**ICCEPM 2020**
The 8th International Conference on Construction Engineering and Project Management
*Dec. 7-8, 2020, Hong Kong SAR*

# Reliability and responsiveness of Equivital Lifemonitor and photoplethysmography based wristwatch for the assessment of physiological parameters during a simulated fatigue task

Shahnawaz Anwer[1*], Professor Heng Li[2], Dr. Waleed Umer[3], Dr. Maxwell Fordjour Antwi-Afari[4], Dr. Arnold YL Wong[5]

[1] *Department of Building and Real Estate, Hong Kong Polytechnic University, Hong Kong SAR,* E-mail address: shahnawaz.anwer@connect.polyu.hk

[2] *Department of Building and Real Estate, Hong Kong Polytechnic University, Hong Kong SAR,* E-mail address: heng.li@polyu.edu.hk

[3] *Department of Construction Engineering and Management, King Fahd University of Petroleum and Minerals, Saudi Arabia; Email:* Waleed.umer@kfupm.edu.sa

[4] *Department of Civil Engineering, College of Engineering and Physical Sciences, Aston University, Birmingham, United Kingdom; Email:* m.antwiafari@aston.ac.uk

[5] *Department of Rehabilitation Sciences, Hong Kong Polytechnic University, Hong Kong SAR,* E-mail address: arnold.wong@polyu.edu.hk

**Abstract: Objective**: To investigate test-retest reliability and responsiveness of Equivital Lifemonitor and photoplethysmography based wristwatch tools in assessing physiological parameters during a simulated fatigue task. **Methods**: Ten university students (Mean age, 30.6 ± 1.7 years) participated in this pilot study. Participants were asked to perform a 30-minute of a simulated fatigue task in an experimental setup in a lab. The physiological parameters (e.g., heart rate, heart rate variability, respiratory rate, electrodermal activity, and skin temperature) were measured at baseline and immediately after the fatigue task. An intraclass correlation coefficient ($ICC_{2,1}$) was used to evaluate the test-retest reliability of each tool in assessing physiological measures. In addition, the responsiveness of each tool to measure changes from baseline to posttest was calculated using a standardized response mean. **Results**: The Equivital Lifemonitor has shown good to excellent test-retest reliability for the assessment of heart rate (ICC, 0.97), heart rate variability (ICC, 0.86), respiratory rate (ICC, 0.77), and local skin temperature (ICC, 0.76). However, photoplethysmography based wristwatch showed moderate to good test-retest reliability for the assessment of heart rate (ICC, 0.71), heart rate variability (ICC, 0.73), electrodermal activity (ICC, 0.80), and skin temperature (ICC, 0.72). A large standardized response mean (>0.8) indicates that both tools can capture the changes in heart rate, heart rate variability, respiratory rate, skin temperature, and electrodermal activity after a 30-minute of fatigue task. **Conclusions**: The Equivital Lifemonitor and photoplethysmography based wristwatch devices are reliable in measuring physiological parameters after the fatigue task. Additionally, both devices can capture the fatigue response after a simulated construction task. Future field studies with a larger sample should investigate the sensitivity and validity of these tools in measuring physiological parameters for fatigue assessment at construction sites.

**Keywords:** Heart rate, reliability, skin temperature, heart rate variability, construction workers

## 1. INTRODUCTION

Construction industry is the most vulnerable for workplace accidents given the extremely exhausting nature of construction tasks [1]. Additionally, construction tasks are often performed under very hot and humid conditions [2]. Therefore, construction workers are prone to develop the risk of physical fatigue and fatigue-related workplace accidents [3]. Besides the general workforce, fatigue is a more critical issue for older workers who are more prone to fatigue development because of decreased cardiac output, muscle mass, and physical working capacity [4]. Since about 56% of the workers are 50 years and older in regions like Hong Kong, it has become a matter of huge concern [5]. Therefore, early monitoring of fatigue has become necessary to prevent undesirable workplace accidents in construction workers.

