Centre for Research in Occupational Safety and Health

GUIDE TO PERSONAL HEALTH MONITORING DEVICES IN THE WORKPLACE

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CROSH
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centre for research in occupational safety and health
at Laurentian University
centre de recherche sur la santé et sécurité au travail
à l'Université Laurentienne

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INTRODUCTION

New technology development in the health and wellness industry offers individuals the ability to measure and/or estimate a range of physiological and health metrics throughout the day[1]. Personal health monitoring devices have gained popularity in both the general public and the medical community. Today, there are a wide range of wearable and portable devices, including sensors integrated into textiles, computerized watches, glasses, and pocket-sized monitors[2-4]. The tracking features of personal health monitoring devices can provide feedback on health-related choices (e.g., food and water consumption), provide users numeric information that allow them to gain insight and control over their health (e.g., exercise and sleep duration), and may reduce the risk of developing chronic diseases[5-7]. Additionally, many of these devices can be used while at work and may help employees monitor exposure to hazards and stress in the workplace. This guidebook provides information on what health monitoring devices are currently on the market, how they work, and what health and physiological responses can be monitored.

DISCLAIMER

The information contained in this material is provided as a guide only. Laurentian University (LU) and the Centre for Research in Occupational Safety and Health (CROSH) recognize that individual companies must develop health and safety policies and programs that apply to their workplaces and comply with appropriate legislation. This material does not constitute legal advice. While information provided is current at the time of printing, including references to legislation and established practice, it may become out-of-date or incomplete with the passage of time.

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ABOUT CROSH

The Centre for Research in Occupational Safety and Health (CROSH) at Laurentian University was established to provide a formalized structure for industry, safe workplace associations, labour groups, government organizations and researchers to share workplace injury and disease problems and solutions. CROSH envisions a Northern Ontario where workplaces partner to ensure every worker gets home safe and healthy every day. CROSH will be an agent for innovation and discovery to solve relevant and critical problems facing northern industries so they can eliminate occupational injury and disease from their workplaces. CROSH is proud to fund the *Guide to Personal Health Monitoring Devices in the Workplace*.

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OBJECTIVES OF THIS GUIDEBOOK

This guidebook was developed to provide information about novel technologies and commercially available devices that allow workers to monitor their own personal health. Although the purpose of this guidebook is to empower employees with the tools and resources for self-monitoring in alignment with the internal responsibility system, ultimately it is the employer's responsibility to identify and implement controls for workplace health hazards[8]. This guidebook serves as an information resource for human resource managers, occupational therapists, industrial hygienists, employers, supervisors, and employees, among others, to use to make decisions in the best interest of the employees. Although comprehensive, this guidebook may not encompass all possible ways of monitoring personal health, or minimizing and preventing exposure to health hazards, and therefore is intended to be used in conjunction with other resources (i.e., confidential interviews with trained health and safety professionals) in order to address all concerns in this area. The material contained in this guidebook is not intended as legal or professional advice. The adoption of practices described in this guidebook may not meet the needs, requirements, or obligations of all employees or individual workplaces.

WHAT ARE PERSONAL HEALTH MONITORING DEVICES?

Wearable personal health monitoring devices are defined as "devices that can be worn or mated with human skin to continuously and closely monitor an individual's activities and responses, without interrupting or limiting the user's motions"[2,9]. There are currently a number of devices on the market, and companies are continuously developing, testing, and releasing new devices and versions. Typically, health monitoring devices are geared towards tracking physical activity among the general public, and they can be used to support wellness goals[10] and improve social interactions[11]. An additional subset of health monitoring devices is aimed at clinical monitoring and/or rehabilitation progress[12,13].

In most cases, the sensors within the health monitoring device connect to computational platforms (i.e., an application on your smartphone or tablet) that can store, analyze, and share data[14,15]. Most devices are meant to be worn by the general public, continuously, in order to provide a wealth of data to the individual, while others allow information to be passed along to a health care professional, if required[1]. Personal health monitoring devices can range in price from $50-500+ CAD. As such, some devices can be expensive and unattainable to the general public. However, the average cost of basic commercially available devices is approximately $100 CAD.

WHY SHOULD WE MONITOR OUR HEALTH?

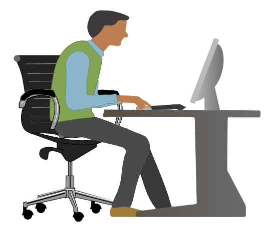
Monitoring health, both at work and at home, can help an individual understand their daily behaviours, identify their risk of developing chronic illness or disease, or manage their current conditions, all of which may impact their quality of life. From an industry standpoint, repeated exposure to certain environments and labour-intensive tasks (e.g., manual lifting, heat stress, vibration) can increase the risk of injury, illness, productivity, safety, and wellbeing[16]. Information about the intensity of occupational and leisure time physical activity, physical fatigue[17], and repetition[18,19] may be important to monitor while at work. Additionally, understanding how an individual responds to a stimulus (biophysical response) can provide information about their own health and mental state[20,21]. Furthermore, individuals who monitor their own health typically have a higher quality of life, reduced time away from work, improved productivity, and fewer work-related errors or mistakes.

WHAT WORKPLACE SITUATIONS AND ENVIRONMENTS CAN IMPACT YOUR HEALTH?

There are certain wearable devices that have the capability to assess occupational risks. These applications include motion detection, activity trackers, recognition of musculoskeletal disorders, fall detection and prevention, emotional states, physical and mental fatigue, and evaluation of exposure to physical agents (e.g., noise, heat stress, vibration)[22,23]. Please see the 'List of Health Monitoring Devices' section for examples of devices that can monitor occupational risk in the workplace.

