

CLAIMS

1. A system for continuous monitoring of core body temperature (T_c) of a user, the system comprising:
 - a detection unit to be worn in the user's ear for measuring physiological data of the user by a plurality of sensors installed at the detection unit wherein the physiological data to be measured comprise first auditory canal temperature (T_{ac1}), second auditory canal temperature (T_{ac2}), external auricle temperature (T_{ea}) and heart rate (HR) of the user; and
 - an analysis unit connected to the detection unit via a communication link for computing T_c of the user with a prediction model using the physiological data measured by the detection unit where the effect of heart rate and external environmental temperature on auditory canal temperature of the user are taken into account;
 - wherein an over-heating state is detected when the computed T_c of the user is above a threshold level.
2. The system of claim 1, wherein the plurality of sensors comprising:
 - a first temperature sensor for measuring the T_{ac1} ;
 - a second temperature sensor for measuring the T_{ac2} ;
 - a third temperature sensor for measuring the T_{ea} ; and
 - an optical sensor for measuring the HR.
3. The system of claim 2, wherein the detection unit comprising:
 - an earbud to fit to the user's ear;
 - a first extension member extends from the earbud for insertion into auditory canal of the user's ear wherein the first temperature sensor, the second temperature sensor and the optical sensor are installed at the first extension member for measuring the T_{ac1} , T_{ac2} and HR respectively;
 - a second extension member extends from the earbud and in contact with the concha part of the user's ear wherein the third temperature sensor is installed at the second extension member for measuring the T_{ea} ; and
 - a control module for receiving and sending the measured physiological data to the analysis unit, and alerting the user when the over-heating state is detected.
4. The system of claim 3, wherein the second extension member has an auricular hook structure to encircle around the back of the user's ear where the third temperature sensor is installed at a position in contact with the eminence of concha of the user's ear.
5. The system of claim 3, wherein the second extension member has an elongate structure extends to the cymba concha of the user's ear where the third temperature sensor is installed at a position in contact with the cymba concha.

6. The system of claim 3, wherein the detection unit further comprising:
an elastic member for sealing the auditory canal thereby minimising air exchange between the auditory canal and external environment.
7. The system of claim 1, wherein the analysis unit comprising:
a data processing module for receiving the physiological data measured by the detection unit and computing T_c of the user with the prediction model using the physiological data where the effect of heart rate and external environmental temperature on auditory canal temperature of the user are taken into account.
8. The system of claim 1, wherein the analysis unit further comprising:
a user interface for displaying the computed T_c and/or the measured physiological data of the user, and allowing the user to change T_c computation parameters; and
a memory for storing the computed T_c and/or the measured physiological data of the user.
9. The system of claim 1, wherein the prediction model is a random forest prediction model which utilises a machine learning algorithm to compute T_c of the user with an acceptable mean bias of less than $\pm 0.27^\circ\text{C}$ where the measured physiological data are used to derive a decision tree to predict T_c of the user.
10. The system of claim 8, wherein the prediction model is a linear regression prediction model which uses a formula and the measured physiological data to compute T_c of the user, the formula is:
 $15.4299 + 3.6506T_{ac1} - 3.1375T_{ac2} + 0.0682T_{ea} + 0.0037HR$.
11. The system of claim 8, wherein the prediction model is a polynomial regression prediction model of degree 2 which uses a formula and the measured physiological data to compute T_c of the user, the formula is:
 $-77.6520 + 82.9429T_{ac1} - 75.4587T_{ac2} - 2.4982T_{ea} - 0.0320HR - 6.1514T_{ac1}^2 + 8.4253(T_{ac1} \times T_{ac2}) + 1.7738(T_{ac1} \times T_{ea}) + 0.0332(T_{ac1} \times HR) - 2.4006T_{ac2}^2 - 1.6639(T_{ac2} \times T_{ea}) - 0.0357(T_{ac2} \times HR) - 0.0355T_{ea}^2 + 0.0040(T_{ea} \times HR) - 0.0001HR^2$.
12. The system of claim 1, wherein the analysis unit can be in the form of a smart device installed with a software application to compute T_c of the user and display the computed T_c and/or the measured physiological data of the user.
13. The system of claim 1, wherein the physiological data of the user are measured repeatedly according to a pre-defined time interval so that T_c of the user can be monitored continuously.
14. The system of claim 1, wherein the threshold level is 40°C .

15. The system of claim 2, wherein the first and second temperature sensors are thermocouple sensors.
16. The system of claim 2, wherein the third temperature sensor is an infrared sensor.
17. A method for continuous monitoring of core body temperature (T_c) of a user, the method comprising:
- measuring physiological data of the user by a plurality of sensors installed at a detection unit to be worn in the user's ear wherein the physiological data to be measured comprise first auditory canal temperature (T_{ac1}), second auditory canal temperature (T_{ac2}), external auricle temperature (T_{ea}) and heart rate (HR) of the user;
 - sending the measured physiological data to an analysis unit connected to the detection unit via a communication link;
 - computing T_c of the user by the analysis unit with a prediction model using the physiological data measured by the detection unit where the effect of heart rate and external environmental temperature on auditory canal temperature of the user are taken into account;
 - determining an over-heating state when the computed T_c of the user is above a threshold level;
 - and
 - generating a warning signal to alert the user when the over-heating state is determined.
18. The method of claim 17, further comprising:
- displaying the computed T_c and/or the measured physiological data on the analysis unit; and
 - storing the computed T_c and/or the measured physiological data in the analysis unit.
19. The method of claim 17, where the prediction model is a random forest prediction model which utilises a machine learning algorithm to compute T_c of the user with an acceptable mean bias of less than $\pm 0.27^\circ\text{C}$ where the measured physiological data are used to derive a decision tree to predict T_c of the user.
20. The method of claim 17, wherein the step of measuring the physiological data of the user is repeated according to a pre-defined time interval so that T_c of the user can be monitored continuously.