Fatigue is the leading cause of construction accidents [6-8]. Mostly, construction accidents are associated with poor work behaviour, poor design (of material, machinery, or workplace), and other factors (such as hot weather conditions) [9,10]. Past studies have pointed out despite significant advancements in technology, training, and communication in the last few decades, the enormous amount of accidents in construction workers might be related to poor work behavior results fatigue [11,12]. A previous study found fatigue to be the topmost reason for workplace accidents at the construction sites [13]. Another study acknowledged fatigue to be one of the primary causes of work place accidents in the building construction industry [14]. Similalry, Wong et al. [15] found fatigue to be one of the important risk factors for falls from height accidents in Hong Kong. In short, monitoring and management of fatigue has become a matter for the safety of construction workers.

Various physiological parameters, including heart rate (HR), heart rate variability (HRV), respiratory rate, electrodermal activity, and skin temperature may be used to monitor fatigue in construction workers [16,17]. For instance, Yi et al. [18] and Aryal et al. [19] have assessed physical fatigue in construction workers using HR metric, and HR and skin temperature metrics, respectively. Recently, Anwer et al. [17] also found positive correlations between physiological parameters (including HR, respiratory rate, and skin temperature) and subjective fatigue scores.

The development of new wearable technologies and recent advancements in physiology have given the opportunities to enable the objective, smooth, and steady monitoring of fatigue during construction tasks. For instance, the Equivital Lifemonitor is a wearable ambulatory device used to measure HR, HRV, skin temperature, and respiratory rate via chest-worn textile-based embedded sensors [20]. Previous studies have indicated the accuracy and validity of Equivital Lifemonitor in monitoring HR, HRV, skin temperature, and respiratory rate [20-22]. However, only one study tested the reliability of this device to monitor physiological parameters [21]. Another wearable device such as photoplethysmography (PPG) based wristwatch has also been used to monitor HR, HRV, and skin temperature by emitting light from light-emitting diodes and then detecting skin blood flow signals by photoreceptors [23,24]. PPG can also measure the electrodermal activity of the skin by two electro-conductors [17]. Previous studies have found high accuracy and validity of PPG based wristwatch to monitor HR, HRV, electrodermal activity, and skin temperature [24-27].

Although Equivital Lifemonitor [21,22,28] and PPG based wristwatch [24-27,29] have been validated in many studies, the reliability and responsiveness of these devices have not been well tested during construction tasks. Additionally, some prior reports found that Equivital LifeMonitor and PPG based wristwatch had high movement artifacts [20,24], and therefore, it may affect the usage of these devices during construction tasks. Therefore, the current pilot study aimed to investigate test-retest reliability and responsiveness of the Equivital Lifemonitor and photoplethysmography based wristwatch in assessing physiological measures during a simulated fatigue task.

## 2. METHODS

### 2.1. Participants

Ten healthy university students (Mean age, 30.6 ± 1.7 years) participated in this pilot study. Individuals with a history of musculoskeletal disorders, neurological disorders, or cardio-pulmonary diseases were excluded. The study followed the guidelines of the Declaration of Helsinki, and the protocol was approved by the Ethical Committee of the University (Reference Number: HSEARS20190824004). The written informed consent of the participant was obtained before data collection. A self-reported questionnaire was used to collect demographics and physical health.

### 2.2. Simulated fatigue task

Participants were performed a manual material handling task to develop self-identified physical exertion. Participants were asked to simulate a manual material handling task by carrying a wooden box of 15 kg from one point to another over a distance of 10-meter and continued this task for a 30-minute. This load was a typical weight handled by construction workers [30]. The simulated fatigue task was conducted using a modified experimental setup as published in the past studies [17,19,31]. Specifically, there was a two point (pickup and dropoff) over the distance of 10-mtere. Participants were asked to pickup the loaded wooden box from the pickup point and took it to dropoff point and after 1-minute of rest they continued this task till they achieved a self-identified fatigue level > 15 out 20 on Borg-20 scale [32].