Motion Detection and Inactivity

Some occupations require a high amount of sedentary (i.e., sitting or reclined) time, often associated with office work and truck operators or transportation drivers. Increased sedentary time at work is associated with an increased adoption of inactive behaviours outside of work compared to those who have more active occupations[24]. Sedentary behaviours also increase the risk of type 2 diabetes, cardiovascular disease, and all-cause mortality[25]. Identifying and tracking long periods of inactivity may promote increased activity during off-work hours.



Musculoskeletal disorders

Musculoskeletal disorders are injuries affecting muscles, joints, and tendons. The risk of developing musculoskeletal disorders is present in many different workplaces; they typically result from continual repetitive motions/ movements, focused force, work pace and/or working in awkward, fixed or constrained postures[26]. A number of devices have been developed to monitor movement patterns and provide feedback during occupational activities[27], including the ability to send warning signals when individuals are adopting incorrect postures and maintaining them for a prolonged period of time[27,28].

Fall Detection and Prevention

Falls can occur due to environmental factors, such as slippery surfaces, clutter, and improper lighting, as well as intrinsic factors including age, mobility impairments, and sleep disturbances[29]. Fall detection and prediction can help reduce the financial, emotional and physical consequences of a fall[29]. Fall prediction devices are aimed at detecting precursor events and alerting the individual before the fall occurs[23,29]. Accelerometers in some smartwatches provide reliable fall detection with factory settings (e.g., sampling rate)[30]. Fall prevention and detection devices may increase confidence and independence in both work tasks and daily living[29].

Emotional State

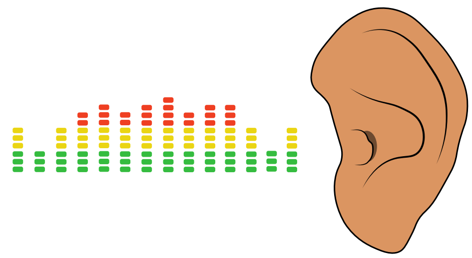
An individual's emotional and mental health and well-being are just as important as their physical health. Awareness of emotional state and changes can impact communication, productivity, focus, and creativity. Health devices that are worn or carried can use physical data to differentiate gestures or movements and provide information associated with relaxed or agitated emotional states. Physiological data can also be used to differentiate emotional states (i.e., stress level) through techniques such as heart rate variability, skin temperature analysis, respiratory rate, biological impedance, and muscle twitch analysis[31]. An increased number of these measures can increase the accuracy of tracking different states.

Fatigue

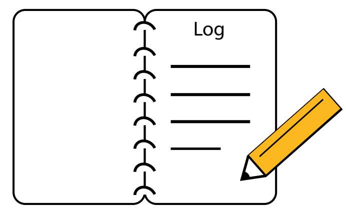
Another workplace concern is the impact of physical and psychological fatigue. Jobs that are physically demanding can lead to fatigue and exhaustion, which are linked to higher risk of injury and illness, especially when exposed to various occupational hazards[28]. Additionally, fatigue can be a risk factor for personal safety while commuting and may influence home life and relationships. The real-time feedback and on-demand data provided by most fatigue monitoring devices may encourage individuals to act

upon the notifications during the workday[28]. Fatigue can be estimated through cardiovascular and thermometer measures, and devices can send signals to identify when physical limits are reached[28].

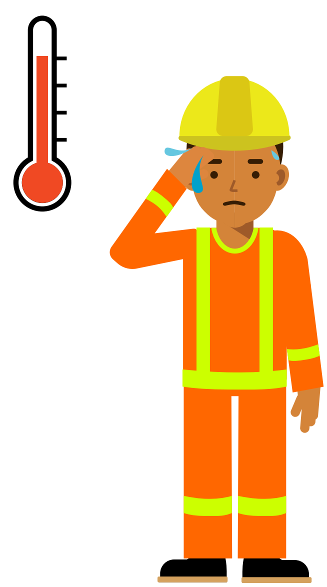
Noise



For some individuals, completion of daily work tasks may need to be performed in continuously noisy environments, or environments with bouts of dangerously high noise levels. Monitoring noise levels and exposure time is important for hearing conservation, as daily exposure to noise can damage the ear and induce deafness over time[28,32]. If an individual's work tasks vary throughout the day (i.e., they operate different machines, they move locations frequently), measuring noise exposure can help identify areas or tasks that exhibit excessive noise exposure[32]. When measuring noise exposure, it is important to keep a log of the tasks performed to help with understanding the measurement results. Individuals may also work with their company or employer to identify when they have exceeded noise exposure limits set by regulations or company limits[32]. It should be noted that noise monitoring devices record sound levels, not words or conversations.



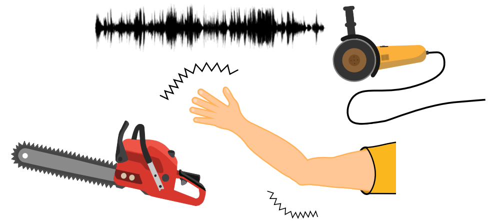
Heat stress



Occupational heat stress can result from performing strenuous activities and tasks in protective clothing, exposure to high seasonal temperatures and the sun, or from machinery that raises the indoor temperature[28]. Typically, heat stress is monitored via subjective techniques, such as surveys and indexes. However, this can lead to self-report biases, as well as interruption of workflow[21]. Advances in technology now allow for physiological responses to be assessed via non-intrusive wearable biosensors, collecting several responses at once[21]. These monitoring devices can allow individuals to be more aware of experienced occupational heat stress, and whether accepted exposure guidelines have been exceeded[28].

