THE PRESENT INVENTION

According to a first aspect of the present invention, there is provided a personal hand-held monitor (hereafter "a PHHM") comprising a signal acquisition device for acquiring signals which can be used to derive a measurement of a parameter related to the health of the user, the signal acquisition device being integrated with a personal hand-held computing device (hereafter "a PHHCD"), wherein the parameter is blood pressure and the signal acquisition device comprises a blood flow occlusion means adapted to be pressed against one side only of a body part or to have one side only of a body part pressed against it, a means for measuring the pressure applied by or to the body part, and a means for detecting the flow of blood through the body part in contact with the blood flow occlusion means, wherein the means for detecting the flow of blood is an optical sensor, and the processor of the PHHM is adapted to detect the flow at a range of pressures applied by or to the body part in any order and to estimate systolic and diastolic blood pressure by fitting the measured data to a theoretical curve that relates blood flow rate to external applied pressure.

The PHHM in embodiments of the present invention must be of such a size and weight that it can readily be manipulated by a normal adult using one hand to hold the PHHM and the other hand to enter or retrieve data. Preferably, the PHHCD includes communications facilities, such as WiFi or wireless telephone connectivity.

By "integrated" is meant that the signal acquisition device and the PHHCD form a single physical unit wherein the signal acquisition device and the PHHCD remain in fixed relationship when either is moved. All electrical connections are provided within the PHHM.

The acquired signals may be analogue or digital and, if analogue, may be converted to digital form for subsequent analysis by the processor of the PHHCD or for analysis by a remote data processing facility with which the PHHCD communicates using the Internet or other data communication means.

The PHHCD with which the signal acquisition device is integrated may be a cellphone, a tablet computer, a PDA or any other computing device which can readily be manipulated by a normal adult using one hand to hold the device and the other hand to enter or retrieve data.

Embodiments of the~~The~~ present invention merge~~s~~ medical technology with PHHCD technology by combining proven technological principles with novel implementation to create a PHHM which allows its user to acquire measurements of personal health data solely by using the PHHM. If desired, the user may communicate those measurements to other parties.

The use of the PHHM in embodiments of the invention may be~~is~~ a significant improvement over the use of the systems described in the studies referred to above because the signal acquisition device is integrated with the PHHCD. Since the signal acquisition device must be small enough to be integrated with the PHHCD without reducing its portability and is able to make use of the infrastructure of the PHHCD, such as its display and battery, it will be significantly less expensive than many of the known medical devices, which are too expensive for most users in low income or emerging countries and would deter even those in developed countries. The signal acquisition device exploits micro-electronic technology to reduce size and cost to a level at which the signal acquisition device integrated with a PHHCD can become ubiquitous and personal to the user.

Preferably, the signal acquisition device is adapted to acquire signals while in contact with or very close to one or more parts of the user's body. In particular, the signal acquisition device may be adapted to acquire signals while at least a part of it is in contact with:

- one or more of the user's digits, especially one or more fingers;
- the skin near the carotid artery;
- the user's chest, advantageously close to the heart; and/or
- the inside of a user's ear or mouth.

The signal acquisition device includes one or more sensors for acquiring signals which can be used to derive a measurement of a parameter which is useful in relation to personal health. Preferably, the one or more sensors is(are) for acquiring signals related to blood pressure, pulse wave velocity, blood pressure waveform, temperature, blood oxygen partial pressure, electrocardiogram, heart rate and/or respiratory rate. The signal acquisition device may include sensors for acquiring signals from which measurements of more than one of the above-mentioned parameters can be derived. The signal acquisition device preferably includes one or more sensor(s) for acquiring signals from which measurements of blood pressure, using, for instance, one or more of sphygmomanometry, photoplesthysmography and measurement of pulse wave velocity, can be derived.

The PHHM in embodiments of the present invention may include one or more of the following sensors and means. Particularly preferred combinations of these sensors and means are referred to below.

Temperature Sensor

The signal acquisition device may include a temperature sensor for acquiring signals from which a measurement of local body temperature (i.e. the temperature near the location the sensor is applied to the body) can be derived by the processor of the PHHCD. Advantageously, the signal acquisition device also includes a sensor for acquiring signals from which a measurement of ambient temperature can be derived by the processor. This may be the same sensor as is used in connection with measuring local temperature or may be a separate sensor. Preferably, the processor is adapted to derive the user's core body temperature from the signals acquired by the temperature sensor.

As is well known, the temperature of a surface may be estimated by measuring the thermal radiation that it emits. For typical body temperatures, the radiation is concentrated at far infra-red wavelengths. It may be detected by a bolometer, in which a target is heated by the incident radiation and its temperature measured, either directly by detecting the change in its resistance or indirectly using a thermocouple, thermistor or other similar device. The field of view may be defined by a lens or window. The temperature sensor may be adapted to receive radiation from the inside of the ear or the temporal artery on the forehead as in existing medical devices using this technique.

The temperature sensor is preferably positioned so as to be able to sense the temperature of the user's ear, whether or not the user is making a telephone call. Alternatively, the temperature sensor may be positioned so that it is able to make measurements of the surface temperature of the body part on which any other measurement made by the PHHM, such as a measurement of blood pressure, is to be made.

Further Sensors and Means

The PHHM may further include means for applying electrical signals to the user's body and for detecting the signals produced in response to those signals, for instance to measure body properties such as body mass index.

