Biosense Telemetry System For Contextual Health And Fitness Assessments

Related Application

[001] The present invention is claims priority to Singapore patent application no. 10202109146U filed on 21 August 2021, the disclosure of which is incorporated in its entirety.

Field of Invention

[002] The present invention relates to biotelemetry for capturing a person's vital physiology using wearable electronic health sensors and analysing any relevant contextual health and fitness states, with considerations for age; medical records indicating an illness or injury; perceived emotional or mental stress; external environmental conditions; energy capacity; fatigue risk; and so on. In particular, this invention relates to a system and method for analysing or conducting such contextual health and fitness assessments in the field of fitness training. This system is useful to enhance a training regime which balances between training load and safety.

Background

[003] Meaningful, contextual interpretation of physiology data requires knowledge of a trainee's age, gender, BMI, physical health and fitness, mental or emotional states, as well as the nature of the physical activity and environmental factors, and so on. For eg., an increase in a trainee's pulse-rate may be caused by load of the physical activity, hot weather, exposure to danger or mental stress, etc.; any meaningful analysis for contextual health and fitness assessments would require several wearable sensors to capture the trainee's physiological states over a period of time. Many systems or methods have been devised to capture such physiological data, as in the examples below.

[004] US 2006/0252999 by Devaul, et al. describes body-worn or -embedded network of sensors controlled by a hub for remote monitoring of human physiology, activity and environment. Monitoring of human physiology includes vital-signs monitoring, tracking the progress of a chronic or acute ailment, etc. Monitoring of human activity includes exertion monitoring; body motions including gait and tremor, and performance; detecting injury or fatigue, etc. Monitoring environmental conditions such as the buildup of toxic gas

or increasing external temperature; detecting exposure to toxic chemicals, radiation, poisons or biological pathogens. The system includes automated detection, real-time classification, and remote communication of any other important and meaningful changes in human physiology, activity, or environmental condition that may require notification, treatment, or intervention.

[005] US 2020/0253476 by Sports Data Lab. describes a browser-based biological tracking system which connects a set of wearable sensors to a computer. Sensor readings derived from multiple data streams provide aggregated insights to analyse athlete performance.

[006] US 9,848,823, issued to Apple Inc., describes a physiological model based on heart rate response to activity and can be informed by context information, such as the user's current activity and/or intensity level as well as user-specific parameters such as age, gender, general fitness level, previous heart rate measurements, etc. The physiological model can be used to determine a final heart rate estimate based on direct heart rate monitoring and modelled heart rate estimate.

[007] Despite disclosures of the above documents, it can thus be seen that there is a need to provide other biotelemetry systems and methods for contextual analysis of a person’s health and fitness states to make meaningful use of such recorded physiological data. Such recorded physiological data can be used to enhance a trainee’s performance, to minimise fatigue injury, to enhance a training program that requires a balance between training intensity and safety, and so on.

Summary

[008] The following presents a simplified summary to provide a basic understanding of the present invention. This summary is not an extensive overview of the present invention, and is not intended to identify key features of the invention. Rather, it is to present some of the inventive concepts of this invention in a generalised form as a prelude to the detailed description that is to follow.

[009] The present invention seeks to provide a system and method for conducting, monitoring or assessing contextual health and fitness states using wearable biosensors and

an analysis engine operable in a cloud server, with an associated database. Raw biosensors data is analysed by the engine to determine a user's health and fitness baseline(s), and estimating user's energy capacity and fatigue risk engineered parameters (such as, perceived energy capacity score; perceived fatigue risk score; heart rate recovery rate; heart rate inter-beat interval; respiration rate, etc.); these health and fitness baselines and energy capacity or fatigue risk parameters are then used to assess the user's health and fitness states in context with historical health reports, past injury, emotional or mental stress, external environments, hydration level, calorie intake, and so on. A reader will understand these features and processes after reading the following description and drawings.

[0010] In one embodiment, the present invention provides a system of biometric health and fitness monitor or assessment for a user undergoing a physical fitness training regime, as defined in the claims.

[0011] In another embodiment, the present invention provides a method for conducting biotelemetry to monitor and to assess a user's contextual health and fitness state whilst undergoing a physical fitness training regime, as defined in the claims.