Vibration

While individuals can feel vibrations, it is hard to self-assess if the vibration felt is harmful[33]. When contact is made with a vibrating machine or tool the energy is transferred to the body, and can impact an organ, or segment of the body (termed segmental vibration). Segmental vibration often affects the area that is in contact, such as the hands and arms (hand-arm vibration) or feet (foot-transmitted vibration) and can occur during tasks such as operating handheld vibrating tools (e.g., chainsaws, jackhammers, grinders). Whole-body vibration results from energy transferred from a vibrating seat or floor, and it can affect the entire body or a large portion of the body[33]. Whole-body vibration is common in operators of transport trucks, buses, and agricultural and mining equipment. Accelerometers are often used to assess vibration, and the degree of potential harm from the vibration is related to the magnitude of acceleration[34]. While smart watches with accelerometers have been shown to detect hand-arm vibration[23,35,36], not all devices may provide accurate information as their sampling rate may be too low for higher frequency vibrations.

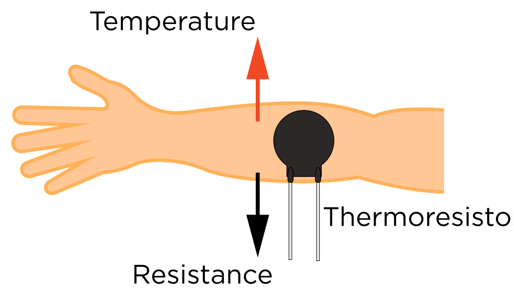


SENSORS USED IN HEALTH MONITORING DEVICES

Technology is advancing to allow for sensors to be flexible and wearable, allowing them to be embedded in fabrics and worn on the skin surface[3]. Understanding the sensors and what they measure can help individuals choose the correct monitoring device for their health needs. The technologies in health monitoring devices process data collected by these mobile sensors and use algorithms to generate measures of physiological function[37,38]. Note: Illustrators are not to scale.

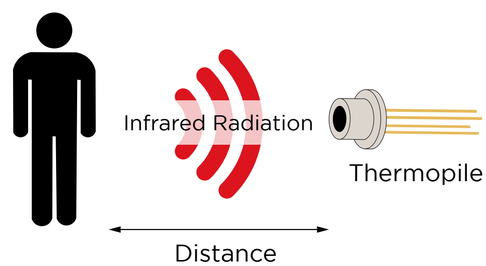
Thermoresistor

Thermoresistors are temperature sensors that operate on the principles of resistance and require direct contact with the skin. As body temperature increases, the resistance decreases, and the change in resistance is computed into changes in temperature[38].



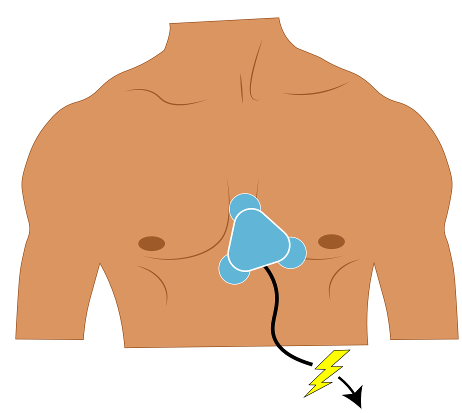
Thermopile

Thermopiles are a type of sensor designed to measure temperature from a distance by detecting infrared energy[38]. As temperature rises, the amount of infrared energy emitted increases. These sensors are also known as infrared thermometers, and they do not require contact with the body.



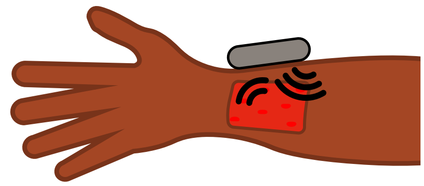
Electrocardiogram (ECG)

ECGs are often patches or chest straps that collect the electrical signals generated by the heart. They often require specific placement on the chest. They can detect heart rate and respiratory rate, as well as having the capability of detecting heart rhythm abnormalities. These sensors may not be comfortable for long-term, continuous wear[38,39], and the quality of the data can be impacted by motion artifacts (noise within the ECG signal that is caused by abrupt body movement).



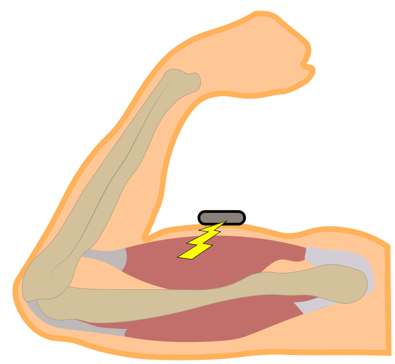
Photoplethysmogram (PPG)

PPG sensors use light to measure changes in blood volume, determined by the amount of light that is absorbed or reflected back to the sensor. PPGs are commonly used to measure an individual's pulse to determine heart rate. Heart rate is calculated by measuring the amount of time between changes in blood volume[38,40]. PPGs can also be used to estimate oxygen saturation (SpO_2, the amount of oxygen in the blood), using light absorption properties of oxygen-saturated hemoglobin[38]. These sensors can be easily embedded within wristwatches, armbands, and unobstructive rings. They are capable of detecting heart rhythm abnormalities, but the quality of the data can be impacted by motion during assessment.



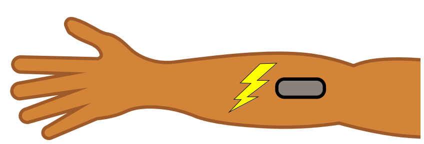
Surface electromyography (sEMG)

sEMG sensors non-invasively measure the electrical activity of skeletal muscles. When muscles contract, electrical activity increases and propagates through nearby tissue to the skin surface. sEMG sensors are placed on the skin surface above the muscle of interest, and multiple sensors are required if measurement of more than one muscle is desired. sEMG sensors can provide information about the timing and the degree of muscle excitation[41,42]. When they are coupled with accelerometers, they can be used to monitor activity and movement[43].