The PHHM may include a sensor adapted to acquire signals from which the identity of the user can be derived, such as for taking a fingerprint of the user. This makes it possible to ensure that the derived measurements relating to the user's health can be associated directly to the user. Such an identity sensor may be associated with the pad of a blood flow occlusion means or may be associated with an electrode of an electrical sensor. It is possible to locate the identity sensor in such a way that it is almost impossible for the measured medical indicators to be of any person other than the identified user.

DATA ANALYSIS

The sensors and means described above may be used in various combinations to allow for the acquisition of various health-related data. The PHHM may include one or more of the temperature sensor, electrical sensor, blood flow occlusion means, blood photosensor for PPG, acoustic sensor, movement sensor, ultrasonic sensor and preferably includes at least the first four of these. Preferred combinations of sensors and means are set forth in the Table below, together with indications of the health-related data that may be derived using these combinations. However, it will be clear to the person skilled in the art that other combinations can be used to provide further health-related data and embodiments of the present invention are ~~is~~ not to be limited to the combinations set forth in the Table below.

The blood photosensor can use PPG to estimate blood oxygen levels. At least four variables may be derived from the measured absorption at two wavelengths. These are the amplitude of the detected signal at each wavelength at systole and between systoles. The arrow in Figure 2 shows one of the values that may be derived from these, the height of the peak corresponding to the change in oxygenated blood signal at systole. It is established that these four values may be analysed to estimate the oxygenation of the blood (see for example Azmal et al., "Continuous Measurement of Oxygen Saturation Level using Photoplethysmography signal", Intl, Conf. on Biomedical and Pharmaceutical Engineering 2006, 504-7).

Pulse Wave Velocity

The pulse wave transition time may be measured as set out above and converted into an estimate of Pulse Wave Velocity. This information is of direct diagnostic value to a skilled medical practitioner, especially if considered with all the other data obtainable from the signal acquisition device in embodiments of the present invention.

Respiration Cycle

The state of the respiration cycle may be detected from several of the data sets measurable by embodiments of the present invention:

- pulse rate (measured by electrical sensor and blood photosensor, see above);
- mean blood pressure (see above); and
- amplitude of the systolic pulse (measured by PPG, see above).

The results of all of these measurements may be combined using an optimising mathematical algorithm such as a Bayesian estimator to obtain the most reliable description of the amplitude and phase of the respiratory cycle.

Blood Flow Rate/Heart Stroke Volume

The volume pumped by the heart on each pulse is conventionally measured using an ultrasound scan. The cross-sectional area of the aorta is estimated from the image and

the flow rate from the Doppler shift. This is a mature and inexpensive technique but is only available at the doctor's office.

Before ultrasound was readily available, a convenient and almost non-invasive technique was to estimate the time taken for blood to circulate around the body. This is related to the pulse rate and the volume pumped on each pulse. The technique used a strong-tasting but harmless chemical that was injected into a vein in the arm and the time measured before it reached the patient's tongue and could be tasted.

Embodiments of the~~The~~ present invention allows a similar measurement to be made by perturbing the respiratory cycle. The PHHCD may be adapted to instruct the user to hold his/her breath. The level of oxygen in the lungs starts to fall and the oxygenation of the blood in the lungs falls with it. Once this blood reaches the body point at which measurements are being made, the blood oxygen level will be seen to fall. The time interval, when combined with assumed or entered data as to the path length, is a measure of flow velocity. The PHHCD then instructs the user to start breathing again and the time taken for the blood oxygen level to start to rise again may also be measured.

REMOTE DATA PROCESSING

The PHHM is capable of making and displaying measurements of any or any combination or all of the "vital signs" listed above without any external data processing. Additional features and improved accuracy may be provided by external data processing, using the communications capability of the PHHCD to connect to the Internet, a cellular telephone network or other communications means.

Preferably, each PHHM according to embodiments of the invention has a unique, unalterable, electronically-readable identifier. This may be provided during manufacture or testing. Furthermore, each PHHM preferably includes circuitry to encrypt the measured data in a manner that is unique to that device.

In one embodiment of the present invention, the PHHCD reads the unique identifier when the PHHM is first used and transmits that identifier to a remote secure data

may be made subject to the payment of a licence fee or to the app having been endorsed by the relevant regulatory authorities.

The PHHCD may also be programmed to provide information related to the derived measurement(s), such a normal ranges or recommendations for action.

The RSDS can offer a service to store many measurements from a PHHM and analyse trends and other derived information for the user. This may be linked to an automatic alert service in the event of any significant changes in the data. In addition, the signals or measurements can be anonymized and gathered from groups of or all PHHMs in embodiments of the invention so that they can be used for research purposes.

PHYSICAL CONSTRUCTION

A number of different sensors and means, as referred to above, can be incorporated into the PHHM. They can be incorporated individually or in any combination of two or more sensors. For instance, a combination of a sensor for measuring the pressure applied by a pad, strap or button, or applied to a pad, strap or button, a photosensor for measuring blood flow in a body part to which the pressure is applied and an electrical sensor for measuring pulse rate is particularly useful for providing more accurate data for determining blood pressure. Preferably, the PHHM integrates one or more Application Specific Integrated Circuits (ASIC), one or more Micro-Engineered Measurement Systems (MEMS) and/or photo-emitters and/or photo-detectors. They may be integrated as separate silicon devices in a single package or, preferably, some or all of them may be incorporated on one or more silicon devices. Such integration will bring several benefits, included reduced cost, improved reliability, reduced size and mass and reduced power consumption.

Preferably the PHHM exploits the other capabilities of PHHCD for calibration and operation.

Four embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings, in which: