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(54) **DETERMINING ENERGY EXPENDITURE OF A USER**

BESTIMMUNG DES ENERGIEVERBRAUCHS EINES BENUTZERS

DÉTERMINATION DE LA DÉPENSE ÉNERGÉTIQUE D'UN UTILISATEUR

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(73) Proprietor: **Koninklijke Philips N.V.**
5656 AE Eindhoven (NL)

(72) Inventors:
- **YIN, Bin**
  NL-5656 AE Eindhoven (NL)
- **DILLEN, Paulus, H., A.**
  NL-5656 AE Eindhoven (NL)

(74) Representative: **Coops, Peter**
Philips Intellectual Property & Standards
High Tech Campus 5
5656 AE Eindhoven (NL)

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- **CARLIJN V C BOUTEN * ET AL: "A Triaxial Accelerometer and Portable Data Processing Unit for the Assessment of Daily Physical Activity" IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 44, no. 3, 1 March 1997 (1997-03-01), XP011006346 ISSN: 0018-9294**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to determining energy expenditure of a user, and in particular to improving determination of energy expenditure of different activities.

BACKGROUND OF THE INVENTION

[0002] Monitoring of humans energy expenditure during a day is used in devices for medical, healthcare and consumer lifestyle applications.

[0003] Known devices for measuring energy expenditure use motion sensors attached to a person's thigh or waist. By analyzing sensor outputs, energy expenditures of e.g. running or walking can be determined. However, such methods have shown to give less accurate measures of energy expenditure for certain activities such as cycling.

[0004] EP 1302162 discloses an exercise amount measuring device comprising an acceleration sensor for detecting a body movement of a living body, means for calculating an exercise amount based on a detection signal of the acceleration sensor, and a display section for displaying the calculated exercise amount, said device further comprising: means for calculating an estimated consumption calorie value representing consumption of energy in a prescribed period; and a display section for displaying the calculated estimated consumption calorie value.

[0005] Whereas EP 1302162 discloses a device for estimating energy consumption during a prescribed period, it is questionable whether the device is capable of determining the consumed energy of different activities such as cycling with sufficient accuracy. Accordingly, it is an object of the present invention to improve the estimation of energy expenditures of different types of activities.

[0006] It should be noted that paper "estimation of activity energy expenditure based on activity classification using multi-site triaxial accelerometry", Kim D. et Al. , Electronics Letters, IEE stevenage, GB, vol. 44, no. 4, 14 February 2008, pages 266-267, XP006030492 ISSN:0013-5194, describes a wireless networked multi-site triaxial accelerometry system to estimate activity energy expenditure during daily life. A feature of the system is the utilization of activity classification based on multi-site acceleration signals. The signal processing and estimation algorithm used, uses the integral of absolute value of accelerometer output. These values were then converted to estimated activity energy expenditure using a linear regression equation based on reference data obtained using a standard method. Activity during a given period was automatically classified into two categories, i.e. arm-dominant and leg-dominant activities, according to the ratio of wrist to ankle acceleration signal amplitudes. This ratio was incorporated into the regression analysis as an additional factor.

[0007] Further, it should be noted that paper "A triaxial accelerometer and portable data processing unit for the assessment of daily physical activity", Carlijn V. C. Bouten et al., IEEE transactions on biomedical engineering, IEEE service center, Piscataway, NJ, US, vol. 44, no. 3, 1 March 1997, XP011006346 ISSN:0018-9294, describes the development of a triaxial accelerometer (TA) and a portable data processing unit for the assessment of daily physical activity. The TA is composed of three orthogonally mounted uniaxial piezoresistive accelerometers and can be used to register accelerations covering the amplitude and frequency ranges of human body acceleration. The data unit enables the online processing of accelerometer output to an estimator of physical activity over eight-day periods. Further, it should be noted that WO 2004/032715 (Bodymedia Inc.) 22 April 2004, describes a method and apparatus for measuring a state parameter of an individual using signals based on one or more sensors. In one embodiment, a first set of signals is used in a first function to determine how a second set of signals is used in one or more second functions to predict the state parameter, In another embodiment, first and second functions are used where the state parameter or an indicator of the state parameter may be obtained from a relationship between the first function and the second function. The state parameter may, for example, include calories consumed or calories burned by the individual.

SUMMARY OF THE INVENTION

[0008] Accordingly, the invention preferably seeks to alleviate or eliminate one or more of the above mentioned disadvantages of incorrect estimations of energy expenditures. In particular, it may be seen as an object of the present invention to provide a device that provides improved estimations of different types of energy expenditures.

[0009] This object and several other objects are obtained in a first aspect of the invention by providing a device for determining an energy expenditure of a user, the device comprising

- a data input for receiving acceleration data of the user as a function of time,
- a parameter input for receiving one or more user parameters Ui characterizing the user,
- a storage for storing constant parameters and activity scaling parameters, the scaling parameters being a function

of an activity of the user, the activity being obtained as a user-input or being determined by an automatic activity recognition algorithm,

- a processor for determining an activity value in dependence of activity by integrating or summing the acceleration data over the duration of an activity, and for determining an estimated value of energy expenditure by obtaining a product of the activity scaling parameters and the activity value and by forming a sum of said product and the one or more user parameters, where the user parameters are scaled by the constant parameters and the duration of the activity.

[0010] The invention is particularly, but not exclusively, advantageous for obtaining a device for determining energy expenditures of activities performed by a user of the device.

[0011] It may be advantageous to calculate activity value from acceleration data of a given activity performed by a person or user since the acceleration data provides an indication of the energy expenditure of the activity.

[0012] It may be seen as a further advantage to obtain a measure of the energy expenditure by multiplying the activity value with an activity scaling parameter since the scaling parameters are a function of an activity of the user and, therefore, may scale the activity value to provide an improved measure of the energy expenditure. Indeed, the activity scaling parameter may correct activity values which overestimates or underestimates the energy expenditure of the actual activity performed by the user. Accordingly, scaling of the acceleration based activity counts may be advantageous since this enables the user to better distinguish between the intensity levels of different activities and may, therefore, motivate the user to exercise activities having otherwise underestimated energy expenditures since the energy consumptions of such activities may be determined with greater accuracy.

[0013] It is understood that or summing the acceleration data may comprise summing magnitudes of the acceleration data.

[0014] In an embodiment the activity scaling parameters k(p) may have been determined by minimizing a difference between a measured energy expenditure value obtained for a given period comprising one or more activities and a sum of values of the estimated energy expenditure values for activities over the same period.

[0015] It may be advantageous to determine activity scaling parameters k(p) by minimizing a difference between a measured energy value, which is considered the correct value, and an energy value that has been estimated using the scaling parameters k(p), since both values are for the same period of time so that the determined scaling parameters k(p) provides an improved estimate of energy for the entire period.

[0016] The embodiment for determining activity scaling parameters k(p) may also be used for determining other constant parameters ai.

[0017] In an embodiment determining the activity scaling parameters (k(p)) may comprise

- obtaining a plurality of data pairs of measured energy expenditure values and acceleration data of a plurality of subjects, where the energy expenditure values and acceleration data are measured over a given period,
- minimizing the difference between measured energy expenditure values and calculated energy expenditure value obtained using a model to determine the activity scaling parameters, where the model determines activity count values from the acceleration values by integrating or summing the acceleration data over the duration of an activity to obtain values of activity count, multiplying values of activity count with the activity scaling parameters and summing products of activity count and the activity scaling parameters over activities.

[0018] It may be an advantage to obtain the plurality of data pairs of measured energy expenditure values and acceleration data of a plurality of subjects so that the determined activity scaling parameters provides improved estimates of energy expenditures for different subject, e.g. persons of different weight and age.

[0019] In an embodiment the activity scaling parameters may be greater than a preset threshold value for activities having activity values determined from the acceleration data which underestimates the actual energy expenditure, and where the activity scaling parameters may be smaller than the threshold value for activities having activity values determined from the acceleration data which overestimates the actual energy expenditure.

[0020] The preset threshold may be any value such as the value one.

[0021] In an embodiment the processor is further configured for forming a sequence of estimated values of energy expenditure for different activities to determine a time profile of the energy expenditure, e.g. a profile for the period of a day.

[0022] It may be advantageous to provide the estimated energy expenditure values as a sequence in index and order of the performed activities in order to provide the user with an overview of energy expenditures for different activities performed during a period, for example during a day.

[0023] Since the sequence of values of energy expenditures are determined using activity scaling parameters that have been determined by constraining the total estimated energy expenditure for a given period to be the same as the measured and correct energy expenditure of the same period, the total energy expenditure given by the sequence approximates the measured energy expenditure with good accuracy.

[0024] In an embodiment the user parameters comprises age, weight and height, and the sum of said product and user parameters are scaled by the constant parameters and the duration of an activity according to the equation: PAEE(p) = Tp*a0' + Tp*a1'*age + Tp*a2'* weight + Tp*a3'*height + a4*k(p)*AC(p), where the sum additionally comprises the term Tp*a0'.

[0025] In an embodiment, determining the activity value in dependence of activity comprises integrating or summing the acceleration data over the duration of an activity for each acceleration direction of the acceleration sensor.