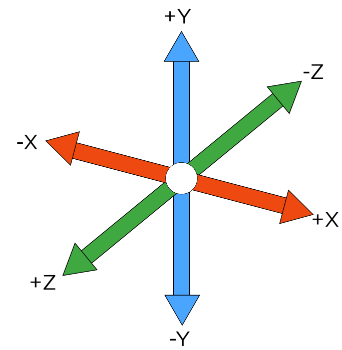
Electrodermal Activity (EDA)

EDA sensors measure the change in electrical conductance of the skin, which is indicative of activities of the sympathetic nervous system[21]. These sensors can be used to assess sweat gland activity, as well as emotional arousal and mental stress detection[49].



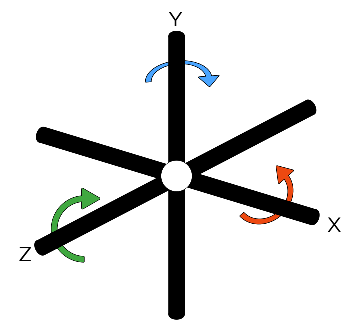
Accelerometers

These sensors measure acceleration forces to determine changes in position and movement along the sensor's axis. Accelerometers are one of the most commonly used sensors in health monitoring devices. There are often three sensors in each accelerometer, one for each axis direction. While accelerometers are typically applied for physical activity detection, they can also be used to assess other aspects of health, including respiratory rate, energy expenditure, sleep, fall detection, and posture assessment[23,45]. Additionally, data from accelerometers can help improve the accuracy of data from other sensors (e.g., sEMG and ECG) by helping reduce data "noise" caused by motion when they are coupled with other sensors[43,46].



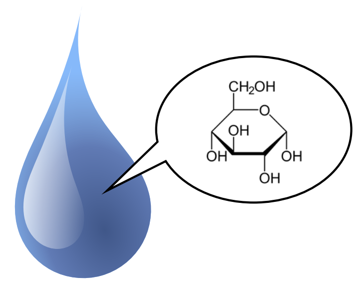
Gyroscope

Gyroscope sensors measure angular velocity, or changes in rotation. They are often coupled with accelerometers to provide a more accurate detection of movement and position.



Biosensors

Biosensors detect biochemical substances and convert the biological response into an electrical signal[47]. Most non-invasive, skin worn biosensors measure bodily fluids, such as sweat, tears, or interstitial fluid (fluid surrounding cells). These sensors can measure various biochemicals, including glucose, lactate and cortisol levels, and antibiotic concentrations[48].

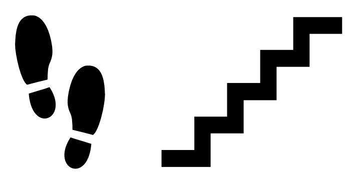


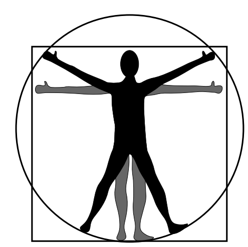
ASPECTS OF HEALTH THAT CAN BE MONITORED

Personal health monitoring devices can measure a wide range of health aspects, including physical movement, body temperature, respiratory rate, heart rate, blood pressure, blood oxygenation, and sleep. Many applications also allow individuals to manually track daily habits, such as nutrition and hydration. Some applications geared more towards exercise performance have also created "readiness" or "recovery" scores to give users an indication of how prepared they are to perform upon waking up. These scores are generally derived from numerous metrics recorded from the previous day and while sleeping, which include, but are not limited to, activity tracking, heart rate/heart rate variability, and sleep duration.

Physical Activity and Movement

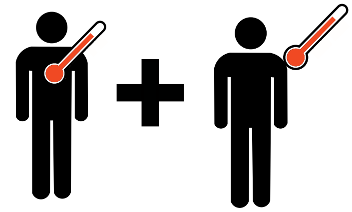
Regular physical activity has physiological and cognitive benefits (e.g., improved focus, muscle strength, weight control, etc.), and reduces the risk of developing chronic diseases (e.g., heart disease, diabetes, some forms of cancer)[49,50]. Many smart watches and health monitoring devices assess an individual's daily activity and habits, including steps taken, distance travelled, stairs climbed, and energy expended. Unfortunately, most devices tend to overestimate energy expenditure and should not be used as an exact measurement but only to monitor trends[51]. Evaluating the movements of the body can also have applications in posture, rehabilitation, and exercise performance[52]. Monitoring daily movement habits can also provide data on time spent in sedentary behaviours (i.e., sitting or reclined)[53].





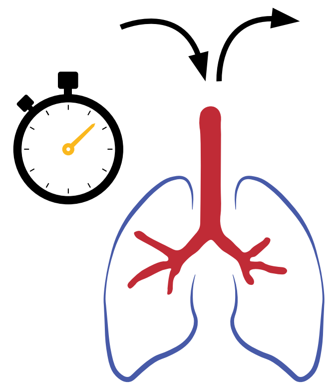
Body Temperature

The body is always balancing heat production and heat loss, with the outcome being the maintenance of body temperature at approximately 37°C. Measurement of body temperature can be important to avoid dysfunction due to high and low temperatures (e.g., heat exhaustion/ stroke, hypothermia)[52,54]. Body temperature is the combination of two measures, core temperature and skin temperature, but most personal health devices only measure skin temperature because direct measurement



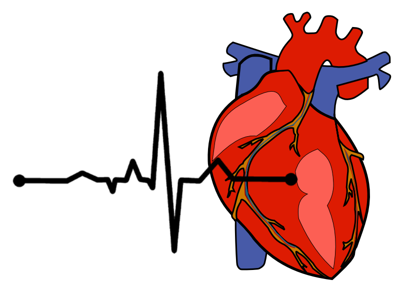
of core temperature can be difficult without an invasive, internal sensor. Skin temperature is related to both heart rate and metabolic rate, as it is affected by the circulation of blood[52,55]. These measures together can allow for mathematical approximations of core temperature.