Brief Description of the Drawings

[0012] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0013] FIG. 1 illustrates a biosensing telemetry system for fitness training and health assessments of a user or users in a squad according to an embodiment of the present invention;

[0014] FIG. 2 illustrates use of controlled trials for collecting structured and non-structured data in order to obtain statistically reliable and repeatable data collection;

[0015] FIG. 3 lists some parameters of physical activities included in the above fitness training and health assessments; FIG. 4 illustrates some parameters of a user's profile useful for the above fitness and health assessments; FIG. 5 illustrates parameters of sleep useful for such assessments and training load recovery analysis; FIG. 6 illustrates

parameters of cadence of movement analysis; FIG. 7 illustrates parameters of temperature taking; FIG. 8 illustrates parameters of blood oxygen level monitoring; FIG. 9 illustrates parameters of heart rate monitoring; FIG. 10 illustrates parameters of ECG monitoring; and FIG. 11 illustrates parameters of blood pressure monitoring;

[0016] FIGs. 12-13 illustrate a 2-stage analysis, where FIG. 12 illustrates a first stage, uni-variate data collection and analysis, whilst FIG. 13 illustrates a second stage, multi-variate data analysis to obtain useful energy capacity and fatigue risk assessments, and patterns for predictive fitness performance or proactive interventions;

[0017] FIG. 14 illustrates acute fatigue risk determination, whilst FIG. 15 illustrates chronic fatigue risk determination in the above fitness and health assessments;

[0018] FIG. 16 illustrates exemplary heart rate data, HR1 to HRn, of a user performing activity 1 on day 1 of a training regime; FIG. 17 illustrates best-fit/boxplot and margins of difference between various HR data; whilst FIGs. 18-21 illustrate compiled HR data for visual and statistical analysis;

[0019] FIGs. 22-24 illustrate various physiological baselines obtained by selecting univariate data with the least margin-of-difference and the corresponding 95% confidence levels in developing the multi-variate correlation to the target variables; and

[0020] FIG. 25 illustrates exemplary heart rate data according to statistical upper threshold, baseline and lower threshold, with the heart rates categorized into zones 1-5 showing fatigue risk safety limits.

Detailed Description

[0021] One or more specific and alternative embodiments of the present invention will now be described with reference to the attached drawings. It shall be apparent to one skilled in the art, however, that this invention may be practised without such specific details. Some of the details may not be described at length so as not to obscure the present invention.

[0022] Effective training, which often involves extensive and intensive running, walking or marching and load-bearing activities are designed to improve a user's physical competency; such physical competency is necessary to prepare for military or law

enforcer's operational readiness. However, such extensive and intensive training regimes often lead to an increase in training-related injuries. In more extreme cases, over-exertion during training can lead to a state of training exhaustion, which can, in turn, cause multi-organ dysfunctions, or even endanger the life of a trainee or user; thus, there is a need to conduct continuous monitoring of the training load, to help each trainee or user adapt positively to the training load and to provide a balance or trade-off between training load or intensity and safety.

[0023] Training load can be divided into two types - external and internal load. External load refers to the physical work carried out by the users, while internal load refers to the physiological and perceived exertion imposed.

[0024] FIG. 1 shows a biosensing telemetry system **100** for fitness training and health assessments of a user or users in a squad according to an embodiment of the present invention. The biosensing telemetry system **100** includes a use of a plurality of biosensors **110**,**110a-110e** that are wearable by the user or users, with the biosensors being tele-communicable with a digital condition monitoring system (DCMS) **130**. The DCMS **130** includes a server **140**, a biosense biotelemetry engine (BBE) **142** operable in the server **140** and an associated database **144**.

[0025] External training load is monitored via these wearable biometric sensors **110**,**110a-110e**, preferably with inertial measurement unit (IMU) and/or GPS, so that work done, such as, step counts, distance travelled, training intensity, training loads (like uphill and downhill), cadence rate, etc. are captured when a trainee or user performs physical activities. Some of the training activities, such as, high-intensity-interval training (HIIT), standard obstacle course (SOC) and Individual Physical Proficiency Test (IPPT) are listed in FIG. 3; these training activities, together with health records, are stored in a metadata module **120** shown in FIG. 1.