[0026] It may be advantageous to integrate acceleration data, e.g. magnitudes of acceleration data, for each axis or direction of the acceleration sensor to provide more reliable values of energy expenditure.

[0027] A second aspect of the invention relates to a method for manufacturing the device according to the first aspect comprising,

- obtaining a plurality of data pairs of measured energy expenditure values and acceleration data of a plurality of subjects, where the energy expenditure values and acceleration data are measured over a given period,
- minimizing the difference between measured energy expenditure values and calculated energy expenditure values obtained using a model for calculating a value of energy expenditure of activities in a recursive loop to determine the constant user parameters and the activity scaling parameters, where an activity value of the model is determined from acceleration data of a given activity from a given subject by integrating or summing the acceleration data,
- providing the determined constant parameters and the activity scaling parameters in a device.

[0028] It may be seen as an advantage to determine the constant user parameters and the activity scaling parameters from a plurality of data pairs of measured energy expenditure values and acceleration data of a plurality of subjects since the determined parameters may provide improved accuracy due to the use of experimental data of a plurality of subjects. The parameters may be provided in a device according to the first aspect. For example, the parameters may be stored in a memory of the device during manufacturing.

[0029] In an embodiment of the second aspect, the step of minimizing comprises, in a recursive loop performing of steps a-c:

a) in a model (PAEE_CAL(j)) for calculating a value of energy expenditure of activities (p), obtaining an activity count value for each data pair of each user, where the activity count value is obtained from the expression Σp k(p)*AC(p) by summing the product of activity scaling parameters and activity values over activities in a period, where the activity value is determined from acceleration data of a given activity from a given subject,

b) using the model, determining the constant parameters by comparing the measured energy expenditure value with the calculated energy expenditure value, and

c) adjusting activity scaling parameters for given activities until the difference between the measured energy expenditure value and the calculated energy expenditure value is below a given threshold.

[0030] Adjusting the activity scaling parameters may comprise adjusting the activity scaling parameters that are defined by a set of intervals according to pre-set step sizes until a set of parameters is found that minimizes the difference between the measured energy expenditure values and the calculated energy expenditure values.

[0031] A third aspect of the invention relates to a system for determining an energy expenditure of a user, the system comprising the device according to the first aspect and a transportable accelerometer for measuring acceleration data of the user.

[0032] The transportable accelerometer may be connectable to the device according to the first aspect via a wired or wireless connection, or the accelerometer and the device may be integrated into a single system component.

[0033] A fourth aspect of the invention relates to a method for determining an energy expenditure of a user, comprising

- obtaining an activity (p) performed by a user (101) as a user-input or by an automatic activity recognition algorithm,
- determining an activity value in dependence of activity performed by a user, by integrating or summing acceleration data of the user over the duration of the activity,
- selecting an activity scaling parameter from a set of scaling parameters according to the actual activity, the scaling parameters being a function of an activity of the user,

[0034] determining an estimated value of energy expenditure by obtaining a product of the activity scaling parameter and the activity value and by forming a sum of said product and one or more user parameters, where the user parameters are scaled by the constant parameters and the duration of the activity, and where the user parameters characterizes the user.

[0035] A fifth aspect of the invention relates to a computer program product enabling a computer processor to carry out the method of the fourth aspect.

[0036] The first, second, third, fourth and fifth aspect of the present invention may each be combined with any of the other aspects. These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

[0037] In summary, the invention relates to an electronic device for estimating energy consumption of a person. The electronic device uses a mathematical model based on acceleration data for estimating the person's energy consumption as a function of the actual performed activity and acceleration values. The acceleration values are converted to an estimate of energy consumption of a given activity by scaling a value of time integrated acceleration data with an activity scaling parameter. The activity scaling parameters for different activities have been determined off-line by comparing measured energy consumptions over e.g. a day with estimated energy consumptions over the same period, where the estimated values are determined using the mathematical model.

BRIEF DESCRIPTION OF THE FIGURES

[0038] The present invention will now be explained, by way of example only, with reference to the accompanying Figures, where

Fig. 1A shows a device and system for determining a user's energy expenditure,
Fig. 1B shows estimated energy expenditure values and an energy expenditure profile,
Fig. 2A shows an implementation of a model for estimating values of energy expenditure,
Fig. 2B is a flow-chart of a method according to the invention,
Fig. 3A shows a flow-chart for determining constant parameters and activity scaling parameters using the model, and
Fig. 3B shows how activity count values can be determined from acceleration values.

DETAILED DESCRIPTION OF AN EMBODIMENT

[0039] Fig. 1A shows a device 100 for determining an energy expenditure of a user 101 on basis of acceleration data ACC provided from an associated accelerometer 105 via a data input 110. The acceleration data is in the form of an analogue or digital time dependent signal. The device 100 further comprises a parameter input 120 for receiving user parameters Ui characterizing the user 101 which carries the accelerometer 105. The device 100 comprises data storage 151 for storing constant parameters ai and activity scaling parameters k(p) (to be explained below). A processor 150, for example a digital processing unit, comprised by the device 100 is used to process acceleration data, user parameters Ui, constant parameters ai and activity scaling parameters k(p) to determine energy expenditure of a user 101. Graphical profiles and values of the energy expenditure determined by the processor 150 may be displayed on a display 140 comprised by the device 100.

[0040] The accelerometer 105 may be carried by the user 101. When the user wishes to inspect an energy expenditure profile or values, the user may connect the device 100 to the accelerometer for transferring accelerometer data stored in the accelerometer 105 to the device 100.

[0041] Alternatively, both the energy expenditure determining device 100 and the accelerometer 105 may be carried by the user during use of the device 100 so that the accelerometer 105 continuously transfers acceleration data ACC to the device 100.

[0042] The energy expenditure determining device 100 and the accelerometer 105 may be comprised by a system 160 as individual components or the device 100 and the accelerometer may be integrated into a single integrated device 160.

[0043] Fig. 1B shows an estimated one-day energy expenditure profile 180 of a user, for example a human or an animal. The profile 180 shows the user's physical activity in terms of energy expenditure PAEE as a function of time t. Different activities p shows different levels of energy expenditure of physical activity PAEE. For example activities p1 due to a user's walking may have relative high levels of physical activity energy expenditure PAEE compared to other activities p performed during a period D, for example a day measured from 6:00 AM to 6:00 AM the next day. The user in Fig. 1A also performs cycling twice that day, as illustrated by activity p2. However, the level of PAEE is under-estimated for activity p2 since the actual amount of energy expenditure is higher as illustrated by the dotted line 181.

[0044] The energy expenditure profile 180 is determined from acceleration values from an accelerometer carried by the user of Fig. 1. However, the cycling activity p2 results in small acceleration values compared to for example walking or running since first of all cycling does not involve direct impact with ground that contributes greatly to the generation of accelerations especially along a direction vertical to the ground; secondly, unlike walking or running, cycling creates little movement of the upper body in both vertical and horizontal directions, leading to a limited level of accelerations when an accelerometer is worn at the waist or chest. Accordingly, use of acceleration values for cycling and other activities may give incorrect estimations of energy expenditure profiles 180 as compared to actual energy expenditure profiles 181 measured using for example a gold standard method such as the doubly-labeled water (DLW) method by determining the washout kinetics of injected hydrogen and oxygen isotopes.

[0045] The actual activity p performed by the user 101 may be provided to the device 100 by a user-input (not shown) by which the user may input an activity, e.g. using activity buttons, a keyboard or a touch sensitive display. Alternatively, the activity may be determined by an automatic activity recognition algorithm processed by the processor 150. The automatic activity recognition algorithm may utilize data from a GPS sensor (Global Positioning System) carried by the user, data from a heartbeat sensor, a blood pressure sensor and a microphone. For example, the activity p may be determined from velocity information provided by the GPS and heartbeat information provided by the heartbeat sensor. The automatic activity recognition algorithm may also utilize acceleration data ACC to automatically determine the actual activity. For example, low acceleration values combined with a GPS measure of a high velocity, e.g. above 20 km/h, may be recognized as cycling.

[0046] Physical activity related energy expenditure PAEE may be determined from acceleration measurements using various methods. Equation 1 below provides one method for estimating PAEE from acceleration measurements:

$$PAEE = a0 + a1*age + a2*weight + a3*height + a4*ACD, \qquad \text{eq. 1,}$$

where a0-a4 are constant parameters and the factors *age, weight* and *height* are user characteristic parameters. The coefficients a0-a4 may be gender-dependent, so eq.1 may be different for males and females.

[0047] The factor ACD represents an activity count per day and is determined from acceleration data of the user carrying an accelerometer. The accelerometer used may provide acceleration data in one direction, for example in Earth gravity direction, in two perpendicular directions or in all three perpendicular directions. The activity count per day ACD may be determined by integrating or summing the acceleration data from the accelerometer. When the accelerometer has more than one accelerometer direction, the activity count per day ACD may be determined from the acceleration data by summing integrated magnitudes of the acceleration data obtained for each acceleration direction, where integration is performed over a given period of acceleration data, for example one day of acceleration data. For example the following equation,

$$ACD = \Sigma_n \Sigma_{ti} |ACC(ti)_n|$$

equates ACD by summing magnitudes of acceleration samples *ACC* over the sampling index *ti* and summing over each direction *n* of the accelerometer. When the acceleration signal is an analogue signal, the summation over samples *ti* can be replaced by integration over time.