Respiratory Rate



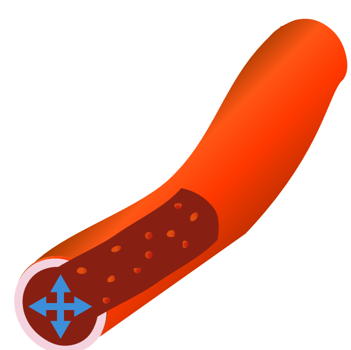
Respiratory rate reflects the number of breaths taken per minute and is regulated by the nervous system. Changes in respiratory rate occur when there is a need for more, or less, oxygen or carbon dioxide in the body[56]. Respiratory rate is one of the most early and sensitive indicators of distress and is a predictor of severe health events, such as cardiac arrest[52,56,57]. Additionally, respiratory rate is a good indicator of physical fatigue, and can respond to a variety of stresses, including changes in body temperature, stress, and cognitive load[16,58,59].

Heart Rate



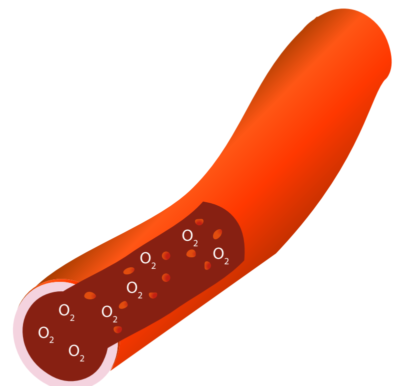
Heart rate is a common measurement in both clinical and fitness activities. It can easily be extracted from ECG or PPG data signals and provides indications of changes in heart cycles[52,60]. Measures of heart rate are closely associated with activity level and can indicate how the heart performs during different intensities of physical activity and recovery[52]. Variability in the time between one heartbeat and the next (heart rate variability (HRV)) can also be used to evaluate the health of the cardiovascular system and may reflect the overall capacity of the body[61]. Variability in heart rate is sensitive to changes in autonomic nervous system activity associated with psychological and physical stress. As such, HRV can also be used as an indicator of autonomic health and stress responses.

Blood Pressure



Blood pressure is an important cardiopulmonary measure, signifying the amount of pressure the blood is exerting against the arterial wall[52]. Blood pressure can also provide indirect measures of blood flow when the heart is contracting and relaxing. It is traditionally measured with an inflatable cuff, but now PPG and ECG can estimate beat-by-beat blood pressure through capturing arterial pulse wave transit time[12,25,52]. Monitoring blood pressure is important for identifying high blood pressure earlier than when it is checked only at occasional medical appointments. When blood pressure is within a normal range (i.e., approximately 120/80 mmHg), the risk of heart disease and stroke are reduced.

Blood Oxygenation



Measurements of blood oxygen saturation estimates the amount of oxygen that is being carried by blood cells. Blood oxygenation is easy to measure using PPG, and most commonly measured from the finger[52]. Under normal conditions, blood oxygenation is approximately 95-100%, and lower percentages (<95%) may indicate insufficient oxygen supply throughout the body[52]. While commonly used for medical monitoring, blood oxygen saturation can also be used to evaluate aerobic efficiency during physical activity, as an individual's performance during a physical task increases with increased oxygenation responses[52,54].

Sleep

Sleep is important throughout life, and getting enough sleep can improve mental health, physical health, quality of life, and safety[62]. Good quality and quantity sleep is important for the brain to develop new pathways, for enhancing learning and problem-solving skills, and for improving attention, decision making and creativity[62]. Sleep is also important for recovering from injury, the balance of hormones, and supporting the immune system. Devices that measure bio-signals (e.g., heart rate, skin temperature) and motion can extract information about certain behaviours, including sleep[63]. Tracking of sleep patterns with a device is more valid when coupled with a sleep diary[64]; however even coupled with a sleep diary, health monitoring devices are not validated for determining circadian rhythm and/or sleep disorders[63].

Nutrition and Hydration

Tracking nutritional habits is another useful tool to bring awareness to the quantity and quality of food and beverages being consumed each day. Monitoring nutritional intake may also be of importance for those who are looking to maintain, lose, or gain weight, as these applications allow for the estimation of calories consumed. Importantly, individuals who track their diet regularly are more successful at losing and maintaining weight[65,66]. Applications that include diet tracking often have expansive food databases and/or barcode scanners features for user ease. However, individuals should be aware that some applications provide more accurate estimations than others, and many commonly underestimate nutrient intake[67]. Consumption of water is essential for a number of bodily functions (e.g., temperature regulation via sweat production, urine production)[68]. A lack of water intake can lead to dehydration, low blood pressure, confusion, headache, nausea, and in extreme cases muscular weakness and kidney failure[69]. Furthermore, individuals who are more active, or are exposed to heat stress, require greater water intake than those who are sedentary or are in thermoneutral (neither hot nor cold) conditions. Conversely, consumption of too much water can lead to hyperhydration, accompanied by nausea, confusion, elevated blood pressure, and edema[69] (swelling).