[0026] The biosensors **110**,**110a-110d** may be worn on the user's wrist, arm, embedded in the clothing or in-soles; it is also possible that other additional biosensors **110e** can be attached to other parts of a user's body, such as, the lower limbs, in a helmet or headband. It is possible that some of these wearable biosensors **110f** are used to monitor environment conditions during the above training. Preferably, the biosensors are chosen for their functionalities in consideration of comfort for wearing. Internal training load is an

aggregate of each user's perception (mental and/or psychological) of physical stress and actual physiological stresses experienced during training. These biosensors provide measures of internal training loads by monitoring a user's vital bio-signs, which include, heartbeat rate (HR), respiration rate (RR), body surface temperature (ST) which is used to predict a core body temperature (CT), blood pressure (BP), blood oxygen level (SpO2), heart rate inter-beat interval (IBI) and so on, movement/cadence rates using accelerometers, step counter and distance travelled, and so on; it is possible that other biosensors are used to capture a user's vital bio-signs (such as, ECG, PPSG, etc.) when the user is at rest or during sleep. Other parameters to capture may be: calories intake data, hydration intake data, etc., as shown in FIGs. 5-11. FIG. 4 shows a user profile to be captured for the above fitness and health assessments. Some of the parameters characterised in the present invention are called engineered parameters. The user may be a security personnel (including a trainee, a soldier; a civil defence, police, commando or navy frontliner, etc.), an athlete or a patient; the user may be undergoing physical and fitness training, rehabilitating or medical screening process, and so on.

[0027] As seen from FIG. 1, data from the wearable biosensors **110**,**110a-110f** are sent wirelessly to the server **140** or via a user's wearable or mobile smart electronic device operating a mobile application **125** to capture and monitor the relevant bio-signs. In another embodiment, some of the biosensors are powered by batteries and are programmed to send the raw biosensor data to the server **140** at regular predetermined intervals.

[0028] These raw biosensor data are filtered and structured at an ETL (extra-transform load) and data staging module **132** into a predetermined data structure format or schema before processing at the BBE **142** and storing at the database **144**. Preferably, the biosensor data are additionally statistically processed in a data quality check and transformation module **135** to ensure data credibility and repeatability before the biosensors data are received by the server **140** and stored in the database **144**. For eg., in FIG. 1, the biosensor data are tested for consistent repeatability in module **135a**, where the error margins in **135b** are verified to be within predetermined bands, data are compared using Bland-Altman technique **135c**, data are examined to elicit a pattern or trend in pattern matching **135d** or examined for correlations in module **135e**. Any correlations in the biosensor data are useful in a later described multi-variate analysis **200** operable in the BBE **142**. In addition, the biosensor data are verified by performing Mean Absolute Percentage Error (MAPE)

analysis in module **135f** or Root Mean Square Error (RMSE) analysis in module **135g**. MAPE provides a measure how close a value is to the true value; a biosensor sensor is considered accurate if MAPE ≤10%. RMSE provides a measure of accuracy of a value to the value observed; after comparing, data with a lower RMSE is more accurate.

[0029] FIG. 2 shows a trial of experiments for capturing the raw biosensor data for the data to be statistically reliable. Preferably, the numbers of users or trainees participating in a training regime are 30 or more. For each physical activity, for eg. as shown in FIG. 3, constituting a training regime, the biosensors **110**,**110a-110f** data are recorded over 4 days of training. For eg., the 3rd day training may involve a change in intensity of the physical activity. On the 4th day, the fitness and health bio-signs, such as, heart rate, SPO2, respiration rate, etc. are recorded, together with any observeable signs of fatigue or health responses; signs of fatigue may be expressed by sluggish gait after a fitness trial. These trials are carried out to choose the fitness and health bio-signs to monitor for purposes of evaluating each training regime. After this proof of concept was verified, the above biosensing telemetry system **100** for fitness training and health assessments was then launched.