[0048] Since the derivation of PAEE from eq. 1 does not distinguish between different activities p, the values of PAEE for different activities may be under- or overestimated since the acceleration values used for calculation of ACD does not correctly represent the actual energy expenditure of different activities p. For example, low acceleration values of cycling may underestimate the PAEE value of cycling.

[0049] Values of physical activity related energy expenditure PAEE may be determined by scaling acceleration data or the ACD value according to the type of activity p associated with acceleration data in order to more accurately estimate energy expenditure profiles 180 for different types of physical activities p. Equation 2 below uses activity scaling parameters k(p) for scaling acceleration data according to the type of activity:

$$PAEE(p) = \qquad \text{eq. 2}$$
$$Tp*a0' + Tp*a1'*age + Tp*a2'*weight + Tp*a3'*height + a4*k(p)*AC(p)$$

[0050] In general the constant parameters a0', a1', a2', a3' are given as a rate of change per time and, therefore, a0', a1', a2', a3' are multiplied with the duration Tp of the activity p in order to determine the energy expenditure for an activity p. Thus, Tp is a function of the actual activity p. The last term in eq. 2 is multiplied with the constant parameter a4 which is not given as a rate of change per time since AC(p) is already determined for the duration Tp. Accordingly, the last term is not multiplied with Tp.

[0051] When the constant parameters a0-a4 of eq. 1 are equated to give a one-day PAEE value in eq. 1, the equivalent rate of change in time of a0 (or a1-a3) may be given by a0'=a0/D, where D may be the duration of a day given in minutes.

[0052] Thus, in eq. 2, instead of using an activity count per day ACD which integrates accelerations of different activities, an activity value AC(p) obtained from acceleration values for different activities p and scaled by the activity dependent parameters (k(p)) is used.

[0053] It is understood that equation 2 gives a value or height 182 of an activity p of the PAEE time profile 180.

[0054] Accordingly, the entire PAEE profile 180 of one or more activities p within a period D can be determined by forming a sequence of PAEE values 182 for each activity p1,p2 up to pm as follows

$$PAEE(p1,p2,\ldots,pm) = \{PAEE(p1), PAEE(p2),\ldots,PAEE(pm)\}. \qquad \text{eq. 3}$$

[0055] The activity value AC(p) in eq. 2 is determined by integrating or summing magnitudes of acceleration data obtained from an acceleration sensor carried by the user. When the acceleration sensor has multiple sensor directions *n*, the activity value AC(p) is determined from the acceleration data by summing integrated, summed or averaged magnitudes of the acceleration data *ACC(ti)* obtained for each acceleration direction. The activity value AC(p) is obtained by integrating, summing or averaging data *ACC(ti)* over the duration of each activity p. As an example, the activity value AC(p) may be determined from:

$$AC(p) = \Sigma_n \Sigma_{ti} |ACC(ti)_n|,$$

where magnitudes of acceleration values *ACC* of a given activity p are summed over sampling times *ti* and over each direction *n* of the accelerometer for the duration of the activity p. When the acceleration signal ACC is an analogue signal, the activity value AC(p) is obtained by integrating the magnitude of the acceleration signal over time t. It is understood that sampling times ti or continuous times t are given as functions of activities p and, therefore, AC(p) becomes a function of activity p.

[0056] Calculation of the activity value AC(p) from acceleration values ACC may include removing acceleration components due to Earth gravity, e.g. by filtering away the DC component of the acceleration values.

[0057] Fig. 2A shows an implementation 200 of equation 2, for example an implementation on a computer running a program for carrying out the diagram shown in Fig. 2. In step 201 acceleration data ACC of a given activity p is integrated or the signal magnitude area (SMA) of the acceleration data is determined, e.g. using $AC(p) = \Sigma_n\Sigma_{ti} |ACC(ti)_n|$. The result from the step 201 is multiplied with k(p) and a4 in the subsequent steps 202 and 204. User input U1, U2, U3, for example age, weight and height, are multiplied with Tp in steps 205, 207, 209 and a1', a2' and a3', respectively, in steps 206, 208 and 210. In step 213 the products from steps 201-210 are summed together with a0' multiplied by Tp provided from steps 211-212. As shown in Fig. 2A, the constant a0' may be determined by use of the value 1 as a user parameter U0.

[0058] Equation 2 only represents one possible method for determining physical activity related energy expenditure PAEE in dependence of physical activity p. In general, any number of constant parameters ai' and any number of user parameters Ui may be used instead of a1'-a3' and *age, weight,* and *height,* respectively. As an example, with N-1 user parameters Ui, a value or height 182 of physical energy related energy expenditure PAEE may be determined from:

$$PAEE(p) = \Sigma_i\, ai' * Tp * Ui + aN * k(p) * AC(p) \qquad \text{eq. 4a.}$$

or,

$$PAEE(p) = \Sigma_i\, Tp * ai' * Ui + k(p) * AC(p), \qquad \text{eq. 4b}$$

where ai' corresponds to a1'-a3' and aN corresponds a4 in eq. 2. In eq. 4b the constant parameter aN is omitted since it is included in k(p).

[0059] Accordingly, a value height 182 of the energy expenditure PAEE of a user 101 for a given activity p may be determined from acceleration data ACC and user parameters Ui,102, by determining an activity value AC(p) in dependence of activity p by integrating or summing magnitudes of the acceleration data ACC over time or time samples for the activity p, by determining a product of the activity scaling parameter k(p) and the activity value (AC(p)), and by forming a sum of the product k(p)*AC(p) with the sum of one or more user parameters Ui 102 scaled by constant parameters ai' and the period of time Tp of an activity. Thus, when only one user parameter Ui is used, the sum of products ai'*Ui reduces to a single term. The user parameters Ui may have any value including the value one corresponding to the first term Tp*a0' of equation 2.

[0060] Similarly to equation 3, the entire PAEE profile 180 of one or more activities p within a period D can be determined by forming a sequence of PAEE values 182 from equation 4a or 4b for each activity p1,p2 up to pm as follows:

$$PAEE(p1,p2,\ldots,pm) = \{PAEE(p1), PAEE(p2),\ldots,PAEE(pm)\}$$

[0061] In equation 4b it is understood that the product k(p)*AC(p) is implicitly scaled by a constant parameter ai. For example, the constant parameter may be contained in the activity scaling parameter k(p) in the product k(p)*AC(p).

[0062] Fig. 2B shows the method steps of an embodiment of the invention for determining an energy expenditure PAEE(p) of a user 101 based on equation 4a or 4b comprising the steps:

Step 221 : determining an activity value AC(p) in dependence of activity p performed by a user, by integrating or summing acceleration data ACC of the user 101 over the duration Tp of the activity p;
Step 222 : selecting an activity scaling parameter k(p) from a set of scaling parameters according to the actual activity p, the scaling parameters being a function of an activity p of the user 101; and
Step 223 : determining an estimated value 182 of energy expenditure PAEE by obtaining a product of the activity scaling parameter k(p) and the activity value AC(p) and by forming a sum of said product k(p)*AC(p) and one or more user parameters 102 scaled by the constant parameters ai' and the duration Tp of an activity p, where the user parameters 102 characterizes the user 101.

[0063] The diagram in Fig. 3A illustrates a method to determine the constant parameters ai and the activity scaling parameters k(p) from a plurality of data pairs of measured energy expenditure values PAEE(j) and acceleration data ACC(j) of a plurality of persons or subjects j. It should be noted that subjects j used for determining parameters ai and k(p) are generally a selected group of persons whereas users (101) are users of the device 100. The measured energy expenditure values PAEE(j) are obtained from a method step 303 wherein the PAEE value is determined experimentally using a gold standard method. The acceleration data ACC for each subject j corresponds with the experimentally obtained PAEE value. In the method step 301 activity count values ACD(j) are determined from the acceleration values ACC(j).

[0064] Fig. 3B shows how activity count values ACD(j) are determined from the acceleration values ACC(j) by integrating or summing magnitudes of the acceleration data ACC(j) over the duration Tp of an activity p to obtain values of activity count AC(p) for a given activity p in step 311. Each value of activity count AC(p) is multiplied with an activity scaling parameter k(p) in step 312. Finally, the products of activity count values and activity scaling parameters (AC(p)*k(p)) are summed over the different activities p performed by the subject j during a given period D, for example a day. In step 311 it is understood that the integrated or summed acceleration data ACC(j) are summed over the acceleration sensor's directions if the sensor has more than one sensing direction.

[0065] In method step 302 in Fig. 3A, the constant parameters ai and the activity scaling parameters k(p) are determined using an optimization procedure. The optimization procedure is based on a given model used for calculating PAEE values. As an example the model for calculating a value of energy expenditure of activities p may be based on the equation:

$$PAEE\_CAL(j) = \Sigma_i\, ai*Ui + aN*ACD(j) \qquad \text{eq. 6a}$$

corresponding to equation 4a or based on the equation

$$PAEE\_CAL(j) = \Sigma_i\, ai*Ui + ACD(j) \qquad \text{eq. 6b}$$

corresponding to equation 4b when one of the constant parameters ai, e.g. aN, is included in the activity scaling parameter k(p) included in the term ACD(j).