LIST OF MONITORING DEVICES

The following list of health monitoring devices are categorized by desired health measure. This list provides a general guide of products that are currently available, but by no means covers all health monitoring devices on the market. It should be noted that some devices may measure more than one health aspect or physiological response, and may be listed under more than one category.

CROSH does not directly or indirectly endorse, nor has any financial or other conflicting interests, with any of the following products or companies. Other commercially-available products related to this guidebook may have been inadvertently omitted.

Movement and Activity Monitors

Reflex (Kinect)

Form: A belt-mounted wearable sensor.

Purpose: Monitors daily movements to prevent or reduce occupational injuries. Recognizes unsafe postures and movements performed on the job, including bending, overarching, and twisting.

Sensors and Parameters: Biomechanical sensors (e.g., accelerometers and gyroscopes) determines movement and postures. This device offers real-time feedback, where gentle vibrations are given when a high-risk posture is performed.

Specifications: The device is small (58.5mm x 71mm) and fastens securely to the waistband. The device is rugged, drop proof, and waterproof.

Oura Ring (Oura Health Ltd.)

Form: A wearable ring.

Purpose: Monitors daily movement habits and general health.

Sensors and Parameters: Takes measures from the arteries in the finger rather than capillaries in the wrist for increased accuracy. Uses infrared photoplethysmography rather than LED light. The device monitors motion/activity, heart rate, and heart rate variability respiratory rate, ventilation, body temperature, and sleep timing and quality.

Specifications: Connects to smartphones via Bluetooth. The battery lasts 5-7 days, and charges fully in 20-80 minutes. The device is water resistant and lightweight (4-6g).

Hexoskin Smart Shirt (Hexoskin Inc)

Form: Non-invasive smart shirt with embedded sensors.

Purpose: Singlet garment that monitors daily movement habits and general health.

Sensors and Parameters: The garment has a one lead ECG that monitors heart rate and heart rate variability. Also has embedded plethysmography sensors to measure changes in ventilation and breathing rate. Motion/activity are also monitored.

Specifications: Connects with mobile devices. Shirt is available in various sizes. Material is machine washable, quick-dry, breathable, and lightweight. Provides UV protection. Battery lasts 12-30 hours.

Kenzen (Kenzen Solution)

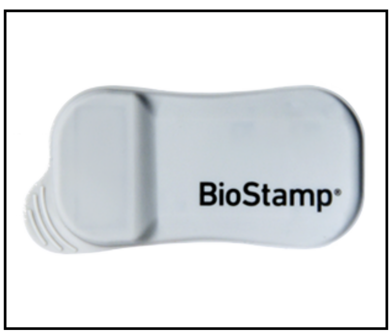
Form: Wireless band worn on the upper arm.

Purpose: Designed for continuous health and safety monitoring in the workplace, particularly in hot temperatures.

Sensors and Parameters: The device measures various vital signs including heart rate, body temperature, sweat loss, and motion/activity. The company is currently developing illness detection systems.

Specifications: Connects with application on smartphones via Bluetooth. The patch is lightweight, unobtrusive, and waterproof.

BioStamp nPoint (MC10 Inc)



Form: Soft, flexible biosensor which can be worn on multiple locations on the body for targeted data.

Purpose: Monitors general health, primarily for remote clinical monitoring.

Sensors and Parameters: The device monitors heart rate and heart rate variability, respiration, motion/activity, muscle activity, posture, and sleep quality.

Specifications: Connects with an application on mobile devices. The patch is soft, flexible and water resistant. Battery lasts anywhere between 2-24 hours depending on how many parameters are being measured.

Heart Rate Monitors

Apple Watch* (Apple Inc)

Form: Smart watch worn on the wrist.

Purpose: Monitors daily movement habits and general health.

Sensors and Parameters: Base versions of this device monitors heart rate, motion/activity, and sleep length and quality. Newer versions also include blood oxygenation and ECG apps, as well as fall detection.

Specifications: Connects with smartphone via Bluetooth. Water resistant up to 50m. Battery lasts up to 18 hours.

Fitbit Charge* (Fitbit Inc)

Form: A device worn on the wrist.

Purpose: Monitors daily movement habits and general health.

Sensors and Parameters: The device monitors motion/activity, blood oxygenation, skin temperature, heart rate and heart rate variability, and breathing rate.
Also allows for sleep tracking and menstrual health tracking.

Specifications: Connects with smartphone via Bluetooth. Battery lasts up to 7 days. Water resistant up to 50m.

*Newer versions of these devices are available, but it is unclear whether they retain the same sensors and parameters as older, validated versions.

E4 Wristband (Empatica Inc)

Form: Medical grade device that is worn on the wrist.

Purpose: Monitors daily movement habits and general health.

Sensors and Parameters: The device monitors skin temperature, heart rate, activity/motion, and activity of the sympathetic nervous system (sweat rate, stress level).

Specifications: Connects with smartphone via Bluetooth. Battery lasts up to 36 hours. The device is splash resistant.

Gait and Fall Monitors

FeetMe Insoles (FeetMe)

Form: Shoe insole.

Purpose: Provides real-time assessment of walking patterns.

Sensors and Parameters: The insoles have both pressure and motion sensors to measure walking speed, step length, cadence, stride length differences, pressure distribution, and time in single, double and asymmetrical support.

Specifications: Available in 12 sizes. The device charges wirelessly, and the battery lasts up to 24 hours.

Digitsole Walk Active (Digitsole)

Form: Shoe insole.

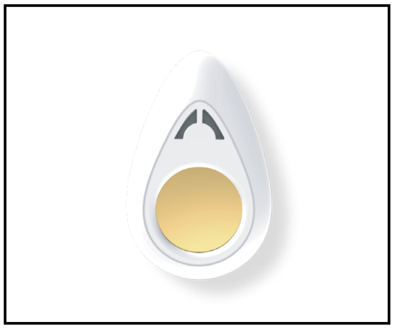
Purpose: Monitors walking patterns.