[0030] Referring back to FIG. 1, the BBE **142** analyses and processes the biometric data to obtain meaningful information from the participant's health, fitness and psychometric data stored in the database **144**. Preferably, the server **140** is cloud-hosted and data can be accessed by logging into the server and the database, for eg. from a squad device **180** (such as, an ipad) belonging to a trainer or a training organisation. The BBE **142** may employ artificial intelligence computations to determine any pattern or correlation in context with the user's health, fitness and psychometric data, and external environmental factors. With continuous collection of biosensors data, physical activities and external environment factors over a period of time, a wealth of fitness and health data are collected, validated and stored in the database **144**. In one embodiment, from the wealth of fitness and health data, captured during fitness training, resting and sleep periods, a user's fitness and health baselines **155** are determined, which baselines **155** characterise the user's fitness level for a period after undergoing the training regime. With the BBE **142**, the processed data can be visually presented, for example, via graphs and animations, for example, in a time series domain or window with information of the user's health and fitness performance with respect to the relevant baselines **155**. It is also possible to visualize the processed data by

spectrum analysis to determine contextual occurrences, for example, to detect any arhythmic heartbeats above a predetermined raised pulse rate or threshold caused by performing a training activity, or to detect any health anomaly for predictive or preventive actions.

[0031] From the wealth of processed date, the BBE **142** is also programmed to output an alert **174** (when hazard to a life is predictable) or to generate a health/fitness status report **172**, before, during or after a training program, so that the training program can be adjusted or tweaked to achieve some predetermined purposes. Such alert **174** or status reports **172** can be sent directly to the user and/or through the squad device **180**. It is also possible that output documents **176** from the BBE are useful for short-term, mid-term and long-term training scheduling **176a-176c**.

[0032] A user's health and fitness do vary with time and may vary with mental, emotional and environmental factors. With these considerations, the BBE **142** analyses historical biometric data stored in the database to determine current engineered parameters of energy capacity (EC) **160** and fatigue risks (FR) **165** of an individual user and the entire squad.

[0033] Training loads can be further influenced by environmental conditions, including, environment temperature (T), wet-bulb temperature (WBT), relative humidity (RH), wind velocity, and so on. Collection and analysis of these biometrics and environment metrics could provide insights into the training loads experienced by the users and the ensuing physiological responses depending on users' health and fitness conditions.

[0034] In addition, training safety are influenced by other factors, such as, age, BMI, sleep pattern, smoking habit, alcohol drinking habit, medication and other health conditions.

[0035] As human physiology varies between individuals, the present invention suggests managing a user's training load based on each user's energy capacity and fatigue recovery accumulated during a training regime, in order to strike a balance between training load/intensity and safety. In other words, the need to monitor and assess a user's energy capacity or vigour to undergo a training regime and the risks of fatigue-induced injuries led to the present concepts of measuring or estimating the energy capacity (EC) **160** and fatigue risks (FR) **165** using the above wearable biometric sensors **110**,**110a-110f** coupled to the DCMS **130** and the BBE **142**, as shown in FIG. 1.

[0036] The above DCMS **130** and BBE **142** features serve to provide:

1. individual user and contextual-based baselines for health and fitness assessments;
2. monitoring of individual user's health and fitness parameters compared to those of the respective cohort;
3. ease of analysis to obtain objective individual user's and cohort's health and fitness parameters using biometric, environmental, energy capacity (EC) and fatigue risk (FR) assessments; and
4. safety alerts gleaned from a wealth of biometric, environmental, energy capacity (EC) and fatigue risk (FR) assessments, to reduce training attrition rate and to improve the associated training regime.

[0037] Advantages of the present invention: By monitoring the user's health, physical activity, mental and emotional states, together with external environmental factors, it is possible to:

1. predict a hazardous health condition (such as heat-stroke, fatigue, etc.) and to prevent loss of a life;
2. predict changes or onset of a health condition and to suggest follow-up diagnosis and treatment; and
3. predict physical performance states and to enhance a training program.

[0038] With the present invention, it is also possible to re-design training regimes with desired training loads, intensities and durations; identify gaps in training regime for performance optimisation; improved squad's strength through endurance in physical abilities and better understanding of individual training limits; reduced training-induced fatigue injury rate; reduced training attrition rate; improved user physical fitness; improved training effectiveness and efficiency; improved training safety; and so on.