[0066] The rate of change of ai may be given by ai'=ai/D, where D is the duration over which the measured energy expenditure values PAEE(j) and the activity count values ACD(j) are determined. Thus, D may be chosen as 1440 minutes, i.e. the duration of a day.

[0067] Accordingly, by minimizing the difference between measured energy expenditure values PAEE(j) and calculated energy expenditure values PAEE_CAL(j), the constant parameters ai and the activity scaling parameters k(p) used in ACD(j) can be determined.

[0068] Minimizing the difference between measured energy expenditure values PAEE(j) and calculated energy expenditure values PAEE_CAL(j) may be performed using various methods. For example, in Fig. 3A, the constant factors ai may be determined using linear regression since eq. 6 represents a linear function of the constant parameters ai. The activity scaling parameters k(p) may be determined by iteratively adjusting k(p) using an adjustment feedback 304. For each time k(p) is adjusted, new constant factors ai are determined. The adjustment feedback 304 is used to find a set of k(p) that minimizes the aforementioned difference.

[0069] Since there may be more than one solution to the minimization problem, not only a single set of activity scaling parameters k(p), but a plurality of sets of activity scaling parameters k(p) may be found that each minimizes the difference between the measured energy expenditure values PAEE(j) and the calculated energy expenditure values PAEE_CAL(j). However, the ideal set of activity scaling parameters k(p) should not only correctly determine the accumulated energy expenditure value PAEE for activities p over a period D, but should also correctly determine the variations of the PAEE values or heights 182 for different activities p over the period D. That is, the ideal set of activity scaling parameters k(p) should correctly determine the energy expenditure profile 180 of a user for different activities p.

[0070] The correct activity scaling parameters k(p) and, thereby, the correct energy expenditure profile 180 can be determined by minimizing the difference between measured and calculated energy expenditure values PAEE involving different activities such as p,p1,p2 shown in Fig. 1. Alternatively, the correct activity scaling parameters k(p) can be determined by calculating a so-called Pearson's coefficient R^2 where a high value of the Pearson's coefficient R^2 indicates that equation 6 gives, on average, a good prediction of the actual measured PAEE(j). Pearson coefficient R^2 may be defined as

$$R^2 = 1 - \frac{\sum_j [PAEE(j) - PAEE\_CAL(j)]^2}{\sum_j [PAEE(j) - \overline{PAEE(j)}]^2}$$

where $\overline{PAEE(j)}$ is the average over j of the measured PAEE(j). It can be seen that the term $\sum_j[PAEE(j) - PAEE\_CAL(j)]^2$ in R^2 is the aforementioned calculation difference, so a good prediction would lead to an R^2 value that approaches to one.

[0071] Accordingly, an initial set of activity scaling parameters k(p) may be used as an initial guess. After the Pearson's coefficient R^2 has been calculated a new set of parameters k(p) may be determined by adjusting the values of the k(p) parameters on basis of the value of the Pearson's coefficient R^2.

[0072] The optimum values of k(p) may also be determined using a global searching, where for pre-set ranges of values of k(p)'s R^2 is computed, and the set of k(p) resulting in the highest R^2 is chosen.

[0073] The adjustment of the activity scaling parameters k(p) may be adjusted so that an activity scaling parameter k(p) is adjusted to a value greater than a preset threshold value, e.g. the value one, for activities having activity values AC(p) which underestimates the actual energy expenditure PAEE, and so that an activity scaling parameter k(p) is adjusted to a value smaller than the preset threshold value for activities having activity values AC(p) which overestimates the actual energy expenditure PAEE. In general, when the constant parameter a4 or aN is included in k(p), the preset threshold is different from the value one, and when a4 or aN is not included in k(p) the preset threshold may be equal to the value one.

[0074] Thus, the activity scaling parameters k(p) are determined by minimizing the difference between a measured energy expenditure value for a given period D, e.g. a day, and a sum of values of the estimated energy expenditure values for activities p over the same period D.

[0075] Therefore, an advantage is obtained by using activity scaling parameters k(p) which have been experimentally determined under the constraint that the sum of values of the estimated energy expenditure values for activities p during a period D approximates the measured energy expenditure value measured over the same period D. That is, the determined activity scaling parameters k(p) have the property of up-scaling activity values AC(p) which underestimates the actual energy expenditure PAEE due to acceleration values which are too low to reflect the actual energy expenditure. Similarly, the activity scaling parameters k(p) have the property of down-scaling activity values AC(p) which overestimates the actual energy expenditure PAEE due to acceleration values which are too high to reflect the actual energy expenditure. A further advantage is that the total accumulated estimated energy expenditure over a day approximates the actual measured energy expenditure of a day since the activity scaling parameter k(p) have been determined under the constraint that the estimated total energy spent of the day remains unchanged in comparison with the total measured energy.

[0076] The minimization of the difference between measured and calculated energy expenditure profiles, e.g. by calculation of the Pearson's coefficient R^2, and the adjustment of activity scaling parameters k(p) may be performed in a method step 305 in the adjustment feedback 304.

[0077] It is understood that the method for determining the constant parameters ai and the activity scaling parameters k(p) is not performed during use of the device 100 for determining an energy expenditure of a user 101, but is performed in connection with the manufacturing of the energy expenditure device 100. Thus, the ai and k(p) parameters determined using for example the process shown in Fig. 3A-B, may be applied to the energy expenditure devices 100 during assembly, for example by storing the parameters in a memory of the device 100.

[0078] Although the present invention has been described in connection with the specified embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. In the claims, the term "comprising" does not exclude the presence of other elements or steps. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. In addition, singular references do not exclude a plurality. Thus, references to "a", "an", "first", "second" etc. do not preclude a plurality. Furthermore, reference signs in the claims shall not be construed as limiting the scope.

Claims

1. A device (100) adapted to determine an energy expenditure of a user (101), the device comprising

   - a data input (110) adapted to receive acceleration data (ACC) of the user as a function of time,
   - a parameter input (120) adapted to receive one or more user parameters (Ui,102) characterizing the user,
   - a storage (151) adapted to store constant parameters (ai, ai') and activity scaling parameters (k(p)), the scaling parameters being a function of an activity (p) of the user (101), the activity being obtained as a user-input or being determined by an automatic activity recognition algorithm,
   - a processor (150) programmed for determining an activity value (AC(p)) in dependence of the activity (p) by integrating or summing the acceleration data (ACC) over the duration (Tp) of the activity (p), and for determining an estimated value (182) of energy expenditure (PAEE) by obtaining a product of the activity scaling parameters (k(p)) and the activity value (AC(p)) and by forming a sum of said product (k(p)*AC(p)) and the one or more user parameters (102), where the user parameters are scaled by the constant parameters (ai') and the duration (Tp) of the activity (p).

2. A device (100) according to claim 1, where the activity scaling parameters (k(p)) are a minimum of a difference between a measured energy expenditure value (PAEE(j)) obtained for a given period (D) comprising one or more activities (p) and a sum of values of the estimated energy expenditure values (PAEE_CAL(j)) for activities (p) over the same period (D).

3. A device (100) according to claim 1, where the activity scaling parameters (k(p)) are

   - a plurality of data pairs of measured energy expenditure values (PAEE(j)) and acceleration data (ACC(j)) of a plurality of subjects (j), where the energy expenditure values and acceleration data are measured over a given period (D),
   - a minimum of the difference between measured energy expenditure values (PAEE(j)) and calculated energy expenditure values (PAEE_CAL(j)) obtained using a model to determine the activity scaling parameters (k(p)), where the model determines activity count values (ACD(j)) from the acceleration values (ACC(j)) by integrating or summing the acceleration data (ACC(j)) over the duration (Tp) of an activity (p) to obtain activity values (AC(p)), multiplying the obtained activity values (AC(p)) with the activity scaling parameters (k(p)) and summing products of activity count and the activity scaling parameters ((AC(p))*k(p)) over activities (p).

4. A device according to claim 1, where the activity scaling parameters (k(p)) are greater than a preset threshold value for activities having activity values (AC(p)) determined from the acceleration data (ACC) which underestimates the actual energy expenditure (PAEE), and where the activity scaling parameters (k(p)) are smaller than the threshold value for activities having activity values (AC(p)) determined from the acceleration data (ACC) which overestimates the actual energy expenditure (PAEE).

5. A device according to claim 1, where the processor is further configured for forming a sequence of estimated values (182) of energy expenditure (PAEE) for different activities (p1,p2,pm) to determine a time profile of PAEE values.

6. A device according to claim 1, where the user parameters (Ui,102) comprises age, weight and height, and where the sum of said product and user parameters are scaled by the constant parameters (a1'-a3',a4) and the duration (Tp) of an activity (p) according to the equation: PAEE(p) = Tp*a0' + Tp*a1'*age + Tp*a2'* weight + Tp*a3'*height + a4*k(p)*AC(p), where the sum additionally comprises the term Tp*a0'.