### 2.3. Measurements of physiological parameters

HR, HRV, respiratory rate, electrodermal activity, and skin temperature parameters were measured at baseline and immediately after the 30-minute of fatigue task. These parameters were measured using the Equivital Lifemonitor system and a PPG based wristwatch (Figure 1). The physiological parameters were measured twice over 10 minutes of rest to determine the test-retest reliability of two devices. Additionally, the parameters were measured immediately after the fatigue task to determine the responsiveness of both devices in assessing physical fatigue.

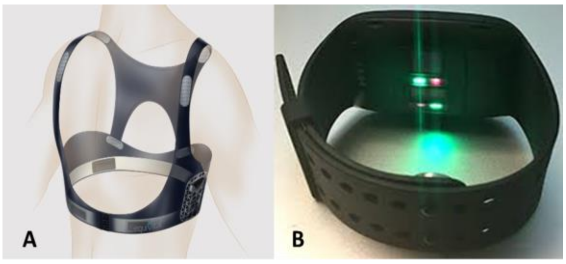


**Figure 1.** (A) Equivital Lifemonitor vest, (B) E4 photoplethysmography (PPG) wristwatch (Picture reproduced with permission)

### 2.4. Statistical analysis

The SPPS version 22 (IBM Inc., Chicago, IL) was used for conducting the statistical analysis. Descriptive statistics (mean and standard error), and an intraclass correlation coefficient ($ICC_{2,1}$) were used to evaluate the test-retest reliability of each device to assess physiological measures. In addition, the responsiveness of each device to measure changes from baseline to posttest was calculated using the standardized response mean (SRM). The level of responsiveness was determined as follows: SRM > 0.8 (large), 0.5 to 0.8 (moderate), and 0.2 to 0.5 (small) [33]. The data was statistically significant if alpha level = 0.05.

## 3. RESULTS

Table 1 illustrates the baseline and post-fatigue data of all variables. Mean HR was increased by about 49 beats/minute after the fatigue task. Similarly, the mean respiratory rate was increased to about 13 rates/min after the fatigue task. The mean changes in the electrodermal activity and skin temperature after the fatigue task were 2.3 µS/cm and 2 ℃, respectively.

Table 2 indicates the test-retest reliability and responsiveness of two devices in assessing the physiological parameters after a fatigue task. The Equivital Lifemonitor has shown good to excellent test-retest reliability for the assessments of HR (ICC, 0.97), HRV (ICC, 0.86), respiratory rate (ICC, 0.77), and skin temperature (ICC, 0.76). However, PPG based wristwatch showed moderate to good test-retest reliability for the assessments of HR (ICC, 0.71), HRV (ICC, 0.73), electrodermal activity (ICC, 0.80), and local skin temperature (ICC, 0.72). In addition, both devices showed a large SRM (>0.8) to measure cardiorespiratory and thermoregulatory parameters after the fatigue task.

Figure 2 depicts the test-retest reliability of the Equivital Lifemonitor and PPG based wristwatch in assessing HR and HRV. The Bland–Altman plots indicate that most of the scores were not beyond the limits of agreement.