[0039] After introducing the above biosensing telemetry system **100** for fitness training and health assessments, and associated advantages, the functionalities of the BBE **142** are now described:

[0040] In one embodiment, an EC score **160a** is a metric derived from a combination of data from physiologic parameters captured by the biosensors **110**,**110a-110e**, metadata

120, and environmental data **110f**, etc. to provide a measure or estimate of a user's energy reserves for the day of training as modelled by the engineered parameters EC, FR. The EC score **160a** is recorded on a chart having a scale of 1 to 10, with 1 denoting the lowest energy capacity and 10 denoting the highest energy capacity. Similarly, a FR score **165a** is also a metric with a scale of 1-10 that gives a measure of risks of injury accumulated during physical exertion in the course of training. For eg., the energy capacity EC score **160a** average aggregate score of, say of 3 or less may indicate that a user may lack sufficient energy reserves to undergo a current day of training. A fatigue risk FR score **165a** average aggregate score of, say of 7 or more, may indicate potential fatigue concern. When the EC score 160a or FR score 165a reaches a predetermined level, a safety flag or alert is issued. In another embodiment, engineered parameter FR can also be derived from threshold limits of parameters constituted in the biometric data for acute risk level, Z-score, acute chronic workflow ratio (ACWR) and consecutive drop (CD) analysis over time for chronic risk level. For example, a heart rate recovery with a drop of > 12 BPM after an intensive activity may indicate a potential fatigue risk concern. In addition, an outward observeable sign of fatigue risk accumulation is reflected by a user's gait and respiration rate (RR) during or after performing a training activity.

[0041] In the present invention, in FIG. 14, the typical health biometric ranges to classify fatigue risk (FR) injury as "acute" are:

1. heart rate (HR):
   a. HR at rest is 60-100 BPM. This range can be lower for more physically fit users;
   b. HR drop during sleep is > 10% compared to daytime resting HR;
   c. HR recovery: HR drop after intensive activity is > 12 BPM may indicate fatigue.
2. body temperature:
   a. skin temperature (ST) is 33 C while body core temperature (CT) is 37 C, depending on environmental factors;
   b. ST will drop during sleep;
   c. ST will have a spike when one wakes up.
3. Oxygen saturation (SpO2):
   a. SpO2 at rest during daytime is 95-100%.
   b. SpO2 during sleep will drop to > 88%.
4. heart rate safety thresholds:
   a. 5-10% higher at low HR (60% incidence); and

b. within 5% at high HR (> 60% incidence).

5. health trending, including respiration rate (RR) and ECG:

a. data drop/rise beyond safety limit thresholds;

b. rate of change obtained with change-point analysis; and

c. onset of fatigue is expressed by a sluggish gait pattern or irregular respiration rate.

[0042] On the other hand, in FIG. 15, the typical health biometric ranges to classify fatigue injury as "chronic, accumulated" are obtained by ACWR, Z-score and consecutive drop (CD) analyses:

1. ACWR: this analysis presents the ratio of work completed by a user over the past week, to the work completed by the user over a predetermined number of past weeks. The ratio between these two variables provides an indication on whether the user is training within an optimal training load, which normal ACWR range is 80-130%. Anything greater or less than this ratio is considered to be "chronic" risk.

2. Z-score: Z-scores calculate how much a user score/result deviates from the mean. This is calculated by (score – mean score)/score standard deviation. Z-scores raise a flag when the score dips suddenly.

3. Consecutive drop (CD) analysis reveals the number of times a user experiences a drop in a target variable. When the number of CD exceeds 3 consecutively, it raises a flag.

[0043] FIG. 12-13 show a two-stage analysis **200** approach is used to obtain in-depth analysis and meaningful correlations of users' health and fitness caused by acute and/or cumulative training loads. FIG. 12 shows a first stage uni-variate data analysis **210** whilst FIG. 13 shows a second stage multi-variate analysis **220**. The second stage multi-variate analysis **220** gives rise to the concepts of using engineered parameters EC **160** and FR **165**.

[0044] The uni-variate analysis **210** forms the first-stage analysis in which health and fitness data-sets are selected based on time and frequency domains of the wearable biometric sensors **110**,**110a-110e**, engineered parameters, meta-data **120** and environmental data **110f**; these data-sets are then carried forward to the BBE **142** to provide a pertinent set of individual user's physiology responses to each of the associated training regimes (having desired training loads, intensities and durations).