7. A device according to claim 1, where determining the activity value (AC(p)) in dependence of activity (p) comprises integrating or summing the acceleration data (ACC) over the duration (Tp) of an activity (p) for each acceleration

direction of the acceleration sensor (105).

8. A method for manufacturing the device (100) of claim 1 comprising,

- obtaining a plurality of data pairs of measured energy expenditure values (PAEE(j)) and acceleration data (ACC(j)) of a plurality of subjects (j), where the energy expenditure values and acceleration data are measured over a given period (D),
- minimizing the difference between measured energy expenditure values (PAEE(j)) and calculated energy expenditure values (PAEE_CAL(j)) obtained using a model (PAEE_CAL(j)) for calculating a value of energy expenditure of activities (p) of the subjects (j) in a recursive loop to determine constant user parameters (ai) and activity scaling parameters (k(p)) of said model, where an activity value (AC(p)) of the model is determined from acceleration data (ACC) of a given activity (p) from a given subject (j) by integrating or summing the acceleration data (ACC),
- providing the determined constant parameters (ai) and the activity scaling parameters (k(p)) in a device (100).

9. A method for manufacturing the device (100) of claim 1 according to claim 10, where the step of minimizing comprises, in a recursive loop performing steps a-c:

a) in a model (PAEE_CAL(j)) for calculating a value of energy expenditure of activities (p), obtaining an activity count value (ACD(j)) for each data pair of each user, where the activity count value is obtained from the expression Σ_p k(p)*AC(p) by summing the product of activity scaling parameters (k(p)) and activity values (AC(p)) over activities (p) in a period (D), where activity value (AC(p)) is determined from acceleration data (ACC(j)) of a given activity (p) from a given subject (j),
b) using the model (PAEE_CAL(j)), determining the constant parameters (ai) by comparing the measured energy expenditure value (PAEE(j)) with the calculated energy expenditure value (PAEE_CAL(j)), and
c) adjusting activity scaling parameters (k(p)) for given activities (p) until the difference between the measured energy expenditure value (PAEE(j)) and the calculated energy expenditure value (PAEE_CAL(j)) is below a given threshold.

10. A system for determining an energy expenditure of a user (101) comprising the device according to claim 1 and a transportable accelerometer (105) adapted to measure acceleration data (ACC) of the user.

11. A method for determining an energy expenditure of a user (101), comprising

- obtaining an activity (p) performed by a user (101) as a user-input or by an automatic activity recognition algorithm,
- determining an activity value (AC(p)) in dependence of the activity (p) performed by a user (101), by integrating or summing acceleration data (ACC) of the user (101) over the duration (Tp) of the activity (p),
- selecting an activity scaling parameter (k(p)) from a set of scaling parameters according to the actual activity (p), the scaling parameters being a function of the activity (p) of the user (101),
- determining an estimated value (182) of energy expenditure (PAEE) by obtaining a product of the activity scaling parameter (k(p)) and the activity value (AC(p)) and by forming a sum of said product (k(p)*AC(p)) and one or more user parameters (102), where the user parameters are scaled by the constant parameters (ai') and the duration (Tp) of the activity (p), and where the user parameters (102) characterizes the user, wherein.

12. A computer program product enabling, when executed, a computer processor to carry out the method of claim 8 or 9.

Patentansprüche

1. Vorrichtng (100), die dafür ausgelegt ist, einen Energieverbrauch eines Benutzers (101) zu bestimmen, wobei die Vorrichtung Folgendes umfasst:

- einen Dateneingang (110), der dafür ausgelegt ist, Beschleunigungsdaten (ACC) des Benutzers als eine Funktion der Zeit zu empfangen,
- einen Parametereingang (120), der dafür ausgelegt ist, einen oder mehrere den Benutzer charakterisierende Benutzerparameter (Ui, 102) zu empfangen,
- einen Speicher (151), der dafür ausgelegt ist, konstante Parameter (ai, ai') und Aktivitätsskalierungsparameter

(k(p)) zu speichern, wobei die Skalierungsparameter eine Funktion einer Aktivität (p) des Benutzers (101) sind, wobei die Aktivität als eine Benutzereingabe erlangt wird oder durch einen automatischen Aktivitätserkennungsalgorithmus ermittelt wird,
- einen Prozessor (150), der programmiert ist, um durch Integrieren oder Summieren der Beschleunigungsdaten (ACC) über die Dauer (Tp) der Aktivität (p) einen Aktivitätswert (AC(p)) in Abhängigkeit von der Aktivität (p) zu ermitteln, und um einen geschätzten Wert (182) des Energieverbrauchs (PAEE) durch Erlangen eines Produkts der Aktivitätsskalierungsparameter (k(p)) und des Aktivitätswerts (AC(p)) und durch Bilden einer Summe des genannten Produktes (k(p)*AC(p)) und des einen oder der mehreren Benutzerparameter (102) zu ermitteln, wobei die Benutzerparameter durch die konstanten Parameter (ai') und die Dauer (Tp) der Aktivität (p) skaliert werden.

2. Vorrichtung (100) nach Anspruch 1, wobei die Aktivitätsskalierungsparameter (k(p)) ein Minimum einer Differenz zwischen einem gemessenen Energieverbrauchswert (PAEE(j)), der für eine gegebene Periode (D) umfassend eine oder mehrere Aktivitäten (p) erlangt wird, und einer Summe von Werten der geschätzten Energieverbrauchswerte (PAEE_CAL(j)) für Aktivitäten (p) über die gleiche Periode (D) sind.

3. Vorrichtung (100) nach Anspruch 1, wobei die Aktivitätsskalierungsparameter (k(p)) Folgendes sind

- eine Vielzahl von Datenpaaren von gemessenen Energieverbrauchswerten (PAEE(j)) und Beschleunigungsdaten (ACC(j)) einer Vielzahl von Personen (j), wobei die Energieverbrauchswerte und Beschleunigungsdaten über eine gegebene Periode (D) gemessen werden,
- ein Minimum der Differenz zwischen gemessenen Energieverbrauchswerten (PAEE(j)) und berechneten Energieverbrauchswerten (PAEE_CAL(j)), die unter Verwendung eines Modells zur Bestimmung von Aktivitätsskalierungsparameter (k(p)) erlangt wurden, wobei das Modell Aktivitätszählwerte (ACD(j)) anhand der Beschleunigungswerte (ACC(j)) ermittelt durch Integrieren oder Summieren der Beschleunigungsdaten (ACC(j)) über die Dauer (Tp) einer Aktivität (p), um Aktivitätswerte (AC(p)) zu erlangen, Multiplizieren der erlangten Aktivitätswerte (AC(p)) mit Aktivitätsskalierungsparametern (k(p)) und Summieren von Produkten des Aktivitätszählwerts und der Aktivitätsskalierungsparameter ((AC(p)) * k(p)) über Aktivitäten (p).

4. Vorrichtung nach Anspruch 1, wobei die Aktivitätsskalierungsparameter (k(p)) für Aktivitäten, deren anhand der Beschleunigungsdaten (ACC) ermittelten Aktivitätswerte (AC(p)) den tatsächlichen Energieverbrauch (PAEE) unterschätzen, größer als ein vorgegebener Schwellenwert sind, und wobei die Aktivitätsskalierungsparameter (k(p)) für Aktivitäten, deren anhand der Beschleunigungsdaten (ACC) ermittelte Aktivitätswerte (AC(p)) den tatsächlichen Energieverbrauch (PAEE) überschätzen, kleiner als der Schwellenwert sind.

5. Vorrichtung nach Anspruch 1, wobei der Prozessor weiterhin konfiguriert ist zum Bilden einer Sequenz von geschätzten Werten (182) des Energieverbrauchs (PAEE) für verschiedene Aktivitäten (p1, p2, pm), um ein Zeitprofil der PAEE-Werte zu ermitteln.

6. Vorrichtung nach Anspruch 1, wobei die Benutzerparameter (Ui, 102) Alter, Gewicht und Größe umfassen, und wobei die Summe der genannten Produkt- und Benutzerparameter durch die konstanten Parameter (a1'- a3', a4) und die Dauer (Tp) einer Aktivität (p) nach der Gleichung PAEE(p) = Tp*a0' + Tp*a1*Alter + Tp*a2'*Gewicht + Tp*a3'*Größe + a4*K(p)*AC(p) skaliert werden, wobei die Summe zusätzlich den Term Tp*a0' umfasst.

7. Vorrichtung nach Anspruch 1, wobei das Ermitteln des Aktivitätswertes (AC(p)) in Abhängigkeit von der Aktivität (p) das Integrieren oder Summieren der Beschleunigungsdaten (ACC) über die Dauer (Tp) einer Aktivität (p) für jede Beschleunigungsrichtung des Beschleunigungssensors (105) umfasst.