**Table 1.** Descriptive Statistics

| | Mean | Std. Error | 95% CI |
|---|---|---|---|
| Age (Y) | 30.6 | 1.7 | 25.6 – 33.7 |
| Height (m) | 1.7 | .03 | 1.6 – 1.7 |
| Weight (kg) | 68.5 | 1.2 | 63.6 – 71.6 |
| Heart rate at baseline, Beats/minute | 74.1 | 5.9 | 57.8 – 86.4 |
| Heart rate at post-fatige, Beats/minute | 122.9 | 6.1 | 106.1 – 139.6 |
| Respiratory rate at baseline, N | 15.1 | 1.6 | 14.7 – 20.5 |
| Respiratory rate at post-fatige, N | 28.2 | 2.9 | 20.3 – 36.1 |
| Skin temperature at baseline, ℃ | 32.8 | .87 | 31.6 – 32.9 |
| Skin temperature at post-fatige, ℃ | 34.8 | .50 | 33.4 – 36.2 |
| Electrodermal activity at baseline, µS/cm | 2.83 | .67 | .19 –.55 |
| Electrodermal activity at post-fatige, µS/cm | 5.1 | 1.9 | -.16 – 10.4 |

**Table 2.** Test-retest reliability and responsiveness of Equivital Lifemonitor and photoplethysmography (PPG) based wristwatch in assessing heart rate (HR), heart rate variability (HRV), respiratory rate, skin temperature, and electrodermal activity

| | | **Equivital Lifemonitor** | | |
|---|---|---|---|---|
| | 1st Test | Re-test | ICC (95% CI) | SRM (95% CI) |
| HR | 74.1 (5.9) | 73.3 (6.7) | 0.97 (0.92 – 0.98) | 3.48 (2.72 to 4.90) |
| HRV | 0.73 (0.02) | 0.72 (0.01) | 0.86 (0.66 – 0.94) | 1.20 (0.90 to 1.5) |
| Skin temperature | 32.8 (0.87) | 32.9 (0.93) | 0.76 (0.43 – 0.90) | 1.80 (1.40 to 2.65) |
| Respiratory rate | 15.1 (1.6) | 14.9 (1.5) | 0.77 (0.46 – 0.90) | 1.40 (0.95 to 1.85) |
| | | **PPG Wristwatch** | | |
| | 1st Test | Re-test | ICC (95% CI) | SRM (95% CI) |
| HR | 72.3 (3.10) | 73.7 (2.94) | 0.71 (0.34 – 0.87) | 3.21 (2.00 to 4.24) |
| HRV | 0.83 (0.05) | 0.82 (0.04) | 0.73 (0.38 – 0.88) | 1.10 (0.90 to 1.3) |
| Skin temperature | 35.1 (0.02) | 35.2 (0.01) | 0.72 (0.37 – 0.87) | 1.56 (0.96 to 2.37) |
| Electrodermal activity | 2.83 (0.67) | 1.91 (0.29) | 0.80 (0.54 – 0.91) | 1.25 (0.85 to 1.65) |

SRM: standardized response mean; CI: confidence interval; Data are mean (standard deviation)

## 4. DISCUSSION

The current study investigated the test-retest reliability and responsiveness of Equivital Lifemonitor and photoplethysmography based wristwatch tools in assessing physiological parameters after the simulated fatigue task. Our results indicate good to excellent, and moderate to good test-retest reliability of the Equivital Lifemonitor and photoplethysmography based wristwatch in evaluating those parameters, respectively, to assess physiological measures. Additionally, the SRMs (>0.8) indicate that both tools could capture the changes in HR, HRV, respiratory rate, skin temperature, and electrodermal activity immediately after the 30-minute fatigue task.