[0045] The uni-variate data-sets contain each individual's user records files, with different date files, stored in the metadata **120**. The individual date files are segregated according to the respective daily training activities, for eg., with start-stop timing, type of activity, intensity and duration, with the associated biosensors captured data; for egs. of the individual's user records files are:

1. Users' profiles, stored in the metadata **120**:

- sort the users into some initial fitness categories based on pre-training records that are available;
- further sort the users according to BMI;
- annotate users' health conditions based on pre-training medical records that are available;
- continuous collection of medical and training attendance records are indexed to detect health anomalies, trend analysis and pattern matching; and
- continuous collection of performance records are indexed to detect fitness anomalies, trend analysis and pattern matching.

2. Activity records, stored in the metadata **120**:

- records of a training schedule with segments of day-to-day biometric data;
- classify physical activities with associated intensities;
- classify physical intensities with duration; and
- divide the training schedule into segments of training loads.

3. Heart rate (HR) monitoring:

- record HR rest, HR max, HR recovery rate, and HR sleep;
- classify physical activity according to impact on HR, percentage of maximum oxygen consumption (VO2 max) and HR recovery rate (after a predetermined HR recovery period);
- continuous collection of HR data are indexed to detect anomalies, trend analysis and pattern matching; and
- annotate HR data to understand each individual heart rate response to training load.

4. temperature monitoring:

- record skin temperature (ST) and body core temperature (CT), at rest and during sleep;
- record max. ST and CT during each activity of training;
- record variation or percentage change of ST and CT during each activity of training;
- continuous collection of ST and CT are indexed to detect anomalies, trend analysis and pattern matching; and

- annotate ST and CT data to understand each individual temperature response to training load.

5. Sleep data capturing:

- record day-to-day sleeping time;
- record periods of sleep according to stages of sleep;
- record stages of sleep with variations of HR and ST or CT; and
- annotate stages of sleep to understand each individual sleep quality response to training load.

6. Perceived fatigue exertion (PFE) and hydration monitoring:

- record scores of perceived fatigue exertion (PFE), such as, the perceived EC score **160a** or FR score **165a**, described above, at the start of a training day, prior to warming up; after enduring a training activity, at regular intervals during a training day, and at the end of each training day; and
- record amount of water intake at the start of a training day, during water parades (before activity) and at the end of each training day.

[0046] From the above description, each of the uni-variate data-sets contains separate biometric data. Data segregation in each of the univariate data-set helps to reduce electronic noises and are useful to detect changes in the collected data. Change-point analysis is deployed to evaluate changes and/or abrupt shifts in time-domain, to detect subtle changes and rates of change. Continuous collection of these uni-variate data-sets facilitates lower recording variance and higher probability of relevance. With continuous collection, boxplot analysis allows a trainer to understand the spread of data and trend or pattern over time in response to training loads.

[0047] Multi-variate analysis **220** forms the second-stage analysis of cumulative training loads to provide a better understanding of the users' health and fitness as predictable or extrapolated from the uni-variate data-sets. Multi-variate analysis **220** aims to provide individual user's dynamic health baselines by taking into account normal variations of a selected set of physiology biometrics recorded by the wearable biometric sensors whilst undergoing a training regime. This multi-variate analysis **220** includes the following steps:

1. consolidating all the uni-variate data-sets according to the training activities, which are characterised by degrees of training loads, intensities and durations;

2. drawing correlations between multiple uni-variate data-sets with statistical correlation analysis (for eg. multivariate regression) to study the impact of training loads on various physiological health responses;

3. drawing correlations for trends or patterns of health anomalies;

4. drawing the closest physiological health characteristics from a wealth of biometric and environmental data monitored during training;

5. assessing training safety by considering individual user's health baselines against the engineered parameters EC and FR in response to various training loads;

6. comparing initial individual user's health baselines with performance baselines captured by the wearable biometric sensors during training;

7. continuous monitoring and collection of data are indexed to gain an understanding of variations between the initial and performance health baselines; and

8. Individual user's health baselines are updated regularly to obtain each dynamic health baseline in response to each designed training load.