8. Verfahren zur Herstellung der Vorrichtung (100) aus Anspruch 1, umfassend:

- Erlangen einer Vielzahl von Datenpaaren von gemessenen Energieverbrauchswerten (PAEE(k)) und Beschleunigungsdaten (ACC(j)) einer Vielzahl von Personen (j), wobei die Energieverbrauchswerte und Beschleunigungsdaten über eine gegebene Periode (D) gemessen werden,
- Minimieren der Differenz zwischen gemessenen Energieverbrauchswerten (PAEE(j)) und berechneten Energieverbrauchswerten (PAEE_CAL(j)), die unter Verwendung eines Modells (PAEE_CAL(j)) zum Berechnen eines Wert des Energieverbrauchs von Aktivitäten (p) der Personen (j) erlangt wurde, in einer rekursiven Schleife, um konstante Benutzerparameter (ai) und Aktivitätsskalierungsparameter (k(p)) des genannten Modells zu ermitteln, wobei ein Aktivitätswert (AC(p)) des Modells anhand von Beschleunigungsdaten (ACC) einer gege-

benen Aktivität (p) von einer gegebenen Person (j) ermittelt wird, indem die Beschleunigungsdaten (ACC) integriert oder summiert werden,
- Bereitstellen der ermittelten konstanten Parameter (ai) und der Aktivitätsskalierungsparameter (k(p)) in einer Vorrichtung (100).

9. Verfahren zur Herstellung der Vorrichtung (100) aus Anspruch 1 nach Anspruch 10, wobei der Schritt des Minimierens das Durchführen der Schritte a bis c in einer rekursiven Schleife umfasst:

a) in einem Modell (PAEE_CAL(j)) zur Berechnung eines Werts des Energieverbrauchs von Aktivitäten (p), Erlangen eines Aktivitätszählwerts (ACD(j)) für jedes Datenpaar jedes Benutzers, wobei der Aktivitätszählwert aus dem Ausdruck $\sum_p k(p) * AC(p)$ durch Summieren des Produkts von Aktivitätsskalierungsparametern (k(p)) und Aktivitätswerten (AC(p)) über Aktivitäten (p) in einer Periode (D) erlangt wird, wobei der Aktivitätswert (AC(p)) anhand von Beschleunigungsdaten (ACC(j)) einer gegebenen Aktivität (p) von einer gegebenen Person (j) ermittelt wird,
b) anhand des Modells (PAEE_CAL(j)), Ermitteln der konstanten Parameter (ai) durch Vergleichen des gemessenen Energieverbrauchswertes (PAEE(j)) mit dem berechneten Energieverbrauchswert (PAEE_CAL(j)), und
c) Justieren der Aktivitätsskalierungsparameter (k(p)) für gegebene Aktivitäten (p), bis die Differenz zwischen dem gemessenen Energieverbrauchswert (PAEE(j)) und dem berechneten Energieverbrauchswert (PAEE_CAL(j)) unter einem gegebenen Schwellenwert liegt.

10. System zum Ermitteln eines Energieverbrauchs eines Benutzers (101) umfassend die Vorrichtung nach Anspruch 1 und einen transportierbaren Beschleunigungsmesser (105), der dafür ausgelegt ist, Beschleunigungsdaten (ACC) des Benutzers zu messen.

11. Verfahren zum Ermitteln eines Energieverbrauchs eines Benutzers (101), das Folgendes umfasst:

- Erlangen einer durch einen Benutzer (101) ausgeübten Aktivität (p) als eine Benutzereingabe oder durch einen automatischen Aktivitätserkennungsalgorithmus,
- Ermitteln eines Aktivitätswerts (AC(p)) in Abhängigkeit von der durch einen Benutzer (101) ausgeübten Aktivität (p) durch Integrieren oder Summieren der Beschleunigungsdaten (ACC) des Benutzers (101) über die Dauer (Tp) der Aktivität (p),
- Auswählen eines Aktivitätsskalierungsparameters (k(p)) aus einem Satz von Skalierungsparametern entsprechend der tatsächlichen Aktivität (p), wobei die Skalierungsparameter eine Funktion der Aktivität (p) des Benutzers (101) sind,
- Ermitteln eines geschätzten Werts (182) des Energieverbrauchs (PAEE) durch Erlangen eines Produkts des Aktivitätsskalierungsparameters (k(p)) und des Aktivitätswerts (AC(p)) und durch Bilden einer Summe des genannten Produkts (k(p)*AC(p)) und eines oder mehrerer Benutzerparameter (102), wobei die Benutzerparameter durch die konstanten Parameter (ai') und die Dauer (Tp) der Aktivität (p) skaliert wurden, und wobei die Benutzerparameter (102) den Benutzer charakterisieren.

12. Computerprogrammprodukt, das, wenn es ausgeführt wird, einem Computerprozessor ermöglicht, das Verfahren aus Anspruch 8 oder 9 durchzuführen.

Revendications

1. Dispositif (100) adapté pour déterminer une dépense d'énergie d'un utilisateur (101), le dispositif comprenant

- une entrée de données (110) adaptée pour recevoir des données d'accélération (ACC) de l'utilisateur en fonction du temps,
- une entrée de paramètres (120) adaptée pour recevoir un ou plusieurs paramètres utilisateur (Ui, 102) caractérisant l'utilisateur,
- un stockage (151) adapté pour stocker des paramètres constants (ai, ai') et des paramètres de mise à l'échelle d'activité (k(p)), les paramètres de mise à l'échelle étant fonction d'une activité (p) de l'utilisateur (101), l'activité étant obtenue en tant qu'entrée utilisateur ou étant déterminée par un algorithme de reconnaissance d'activité automatique,
- un processeur (150) programmé pour déterminer une valeur d'activité (AC(p)) en fonction de l'activité (p) en intégrant ou additionnant les données d'accélération (ACC) sur la durée (Tp) de l'activité (p), et pour déterminer

une valeur estimée (182) de dépense d'énergie (PAEE) en obtenant un produit des paramètres de mise à l'échelle d'activité (k(p)) et de la valeur d'activité (AC(p)) et en formant une somme dudit produit (k(p)*AC(p)) et du ou des paramètres utilisateurs (102), où les paramètres utilisateur sont mis à l'échelle par les paramètres constants (ai') et la durée (Tp) de l'activité (p).

2. Dispositif (100) selon la revendication 1, où les paramètres de mise à l'échelle d'activité (k(p)) sont un minimum d'une différence entre une valeur de dépense d'énergie mesurée (PAEE(j)) obtenue pour une période donnée (D) comprenant une ou plusieurs activités (p) et une somme de valeurs des valeurs de dépense d'énergie estimées (PAEE_CAL(j)) pour des activités (p) sur la même période (D).

3. Dispositif (100) selon la revendication 1, où les paramètres de mise à l'échelle d'activité (k(p)) sont

- une pluralité de paires de données de valeurs de dépense d'énergie mesurées (PAEE(j)) et de données d'accélération (ACC(j)) d'une pluralité de sujets (j), où les valeurs de dépense d'énergie et les données d'accélération sont mesurées sur une période donnée (D),
- un minimum de la différence entre les valeurs de dépense d'énergie mesurées (PAEE(j)) et les valeurs de dépense d'énergie calculées (PAEE_CAL(j)) obtenues en utilisant un modèle afin de déterminer les paramètres de mise à l'échelle d'activité (k(p)), où le modèle détermine des valeurs de compte d'activité (ACD(j)) à partir des valeurs d'accélération (ACC(j)) en intégrant ou additionnant les données d'accélération (ACC(j)) sur la durée (Tp) d'une activité (p) afin d'obtenir des valeurs d'activité (AC(p)), en multipliant les valeurs d'activités obtenues (AC(p)) par les paramètres de mise à l'échelle d'activité (k(p)) et en additionnant les produits de compte d'activité et les paramètres de mise à l'échelle d'activité ((AC(p))*k(p)) par les activités (p).

4. Dispositif selon la revendication 1, où les paramètres de mise à l'échelle d'activité (k(p)) sont plus grands qu'une valeur seuil prédéfinie pour des activités ayant des valeurs d'activité (AC(p)) déterminées à partir des données d'accélération (ACC) qui sous-estiment la dépense d'énergie réelle (PAEE), et où les paramètres de mise à l'échelle d'activité (k(p)) sont plus petits que la valeur seuil pour des activités ayant des valeurs d'activité (AC(p)) déterminées à partir des données d'accélération (ACC) qui surestiment la dépense d'énergie réelle (PAEE).

5. Dispositif selon la revendication 1, où le processeur est en outre configuré pour former une séquence de valeurs estimées (182) de dépense d'énergie (PAEE) pour différentes activités (p1, p2, pm) afin de déterminer un profil de temps de valeurs PAEE.

6. Dispositif selon la revendication 1, où les paramètres utilisateur (Ui, 102) comprennent l'âge, le poids et la taille, et où la somme dudit produit et les paramètres utilisateur sont mis à l'échelle par les paramètres constants (a1'-a3', a4) et la durée (Tp) d'une activité (p) en fonction de l'équation : PAEE(p) = Tp*a0' + Tp*a1'*âge + Tp*a2'*poids + Tp*a3'*taille + a4*k(p)*AC(p), où la somme comprend en outre le terme Tp*a0'.

7. Dispositif selon la revendication 1, où la détermination de la valeur d'activité (AC(p)) en fonction de l'activité (p) comprend l'intégration ou l'addition des données d'accélération (ACC) sur la durée (Tp) d'une activité (p) pour chaque direction d'accélération du capteur d'accélération (105).