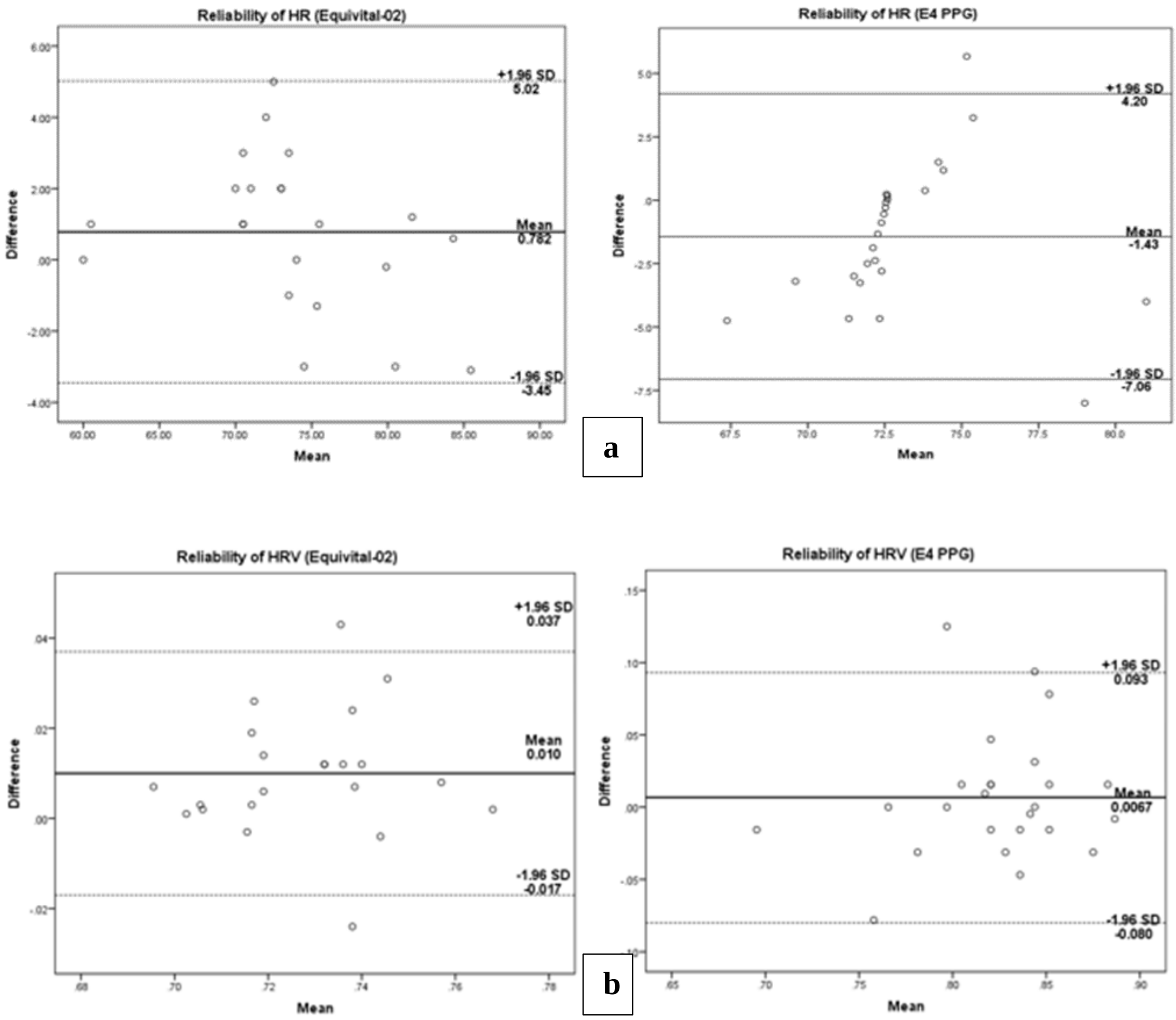


**Figure 2.** Test-retest reliability of Equivital Lifemonitor and photoplethysmography (PPG) based wristwatch in assessing **(a)** heart rate (HR) and **(b)** heart rate variability (HRV)

Our results supplement previous findings that indicate an excellent test-retest reliability of the Equivital Lifemonitor in assessing cardiorespiratory (ICC >0.95) and thermoregulatory measures (ICC, 0.97) [21]. A previous study also indicated that the Equivital Lifemonitor could reliably assess HR and HRV. The Equivital Lifemonitor is easy to wear, while the wireless textile embedded sensors give comfort and make it suitable for real-time monitoring for a prolonged duration [34]. However, textile-based electrodes are vulnerable to movement artifacts because these electrodes do not have clips or adhesives [7,17].