[0048] The univariate analysis **210** in FIG. 12 involves compiling the biosensors data obtained during each physical activity of a training regime and determining margins of difference when the bio-signs are compared. The bio-signs data with the least margin of difference define the fitness and health baselines **155** for each user or trainee, which then form the reference for the above uni-variate and multi-variate analyses. The compiled data are shown in FIG. 16, whilst FIG. 17 illustrates some of the margins of difference between heart rate (HR) data obtained during some training activities, where the least margin of difference defines the HR baseline for the identified user. FIG. 18 shows the HR data captured over time. FIG. 19 shows a scatter plot of the HR data, which provides a basis for best fit of the HR data. FIG. 20 shows a box-plot of the HR data which fall in the upper quartile, 95% confidence, median, 25% confidence and lower quartile bands; the box-plot diagram provides a visual presentation of the skewness and range of spread of the HR data. By comparing the HR data occurring at different zones, the box-plot allows the trainer to appreciate a user or trainee's fitness performance and any outlier data points can be discounted or utilized for anomaly analysis. FIG. 21 shows a horizontal histogram chart where the HR zones are stacked and indicated by the frequency of occurrence.

[0049] FIGs. 22-24 show compiled data of baselines of HR, skin temperature, blood oxygenation SPO2, blood pressure, and so on, with corresponding 95% confidence data to

obtain the target biometric variables, ie., which may then be used to derive further engineered parameters that are indicative of the energy capacity (EC) **160** and fatigue risk (FR) **165**.

[0050] FIG. 25 shows an example of HR variations over time and HR zones, with curves showing the upper safety threshold, baseline and lower safety threshold.

[0051] In the above description, engineered parameters include BMI; heart rate derivatives (such as, HRmax, HRrest, HRreserve and HRsleep); oxygen saturation level, VO2max; body core temperature (CT); hydration level, which requires metadata input of age, gender, height, weight, training schedule (relating to water loss through sweating and respiration rate) and hydration records. From the heart rate data, inventors suggest heart rate inter-beat interval (IBI) data as a useful, additional engineered parameter for the above multi-variate fitness and health analysis **220**. The IBI is a measure of time between adjacent heartbeats; the IBI metric can be used to estimate the following or correlate with the following biometrics:

1. heart rate (HR), heart rate derivatives and heart rate variability (HRV);
2. respiration rate (RR);
3. sleep quality;
4. energy capacity (EC 160); or
5. fatigue risk (FR 165).

[0052] The above two-stage analysis **200** takes into account a wealth of biometric, environmental, EC and FR fitness and health assessment data and engineered parameters obtained in the course of training. The resulting dynamic health baselines obtained provide comprehensive assessments of users' health and fitness during the course of training, as compared to conventional approaches that rely on a limited number of biometric parameters. These dynamic health baselines can thus be used to draw early alerts or warnings before fatigue-induced injuries become symptomatic; thus, early detection and appropriate responses to training loads place users' welfare and safety into considerations. These safety considerations also provide aspects of training regimes for re-design, for eg. to improve training effectiveness and efficiency.

[0053] The above fitness and health assessment analysis of individual trainees and squad or cohort analysis are derived from contextual states using univariate and multivariate data, EC and FR data, engineered parameters, metadata of medical records, metadata of training regimes, environmental factors, etc. can be utilized for additional studies, which include:

1. construing new characterising features for enhancing the above fitness and health assessment analysis;
2. expanding data collection with additional sensors' parameters for analysis enhancement;
3. scaling up sample sizes for better representation of a population of the squad;
4. benchmarking future cohort training performance with obtained datasets and insights;
5. translating obtained datasets and insights into other operational studies; and
6. supplementing other health condition studies, such as, health and environment parameters to detect early covid-19 virus transmission.

[0054] While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations of variations disclosed in the text description and drawings thereof could be made to the present invention without departing from the scope of the present invention, for eg. in implementing the above extended studies.

CLAIMS:

1. A system for fitness and contextual health assessment comprising:

a plurality of biosensors to capture parameters of both external and internal training loads when a user wears the biosensors and undergoes a physical training regime;

a server and an associated database in communication with the plurality of biosensors; and

a biotelemetry engine (BBE) to analyse parameters of both the external and internal training loads collected by the plurality of biosensors to determine the user's health and fitness baseline;

wherein the BBE outputs a safety alert, when a user's health and fitness baseline exceeds a threshold or an engineered parameter of energy capacity (EC) or fatigue risk (FR) crosses or reaches a predetermined level.