8. Procédé pour fabriquer le dispositif (100) selon la revendication 1 comprenant,

- l'obtention d'une pluralité de paires de données de valeurs de dépense d'énergie mesurées (PAEE(j)) et de données d'accélération (ACC(j)) d'une pluralité de sujets (j), où les valeurs de dépense d'énergie et les données d'accélération sont mesurées sur une période données (D),
- la minimisation de la différence entre des valeurs de dépense d'énergie mesurées (PAEE(j)) et des valeurs de dépense d'énergie calculées (PAEE_CAL(j)) obtenues en utilisant un modèle (PAEE_CAL(j)) pour calculer une valeurs de dépense d'énergie d'activités (p) des sujets (j) dans une boucle récursive afin de déterminer des paramètres utilisateur constants (ai) et des paramètres de mise à l'échelle d'activité (k(p)) dudit modèle, où une valeur d'activité (AC(p)) du modèle est déterminée à partir des données d'accélération (ACC) d'une activité donnée (p) depuis un sujet donné (j) en intégrant ou additionnant les données d'accélération (ACC),
- la fourniture des paramètres constants déterminés (ai) et des paramètres de mise à l'échelle d'activité (k(p)) dans un dispositif (100).

9. Procédé de fabrication du dispositif (100) de la revendication 1 selon la revendication 10, où l'étape de minimisation comprend, dans une boucle récursive, la réalisation des étapes a-c :

a) dans un modèle (PAEE_CAL(j)) pour calculer une valeur de dépense d'énergie d'activités (p), l'obtention d'une valeur de compte d'activité (ACD(j)) pour chaque paire de données de chaque utilisateur, où la valeur de compte d'activité est obtenue à partir de l'expression $\sum_p k(p)*AC(p)$ en additionnant le produit de paramètres de mise à l'échelle d'activité (k(p)) et des valeurs d'activité (AC(p)) par les activités (p) dans une période (D), où la valeur d'activité (AC(p)) est déterminée à partir des données d'accélération (ACC(j)) d'une activité donnée (p) depuis un sujet donné (j),
b) à l'aide du modèle (PAEE_CAL(j)), la détermination des paramètres constants (ai) en comparant la valeur de dépense d'énergie mesurée (PAEE(j)) à la valeur de dépense d'énergie calculée (PAEE_CAL(j)), et
c) l'ajustement des paramètres de mise à l'échelle d'activité (k(p)) pour des activités données (p) jusqu'à ce que la différence entre la valeur de dépense d'énergie mesurée (PAEE(j)) et la valeur de dépense d'énergie calculée (PAEE_CAL(j)) soit sous un seuil donnée.

10. Système pour déterminer une dépense d'énergie d'un utilisateur (101) comprenant le dispositif de la revendication 1 et un accéléromètre transportable (105) adapté pour mesurer des données d'accélération (ACC) de l'utilisateur.

11. Procédé pour déterminer une dépense d'énergie d'un utilisateur (101), comprenant

- l'obtention d'une activité (p) effectuée par un utilisateur (101) en tant qu'entrée utilisateur ou par un algorithme de reconnaissance d'activité automatique,
- la détermination d'une valeur d'activité (AC(p)) en fonction de l'activité (p) effectuée par un utilisateur (101), en intégrant ou en additionnant les données d'accélération (ACC) de l'utilisateur (101) sur la durée (Tp) de l'activité (p),
- la sélection d'un paramètre de mise à l'échelle d'activité (k(p)) parmi un ensemble de paramètres de mise à l'échelle en fonction de l'activité réelle (p), les paramètres de mise à l'échelle étant fonction de l'activité (p) de l'utilisateur (101),
- la détermination d'une valeur estimée (182) de dépense d'énergie (PAEE) en obtenant un produit des paramètres de mise à l'échelle d'activité (k(p)) et de la valeur d'activité (AC(p)) et en formant une somme dudit produit (k(p)*AC(p)) et du ou des paramètres utilisateurs (102), où les paramètres utilisateur sont mis à l'échelle par les paramètres constants (ai') et la durée (Tp) de l'activité (p), et où les paramètres utilisateur (102) caractérisent l'utilisateur.

12. Produit de programme informatique permettant, quand il est exécuté, à un processeur informatique de réaliser le procédé de la revendication 8 ou 9.

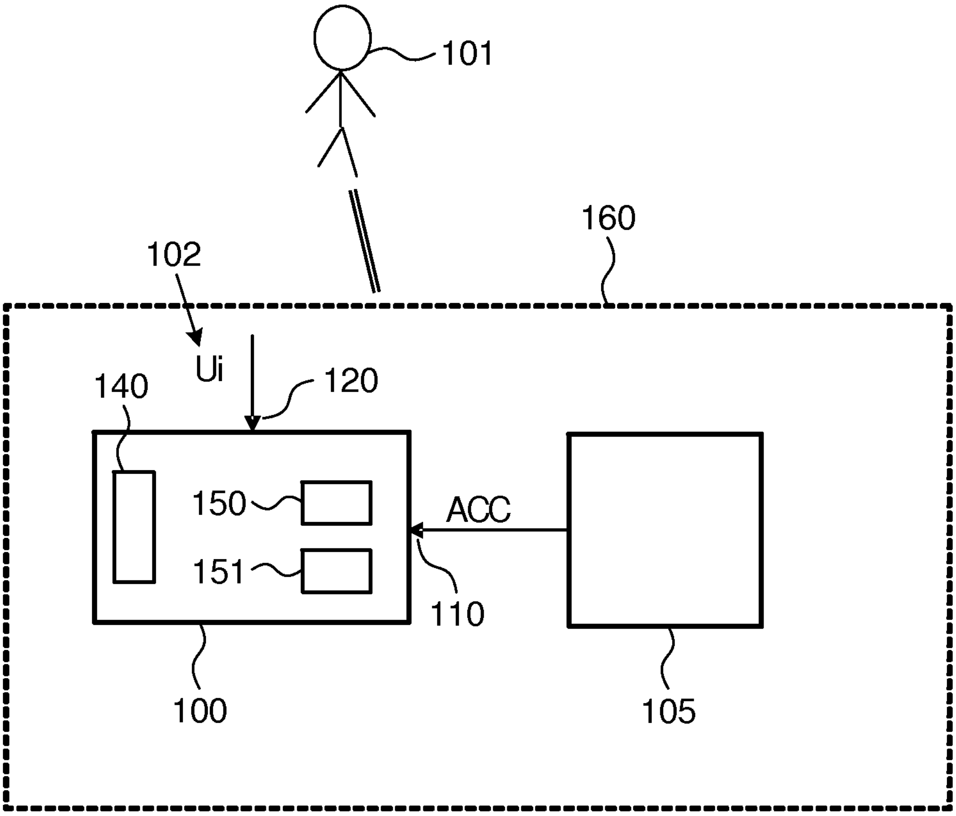
101
160
102
Ui
120
140
150
151
ACC
110
100
105

FIG. 1A

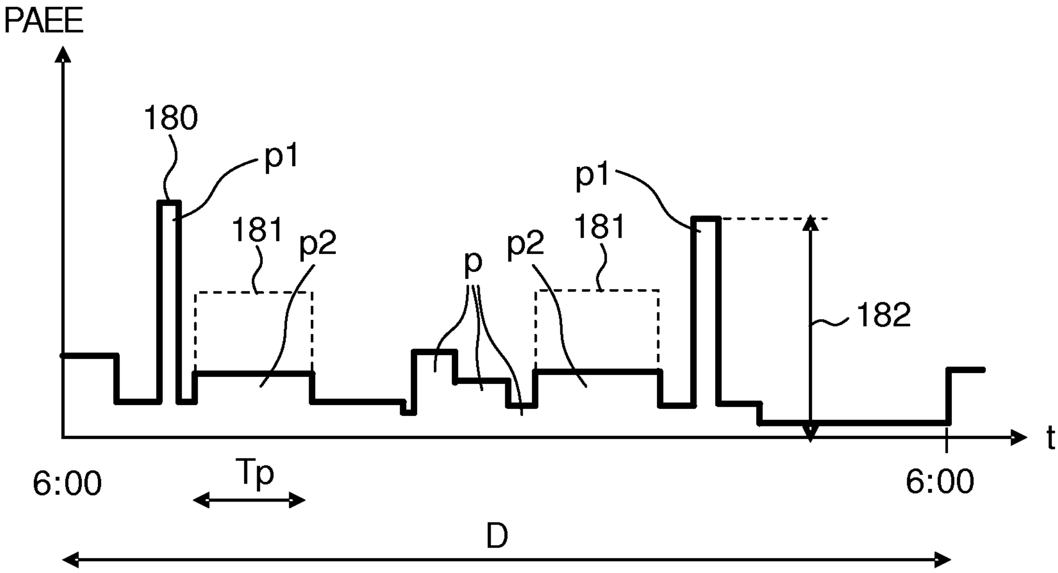
PAEE
180
p1
181
p2
p
p2
181
p1
182
t
6:00
Tp
6:00
D