Similar to the current findings, a previous study indicated an adequate test-retest accuracy of PPG based wristwatch in monitoring HR at construction sites [24]. They used mean-average-percentage-error and correlation coefficient to determine the accuracy of PPG-based HR monitoring. However, the current study used ICC to evaluate the test-retest reliability. Previous studies have considered ICC as a measure of repeatability over time because a reduced values of coefficients could easily indicates systematic errors in trials [35,36]. In use of this technique to determine test-retest reliability, the PPG-based wristwatch showed moderate to good ICCs for monitoring HR, HRV, skin temperature, and electrodermal activity.

This is the first study to use SRM to investigate the responsiveness of the Equivital Lifemonitor and PPG based wristwatch to monitor changes in physiological parameters after a simulated fatigue task. The SRM was calculated by dividing the score difference (posttest – baseline data) by the standard deviation of the group's score differences [37,38]. Both devices showed a large SRM (>0.8) which indicates their ability to capture the fatigue response by monitoring physiological parameters after a simulated fatigue task. Although the findings substantiate the use of these devices for fatigue monitoring, future studies are warranted to further validate these results.

The current study acknowledged some limitations. First, this study had a small sample size including only 10 participants, however, the large effect sizes for measuring physiological parameters after the simulated fatigue task suggests that both devices are useful in monitoring physiological parameters during construction tasks. Future field studies are required to investigate the reliability and responsiveness of these devices on a large sample of construction workers during actual tasks. Second, the current study did not report the validity of the two devices in measuring physiological parameters related to self-reported physical fatigue after construction task. Therefore, future studies should use gold standard measures of physical fatigue (e.g., blood lactate levels) to evaluate the correlations between the measured physiological parameters from these devices and the actual fatigue levels during construction tasks. Third, the current study only used one simulated construction task. Future research should use different tasks and different physical loadings to determine if these devices can reliably estimate physical fatigue during various construction tasks.

## 5. CONCLUSIONS

This study evaluated the test-retest reliability and responsiveness of Equivital Lifemonitor and PPG based wristwatch devices in assessing physiological parameters after a simulated fatigue task. Participants carried a wooden box of 15 kg for a given distance until they perceived physical exertion. Th physiological parameters were measured with the Equivital Lifemonitor system and a PPG based wristwatch. These parameters were measured twice over 10 minutes of rest to determine the test-retest reliability and a third measurement was taken after the fatigue task to evaluate the responsiveness of two devices in assessing physical fatigue. The Equivital Lifemonitor and photoplethysmography based wristwatch devices are reliable in measuring physiological parameters after a fatigue task. Additionally, both devices can capture the fatigue response after a simulated fatigue task. Future field studies in a larger sample should investigate the sensitivity and validity of these tools in measuring physiological parameters for fatigue assessments at the construction sites.

## ACKNOWLEDGMENTS

The authors acknowledged the following two funding grants: 1. General Research Fund (GRF) Grant (BRE/PolyU 152047/19E) entitled “In Search of a Suitable Tool for Proactive Physical Fatigue Assessment: An Invasive to Non-invasive Approach”; and 2. General Research Fund (GRF) Grant (BRE/PolyU 15210720) entitled “The development and validation of a noninvasive tool to monitor mental and physical stress in construction workers”.

## REFERENCES

[1]. Ahn CR, Lee S, Sun C, Jebelli H, Yang K, Choi B. Wearable Sensing Technology Applications in Construction Safety and Health. Journal of Construction Engineering and Management. 2019 Aug 23;145(11):03119007.

[2]. Moohialdin AS, Suhariadi BT, Siddiqui MK. Practical validation measurements of a physiological status monitoring sensor in real construction activities. Streamlining Information Transfer between Construction and Structural Engineering Edited by Shiau, J, Vimonsatit, V, Yazdani, S, and Singh, A. 2018.

[3]. Mitropoulos P, Namboodiri M. New method for measuring the safety risk of construction activities: Task demand assessment. Journal of Construction Engineering and Management. 2010 Jun 16;137(1):30-8.

[4]. Kenny GP, Yardley JE, Martineau L, Jay O. Physical work capacity in older adults: implications for the aging worker. American journal of industrial medicine. 2008 Aug;51(8):610-25.

[5]. Egdell V, Fuertes V, Tjandra N, Chen T, Raeside R. The Impact of an Ageing Workforce on Employers in Hong Kong: A Study of the Service Sector, 2017.

[6]. Li J, Li H, Wang H, Umer W, Fu H, Xing X. Evaluating the impact of mental fatigue on construction equipment operators' ability to detect hazards using wearable eye-tracking technology. Automation in Construction. 2019 Sep 1;105:102835.

[7]. Fang D, Jiang Z, Zhang M, Wang H. An experimental method to study the effect of fatigue on construction workers' safety performance. Safety science. 2015 Mar 1;73:80-91.

[8]. Dawson D, Reynolds AC, Van Dongen HP, Thomas MJ. Determining the likelihood that fatigue was present in a road accident: A theoretical review and suggested accident taxonomy. Sleep medicine reviews. 2018 Dec 1;42:202-10.

[9]. Haslam RA, Hide SA, Gibb AG, Gyi DE, Pavitt T, Atkinson S, Duff AR. Contributing factors in construction accidents. Applied ergonomics. 2005 Jul 1;36(4):401-15.

[10]. Kartam NA. Integrating safety and health performance into construction CPM. Journal of Construction Engineering and Management. 1997 Jun;123(2):121-6.

[11]. Langford D, Rowlinson S, Sawacha E. Safety behaviour and safety management: its influence on the attitudes of workers in the UK construction industry. Engineering, Construction and Architectural Management. 2000 Feb 1;7(2):133-40.

[12]. Techera UD. Measuring and Managing Construction Worker Fatigue (2017). University of Colorado, Boulder.

[13]. Chan M. Fatigue: the most critical accident risk in oil and gas construction. Construction Management and Economics. 2011 Apr 1;29(4):341-53.

[14]. Adane MM, Gelaye KA, Beyera GK, Sharma HR, Yalew WW. Occupational injuries among building construction workers in Gondar City, Ethiopia. Occupational Medicine & Health Affairs. 2013:1(5).

[15]. Wong FK, Chan AP, Yam MC, Wong EY, Tse KT, Yip K. A study of the construction safety in Hong Kong: Accidents related to fall of person from height, 2005.

[16]. Umer W, Li H, Yantao Y, Antwi-Afari MF, Anwer S, Luo X. Physical exertion modeling for construction tasks using combined cardiorespiratory and thermoregulatory measures. Automation in Construction. 2020 Apr 1;112:103079.

[17]. Anwer S, Li H, Antwi-Afari MF, Umer W, Wong AY. Cardiorespiratory and Thermoregulatory Parameters Are Good Surrogates for Measuring Physical Fatigue during a Simulated Construction Task. International Journal of Environmental Research and Public Health. 2020 Jan;17(15):5418.

[18]. Yi W, Chan AP, Wang X, Wang J. Development of an early-warning system for site work in hot and humid environments: A case study. Automation in Construction. 2016 Feb 1;62:101-13.

[19]. Aryal A, Ghahramani A, Becerik-Gerber B. Monitoring fatigue in construction workers using physiological measurements. Automation in Construction. 2017 Oct 1;82:154-65.

[20]. Akintola AA, van de Pol V, Bimmel D, Maan AC, van Heemst D. Comparative analysis of the equivital EQ02 lifemonitor with holter ambulatory ECG device for continuous measurement of ECG, heart rate, and heart rate variability: A validation study for precision and accuracy. Frontiers in physiology. 2016 Sep 21;7:391.

