technologies). The RMSSDand absolute values of High Frequency Power HRV (HF-HRV) were derived using the Analysis Software.	-	Greater HRV reduction and impaired HRV recovery in response to food stimuli in obese patients compared to controls.

	for treatments of eating disorder were enrolled in the study			
10	Herzig et al. [31] Subject: 309 subjects Condition:- Country: Switzerland	HRV was determined of three different segments: (1) identified automatically based on HRV characteristics over 5 min during deep sleep; (2) during 20 min segment starting 15 min after sleep onset; (3) over 4-h segment between midnight and 4 a.m.	-	HRV parameters decreased with increasing age, height, and weight in HR-adjusted regression models. Only found in segments of deep sleep detected automatically based on HRV or manually 15 min after sleep onset, but not in the 4-h segment with random sleep phases
11	Heinze et al. [32] Subject: 8 subjects Country: Germany Condition: Isolated with constant dim light.	HR and HRV in the TD as well as numerous spectral features and phase space trajectory descriptors were computed over RR interval series and cross-correlated with body temperature and sleepiness. TD measures of HR and its variability were the Mean HR and HRV.	EEG, EOG, VAS	HR, specific high-frequency spectral features and Poincaré descriptors of short-term HRV showed the best overall coherence.
12	Vicente et al. [33] Subject: 30 subjects Country: Spain Condition: -	The drowsiness detector assessed each minute of driving as "awake" or "drowsy" with seven HRV derived features (positive predictive value 0.96, sensitivity 0.59, specificity 0.98 on 3475 min of driving), the sleep-deprivation detector discerned if a driver was suitable for driving or not, at driving onset, as function of his sleep-deprivation state. Sleep-deprivation state was estimated from the first three minutes of driving using only one HRV feature (positive predictive value 0.80, sensitivity 0.62, and specificity 0.88 on 30 drivers).	RF	Incorporating drowsiness assessment based on HRV signal may add significant improvements to existing car safety systems.
13	Gouin et al. [34] Subject: 22 subjects Country: Canada Condition:-	HF-HRV during waking restfulness and in response to a worry induction was measureduring a low-stress period.	PSQI and ISI	During both the low- and high-stress periods, lower HF-HRV during worry was associated with greater PSQI scores. Importantly, lower HF-HRV during the worry induction prospectively predicted greater increases in the PSQI score from the low-stress to the high-stress periods
14	Aeschbacher [35] Subject: 1255	HRV was assessed using 24-h ECG monitoring.	LF, HF, TP	Early stages of sleep-related breathing disorders are

	subjects Country: Switzerland Condition: Aged 25-41 years with a body mass index <35kg/m^2	Time and frequency domain HRV and mean HR were automatically calculated by a software.		inversely associated with HRV in young and healthy adults, suggesting that they are tightly linked with autonomic dysfunction.
15	van Leeuwen et al. [36] Subject: 23 subjects Country: Finland Condition: Participants completed sleep diaries, had an adaptation night in the sleep laboratory, and carried actigraphs to verify adherence to a regular sleep–wake schedule	After two BL nights of 8 h time in bed, time in bed was restricted to 4 h per night for five nights (SR, n=15), followed by three REC of 8 h time in bed, representing a busy work week and a recovery weekend. The control group (n=8) had 8 h time in bed throughout the experiment.	-	Heart rate increased from 60±1.8 beats per minute (bpm) at BL, to 63±1.1 bpm after SR and further to 65±1.8 bpm after REC. Whole day low-frequency to-high frequency (LF/HF) power ratio of heart rate variability increased from 4.6±0.4 at BL to 6.0±0.6 after SR.
16	Sessa et al. [37] Subject: Condition: Country:Italy	The intrinsic HR generated by the sinoatrial node (SA node) in the absence of any neural or hormonal influence is about 100 to 120 beats per minute (BPM).	-	Low HRV has been shown to be independently predictive of increased mortality in post-myocardial infarction patients, CHF patients, in contrast with the data of the general population.
17	Fairclough & Venables [38] Subject: 35 subjects Country: UK Condition: 80 minutes	HR recorded using a standard Lead II configuration, and amplified using electrodes positioned on the 7th intercostal space on the right and left body sides. A common ground electrode was placed on the sternum. ECG was measured using a BIOPAC differential amplifier. HRV (MF and HF) bands were calculated from the IBI data by means of an FFT analysis with CARSPAN software.	Performance test, EEG, eye blink, EOG, respiration, skin conductance, Dundee Stress State Questionnaire	There is an HR increase at initial 40 min of performance.
18	Sutarto, et al. [39] Subject: 9 acting operators and 20 real operators Country: Malaysia Condition: Three cognitive tests	LF power % of HRV spectral recorded during 4-minutebaseline, 2-minute stressor and 4-minute recovery period. After that, participants in the both groups performed cognitive tests. Post assessment was carried out 1 week after the final training period, thus allowing for some measure of maintenance. Training participants received 5 session of weekly HRV	Physiological stress profile assessment	Resonant frequency training (RFT), a specific of HRV biofeedback strategy showed the potential to be an inexpensive psychophysiological approach to improve autonomic balance and respiratory control. Limitation: all subjects were women and further clarify the interrelationship between autonomic nervous system and cognitive function and features.

		biofeedback training of 30-50 minutes each. In the session 4 and 5, subjects in the biofeedback group also performed mental arithmetic task. The control group attended 5 sessions and was monitored physiologically. Physiological measurements were collected by biofeedback system using an I-330 C-2 interface.		
19	Hashem, et al. [40] Subject: 90 subjects Country: Bangladesh Condition:-	Compared ECG data with HRM. Used 3 phases are used to detect pulses on the fingertip that include pulse detection, signal extraction, and pulse amplification. Qualitative and quantitative performance evaluation of the device on real signals shows accuracy in heart rate estimation, even under intense of physical activity.	-	Findings showed that the error rate of the device is negligible.
20	Cadmus-Bertram et al. [41] Subject: 40 subjects Country: Condition:-	Measured the HR at 1-minute intervals for 10 minutes while the subjects exercised on a treadmill at 65% of the maximum HR. The Bland–Altman plot was used to compare the HR measured by electrocardiography with those measured by each of the wrist-worn trackers.	-	When participants exercised at 65% of the maximum heart rate, the limits of agreement were relatively poor for all the activity trackers (Mio Fuse, −22.5 to 26.0 beats/min; Basis Peak, −27.1 to 29.2 beats/min; Fitbit Surge, −34.8 to 39.0 beats/min; and Fitbit Charge, −41.0 to 36.0 beats/min). Some of the wrist-worn activity trackers that we studied measured values for heart rate that were similar to those measured by the electrocardiograph, and some measured similar values when the same device was used to repeat the measurements in the same study participant under the same conditions.
21	Wang et al. [42] Subject: 50 subjects Country: United State Condition:-	HR was assessed with the subjects on a treadmill at rest and at 2 mph, 3 mph, 4 mph, 5 mph, and 6 mph. Subjects exercised at each setting for 3 minutes to achieve a steady state; HR was recorded instantaneously at the 3-minute point. After completion of the treadmill protocol, HR	-	The variable accuracy among wrist-worn HR monitors; none achieved the accuracy of a chest strap-based monitor. In general, accuracy of wrist-worn monitors was best at rest and diminished with exercise.

was recorded at 30, 60, and 90 seconds' recovery.