Sensors and Parameters: The insoles measure contact pressure, stride length and stability, contact time, and propulsion force.

Specifications: Device connects to smartphone via Bluetooth. Lightweight (66-90g) and are cut to size. Battery life lasts up to 10 days.

Psychological Stress and Emotion Monitor

PIP (The PIP)



Form: A personal, wireless handheld device.

Purpose: Measure and visualize changes in stress levels.

Sensors and Parameters: This device measures electrodermal activity of the finger.

Specifications: Device connects to smartphone via Bluetooth. The battery lasts for up to 8 hours.

Noise Monitor

The Original doseBadge (Cirrus Research plc)

Form: Wireless cone-shaped device worn on the shoulder, close to the ear.

Purpose: The device measures and assesses noise exposure and records long term noise exposure. There are several versions of the doseBadge, each designed for specific environments or industries.

Sensors and Parameters: Noise dosimeter (microphone) measures the dosage and level of sound or noise a person is exposed to.

Specifications: Connects with NoiseTools software for visualization of data. Lightweight (1.8oz/51g) and simple design with no cables, controls, or displays. Designed to be robust and handle harsh environments.

Versions:
CR:110A – Standard version
CR:110AIS – Intrinsic Safety Certifications, ideal for Mining, Petrochemical and Confined Spaces.

Body Temperature Monitors

TempDrop (Tempdrop LLC)

Form: A band that is worn on the upper arm, with the sensor facing towards the armpit.

Purpose: Intended to monitor changes in temperature for tracking of female menstrual cycles and fertility.

Sensors and Parameters: Measures both ambient and body temperature during sleep. The device can also monitor motion/activity during sleep.

Specifications: Connects with smartphones via Bluetooth. Battery life is 6-9 months. Uses algorithms to filter out ‘noise’ from movement, blankets, and sleep position.

Fever Scout (VivaLNK)

Form: A patch worn just below the armpit.

Purpose: Wireless, wearable device to continuously monitor temperature in order to track fevers.

Sensors and Parameters: Measures auxiliary (armpit) temperature.

Specifications: Currently only available in Greece and China. Compatible with mobile devices. The device is water resistant and reusable. The battery lasts up to one week.

Digitsole Warm Series (Digitsole)

Form: Heated shoe insole.

Purpose: Controls the temperature within the shoe and monitors walking patterns.

Sensors and Parameters: The temperature of the foot/shoe is measured, as well as all of the metrics of the Digitsole Walk Active (listed above) (contact pressure, stride length and stability, contact time, propulsion force).

Specifications: The device connects to smartphones via Bluetooth. The insoles maintain temperature in the shoe between 20-45°C. They are lightweight (66-90g) and cut to size. The battery lasts up to 8 hours.

EMFIT QS+ Active (Emfit Corp)

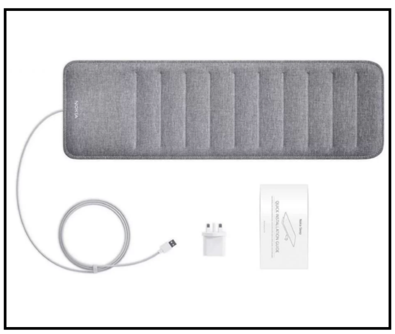
Form: A contact-free sensor placed underneath a mattress.

Purpose: The device monitors sleep (breathing, movement) and detects changes in sleep patterns.

Sensors and Parameters: Measures movement and activity during sleep and sleep quality. The device uses ballistocardiography (a measurement of the repetitive body motion generated by the ejection of blood with each heart cycle) for heart rate and heart rate variability, and breathing rates.

Specifications: The device has its own processor and memory. Data is viewed on a web-browser (no app or software is required). Device can be used for many years when properly maintained.

Withings Sleep Mat (Withings)



Form: A contact-free mat that is placed underneath a mattress.

Purpose: Monitors sleep duration, sleep cycles, and produces a sleep score.

Sensors and Parameters: Pneumatic sensor in the mat measures respiratory rate and heart rate through ballistocardiography and body movements.
Sound sensors identify audio signals related to snoring.

Specifications: Connects with smartphones or tablets via Bluetooth. The device can be used for many years when properly maintained.

Nutrition, Digestion, and Metabolism Monitors

Food Marble (FoodMarble)

Form: Handheld digestive tracker, breath testing device.

Purpose: Measures a body's unique response to how it digests food. An optional FODMAPs program specifically tests how the body digests certain carbohydrates (inulin, sorbitol, fructose, and lactose).

Sensors and Parameters: Measures the hydrogen produced when foods are not fully digested, and bacteria has to break it down through a process of fermentation. The hydrogen produced goes to the blood stream and to the lungs to be released.

Specifications: Connects with smartphones via Bluetooth. Application allows for food logging. Has a food library that shows different components of everyday foods. Mouthpiece is detachable for easy washing.

SugarBEAT (Nemaura Medical Inc)

Form: Disposable patch worn on the upper arm.

Purpose: A non-invasive glucose monitor, which may help individuals with diabetes, and pre-diabetes.

Sensors and Parameters: Takes real-time glucose measurements and provides daily glucose trend data. Provides both real-time and predictive alerts.

Specifications: Connects with smartphones via Bluetooth. The patch is hypoallergenic and flexible. Battery in transmitter is rechargeable. The patch sensor is changed daily (lasts for 14 hours of wear time) and requires a 30-60 minute warmup/calibration period.

Medical/Health Condition Specific Monitors

SurroSense Rx (Orpyx Medical Technologies)

Condition: Diabetes

Form: Custom insoles, designed for diabetics.

Purpose: The insoles fit in your shoes and monitor development of foot ulcers.

Sensors and Parameters: The insoles measure temperature of the foot, plantar pressure and motion/activity.

Specifications: Connects with smartphones via Bluetooth. Real-time alerts are given when foot pressure or temperature is elevated.

Siren Socks and Foot Monitoring System (Siren)

Condition: Diabetes

Form: Socks worn on the foot.

Purpose: Continuously monitors foot temperature to track issues related to inflammation and development of foot ulcers.

Sensors and Parameters: The socks continuously monitor temperature at 6 sites on the foot.

Specifications: New socks are shipped every 6 months. Connects with smartphones via Bluetooth. Real-time alerts are given when signs of inflammation are detected. Socks are machine washable.

Embrace 2 (Empatica Inc)

Condition: Epilepsy

Form: A medical grade, wrist-worn device.

Purpose: Detects tonic-clonic seizures lasting longer than 20 seconds.

Sensors and Parameters: The device measures heart rate, temperature, activity/motion, and stress levels.

Specifications: A subscription is required. Connects with smartphones via Bluetooth. The device is water resistant. The battery lasts up to 48 hours and fully charges in 30 minutes.

Spire Health Tag (Spire Health)

Condition: Chronic Respiratory Conditions

Form: A health tag that attaches to everyday clothing.

Purpose: The tag is designed to detect changes in respiration. Data can be shared directly to healthcare provider.

Sensors and Parameters: The device monitors respiratory rate and effort, motion/activity, and pulse rate.

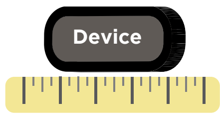
Specifications: The device connects to smartphones via Bluetooth. The tag is designed to be washed and does not require charging. The tag lasts approximately 12 months.

LIMITATIONS TO MONITORING YOUR HEALTH IN THE WORKPLACE

There are some aspects of devices that may impede the implementation of health monitoring in the workplace. It is important to ensure that the health monitoring device does not impede with an individual's ability to perform work tasks.

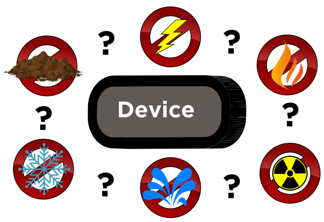
Size and Weight of the Device

The dimensions and weight of the device needs to be considered when implementing them in the workplace. Devices should not impede an individual's actions or ability to complete daily work activities.



Robustness

Not all devices may be suitable for all workplaces. For instance, not all devices may be resistant to water, radiation, shock, dirt, or other elements in the workplace[28].

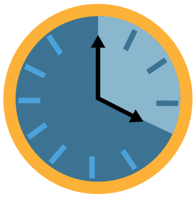


Company or Workplace Regulations

Some company and workplace regulations may inhibit the use of personal health monitoring devices while at work. For example, a workplace may not allow mobile phones on the worksite, which may be required to access data and feedback when using a health monitoring device. Another example is that a workplace's required protective clothing (hard hats, gloves, reflective shirts and jacket) may impede the ability to wear certain devices.

Time and Training

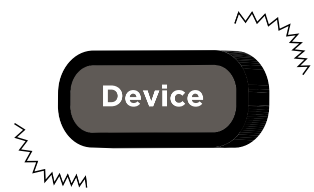
The time needed to operate the device may also impact its useability in the workplace. Some devices need to be configured throughout the day or require data entry, while others may require additional time in order to understand how the device works and how to operate it.



Data Interpretation

Personal health monitoring devices can provide a lot of different information, some of which can be difficult to interpret without certain knowledge[28]. For example, if your heart rate increases, how high is too high? Additional education may be required to be able to fully interpret and use the information appropriately.

Feedback Delivery



Devices that provide real-time feedback (tactile or visual), may only provide the signal in one method and may not be suitable for all workplaces. For example, tactile feedback signals, such as a vibration, may not be felt when handling certain materials or working on certain machines[28]. Additionally, there may be instances where immediate feedback can take focus away from the work task, which could lead to injury or reduced productivity.

IMPORTANCE OF VALIDITY AND RELIABILITY

The technologies for evaluating both physical and psychological health are at various stages of development and are constantly evolving. As new technology and devices are developed, it is important to test the device's ability to assess the intended feature compared to the highest standard of measurement. Some health monitoring devices have been independently tested to determine reliability (produces consistent results) and validity (accurately measures what it was intended to measure). However, there are a large number of devices on the market that have not been properly tested[70]. This is primarily due to the popularity and demand of these devices, causing companies to produce and release devices faster than researchers can test them[71,1,72]. Therefore, the devices listed in this guidebook only include validated devices and thus may not encompass all devices that are commercially available. It should be noted that even though these devices have been validated, they may not generate the same results in all workplace settings.

DATA OWNERSHIP AND PRIVACY

The health monitoring devices presented in this guidebook are intended for personal information, and therefore the data collected would belong to the individual wearing the health monitoring device. The data can also be shared with others, such as general practitioners, if the individual chooses to disclose this information, or if a device is being used to monitor a specific health/medical condition. This should be differentiated from workplace provided health monitoring devices, where internal health and safety services, as well as employers, may have access to the data.

Individuals must also be aware that the majority of health monitoring services upload data collected by the device's sensors to servers that are owned and provided by the company[73]. It is important to review the 'User Privacy' and 'Data Security' sections in the terms and conditions, as well as any specific privacy policies the service company provides for the health monitoring device chosen. These policies inform the user of their rights, and details if or how the data may be accessed or shared by the service company[73].

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