2. The system according to claim 1, further comprising:

an ETL (extra-transform load) and staging module to filter and to structure biosensor data into a predetermined data structure; and

a data quality check and transform module to ensure data credibility before the biosensor data are received by the server and stored in the database.

3. The system according to claim 1 or 2, further comprising an electronic device wearable by the user or a squad device, wherein the electronic device or squad device operates on a mobile application to capture and to send biosensor data to the server, continuously or at predetermined time intervals.

4. The system according to any one of the preceding claims, wherein the BBE further analyses a metadata containing user's profile, training records, biometric records, perceived energy capacity and fatigue risk scores, sleep data, hydration data and calorie intake data.

5. The system according to any one of the preceding claims, wherein the BBE further estimates the engineered parameter of fatigue risk (FR) from a respiration rate, heart rate recovery rate or heart rate inter-beat interval data after a user has undergone a training regime.

6. A method for conducting biotelemetry to monitor and to assess a user's contextual health and fitness state, the method comprises:

wearing a plurality of biosensors by a user whilst undergoing a physical training regime;

transmitting biosensors data to a server and an associated database; and

a biotelemetry engine (BBE) processing the biosensor data to monitor external and internal training loads experienced by the user and to determine a user's health and fitness baseline;

wherein the BBE outputs a safety alert when the user's health and fitness baseline exceeds a threshold, or an engineered parameter of energy capacity (EC) or fatigue risk (FR) crosses or reaches a predetermined level.

7. The method according to claim 6, further comprises;

performing a first stage univariate analysis wherein the biosensor data is presented in time and frequency domains;

analysing the biosensor data in the time domain to determine whether there is any health or fitness trend or pattern; and

analysing the biosensor data in the frequency domain to determine whether there is any contextual occurrence or anomaly.

8. The method according to claim 6 or 7, wherein the user's health and fitness baseline is obtained by compiling biosensor data over a period of training and selecting the biosensor value with a least margin of difference.

9. The method according to claim 6 or 7, wherein a fatigue risk (FR) acute safety alert occurs when the biosensor data exceeds a normal range or exceeds a normal trend or pattern.

10. The method according to claim 8, wherein a fatigue risk (FR) chronic safety alert occurs when the compiled biosensor data shows:

an acute chronic workflow ratio (ACWR) analysis showing the biosensor data falls outside a normal range of substantially 80-130%;

a Z-score analysis showing a sudden dip; or

a consecutive drop analysis showing a predetermined number of consecutive drops.

11. The method according to any one of claims 6-10, wherein the engineered parameter is obtained by the following steps:

recording in a chart with a user responding to questions to elicit perceived energy capacity and perceived fatigue risk, and aggregating each score for the engineered parameter of EC or FR;

determining a heart rate recovery rate after giving a user a predetermined rest period, so that the heart rate recovery rate provides a measure of the engineered parameter FR;

recording a respiration rate, wherein a relatively high or irregular respiration rate provides a measure of the engineered parameter FR; or

determining a heart rate inter-beat interval, so that the heart rate inter-beat interval provides a measure of the engineered parameter FR.

12. The method according to any one of claims 7-11, further comprises a second stage multi-variate analysis of the biosensor data, which comprises:

consolidating all the uni-variate data-sets according to the training activities, which are characterised by degrees of training loads, intensities and durations;

drawing correlations between multiple uni-variate data-sets with statistical correlation analysis to study the impact of training loads on various physiological health responses;

drawing correlations for trends or patterns of health anomalies;

drawing the closest physiological health characteristics from a wealth of biometric data and environmental data monitored during training;

assessing training safety by considering estimating individual user's health baselines against the engineered measure or parameter of EC and FR;

comparing initial individual user's health baselines with performance baselines captured by the wearable biometric sensors during training;

continuous monitoring and collection of data are indexed to gain an understanding of variations between the initial and performance health baselines; and

Individual user's health baselines are updated regularly to obtain each dynamic health baseline in response to each designed training load.

13. The method according to any one of claims 6-12 providing a way to enhance the trainee's fitness performance, to minimise training injury, and to enhance the training regime to achieve a balance between training loads and safety.

14. The method according to any one of claims 6-13 providing a way to re-design a training regime effectiveness and efficiency by reducing training attrition rate.