[21]. Liu Y, Zhu SH, Wang GH, Ye F, Li PZ. Validity and reliability of multiparameter physiological measurements recorded by the Equivital LifeMonitor during activities of various intensities. Journal of occupational and environmental hygiene. 2013 Feb 1;10(2):78-85.

[22]. Tharion WJ, Buller MJ, Potter AW, Karis AJ, Goetz V, Hoyt RW. Acceptability and usability of an ambulatory health monitoring system for use by military personnel. IIE Transactions on Occupational Ergonomics and Human Factors. 2013 Oct 1;1(4):203-14.

[23]. Can YS, Chalabianloo N, Ekiz D, Ersoy C. Continuous stress detection using wearable sensors in real life: Algorithmic programming contest case study. Sensors. 2019 Jan;19(8):1849.

[24]. Hwang S, Seo J, Jebelli H, Lee S. Feasibility analysis of heart rate monitoring of construction workers using a photoplethysmography (PPG) sensor embedded in a wristband-type activity tracker. Automation in construction. 2016 Nov 1;71:372-81.

[25]. Gjoreski M, Gjoreski H, Luštrek M, Gams M. Continuous stress detection using a wrist device: in laboratory and real life. In proceedings of the 2016 ACM international joint conference on pervasive and ubiquitous computing: Adjunct 2016 Sep 12 (pp. 1185-1193).

[26]. Gjoreski M, Luštrek M, Gams M, Gjoreski H. Monitoring stress with a wrist device using context. Journal of biomedical informatics. 2017 Sep 1;73:159-70.

[27]. Fukushima H, Kawanaka H, Bhuiyan MS, Oguri K. Estimating heart rate using wrist-type photoplethysmography and acceleration sensor while running. In2012 Annual International

Conference of the IEEE Engineering in Medicine and Biology Society 2012 Aug 28 (pp. 2901-2904). IEEE.

[28]. Bizzini M, Impellizzeri FM, Dvorak J, Bortolan L, Schena F, Modena R, Junge A. Physiological and performance responses to the "FIFA 11+" (part 1): is it an appropriate warm-up?. Journal of sports sciences. 2013 Sep 1;31(13):1481-90.

[29]. Jebelli H, Choi B, Kim H, Lee S. Feasibility study of a wristband-type wearable sensor to understand construction workers' physical and mental status. InConstruction Research Congress 2018 (pp. 367-377).

[30]. Zhang M. Association between fatigue and safety performance of construction workers (Doctoral dissertation, PhD dissertation, Tsinghua University), 2014.

[31]. Cohen J. Statistical power analysis for the behavioral sciences. Academic press; 2013 Sep 3.

[32]. Day ML, McGuigan MR, Brice G, Foster C. Monitoring exercise intensity during resistance training using the session RPE scale. The Journal of Strength and Conditioning Research. 2004 May 1;18(2):353-8.

[33]. Shen YH, Zheng JW, Zhang ZB, Li CM. Design and implementation of a wearable, multiparameter physiological monitoring system for the study of human heat stress, cold stress, and thermal comfort. Instrumentation Science & Technology. 2012 Jul 1;40(4):290-304.

[34]. Nangalia V, Prytherch DR, Smith GB. Health technology assessment review: Remote monitoring of vital signs-current status and future challenges. Critical Care. 2010 Oct 1;14(5):233.

[35]. Hopkins WG. Measures of reliability in sports medicine and science. Sports medicine. 2000 Jul 1;30(1):1-5.

[36]. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports medicine. 1998 Oct 1;26(4):217-38.

[37]. Rosenthal R, Cooper H, Hedges L. Parametric measures of effect size. The handbook of research synthesis. 1994;621(2):231-44.

[38]. Liang MH, Fossel AH, Larson MG. Comparisons of five health status instruments for orthopedic evaluation. Medical care. 1990 Jul 1:632-42.