FIG. 1B

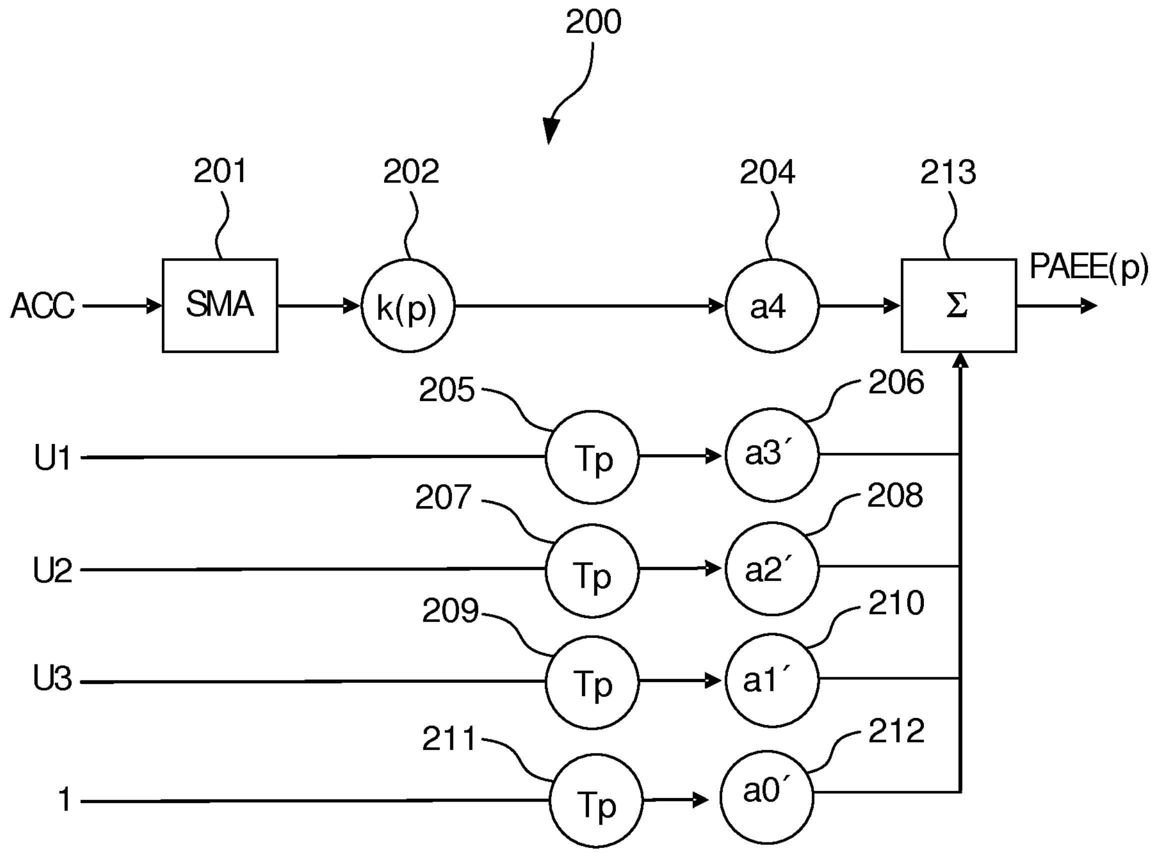
200
201
202
204
213
ACC
SMA
k(p)
a4
Σ
PAEE(p)
205
206
U1
Tp
a3´
207
208
U2
Tp
a2´
209
210
U3
Tp
a1´
211
212
1
Tp
a0´

FIG. 2A

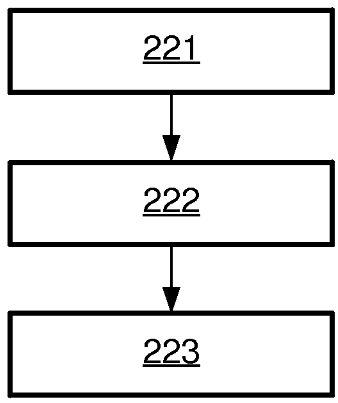
221
222
223

FIG. 2B

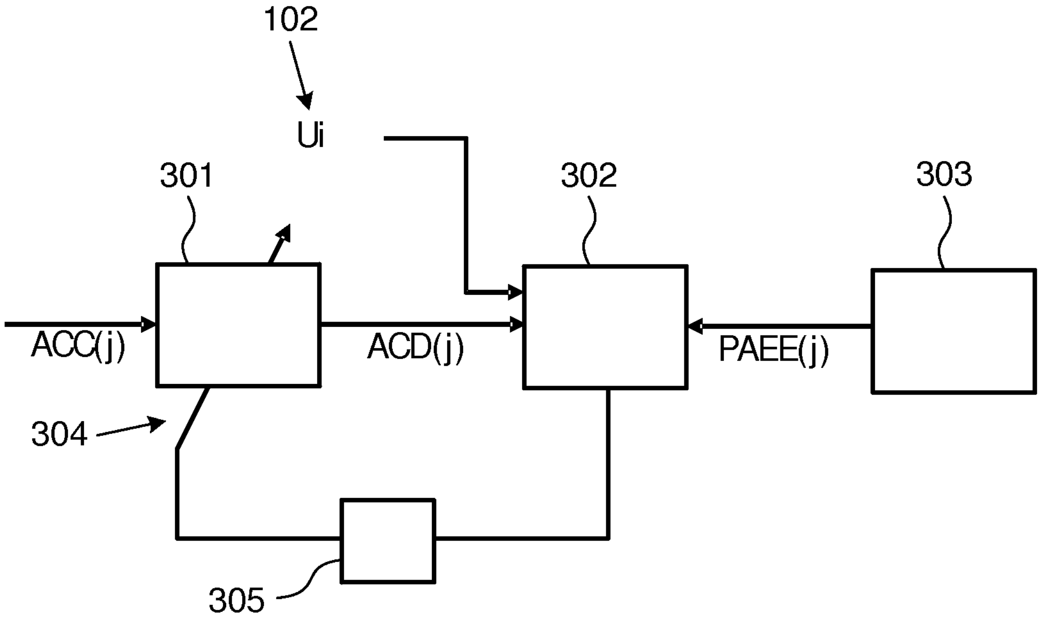
102
Ui
301
302
303
ACC(j)
ACD(j)
PAEE(j)
304
305

FIG. 3A

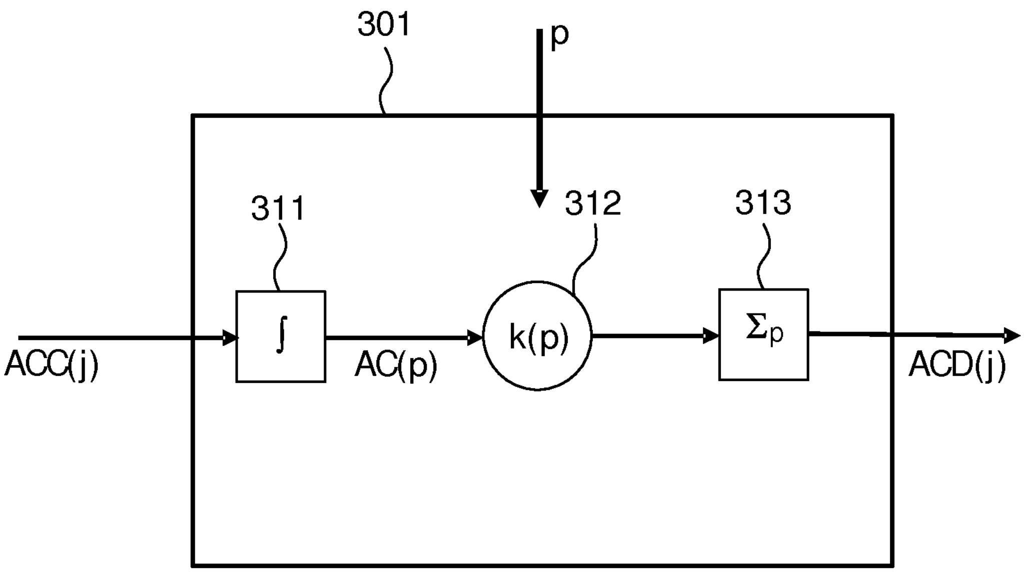
301
p
311
312
313
∫
k(p)
Σp
ACC(j)
AC(p)
ACD(j)

FIG. 3B

REFERENCES CITED IN THE DESCRIPTION

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patsnap

专利名称(译)	确定用户的能量消耗		
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申请(专利权)人(译)	皇家飞利浦电子N.V.		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
[标]发明人	YIN BIN DILLEN PAULUS H A		
发明人	YIN, BIN DILLEN, PAULUS, H., A.		
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摘要(译)

本发明涉及一种用于估计人的能量消耗的电子设备。电子设备使用基于加速度数据的数学模型来估计人的能量消耗，作为实际执行的活动和加速度值的函数。通过利用活动缩放参数缩放时间积分加速度数据的值，将加速度值转换为给定活动的能量消耗的估计。通过比较测量的能量消耗，例如，通过比较测量的能量消耗来离线确定不同活动的活动缩放参数在同一时期估计能量消耗的一天，其中使用数学模型确定估计值。

$$PAEE = a0 + a1*age + a2*weight + a3*height + a4*ACD, \quad eq. 1,$$