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Physiological variables in energy expenditure estimation by actigraphy: a systematic review protocol

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Abstract

Background: Energy expenditure measurement based on movement quantity is presented as a relevant alternative in clinical and research contexts. The best recommended and validated methods are expensive and inconvenient to field measurement, limiting their use to the laboratory. Lately, several devices have been developed to identify and classify activities by body movements, showing acceptable outcomes. These devices and techniques have been used to estimate energy expenditure in many physical activity situations. However, for this, it is necessary include physiological variables. Methods: A systematic review is proposed to identify evidence of the influence and relevance of physiological variables in energy expenditure measurement by actigraphy. The search will be carried out in reference databases. Discussion: The outcomes will be synthesized in order to identify the variables used in energy expenditure calculation methods and analyze the error between measured and calculated values, considering the influence of physiological variables on this. Systematic review registration: PROSPERO CRD42018089247.

1. INTRODUCTION

Energy expenditure has been studied for a long time. There are records about this theme since the classical Greek Era (Heymsfield, Bourgeois, & Thomas, 2017). Once an important feature of metabolic processes and energy expenditure is the human heat generation, some estimation and measurement methods are priory recommended due to its precision and are considered gold standard methods: the double labeled water method, direct calorimetry and indirect calorimetry by oxygen consumption rate (ISO, 2004).

Several studies related to energy expenditure have been developed; for example, sleep disturbance, as Robillard, et. al. (2016), Roveda, et. al. (2016) and Dobrosielski, et. al. (2016) studies; energy expenditure and disease as the works of Singh, et. al. (2016), Moura, et. al. (2014) and Celikagi, et. al.

(2014); energy expenditure and work activities, as Chen, et. al.(2016), Cao, et. al. (2016) and Sprod, et. al. (2016); among others.

Energy expenditure also has been studied on ergonomics, and occupational safety and health, as presented by Agashe & Deshpande, (2018), Burns, Forde, & Dockrell, (2017), Lee, Lin, Seto, & Migliaccio (2017), and Vincent et al., (2016). However, direct measurement may be complex, expensive and less accurate for field studies (Broderick et. al., 2014).

Alternative methods emerged based on physical activities quantification to estimate energy expenditure and these methods have provided satisfactory outcomes. Actigraphy is among this methods and may be considered an instrumented method to physical activity measurement (Tryon, 2008). The actigraphs are normally composed of accelerometers, but some have other sensors such as gyroscopes, inclinometers, GPS, light sensors, among others. Studies on energy expenditure by actigraphy have been developed in several areas and contexts; for example, sleep studies as presented by Robillard et al. (2016), work contexts (Mac et al., 2017)(Vincent et al., 2016), specific diseased populations (Slinde & Gro, 2011), and free-living activities (Rousset et al., 2015).

There are several equations to estimate energy expenditure by actigraphy. Most of these were developed by regression mathematical methods using oximetry, some physiological variables, and movement variables (Lyden, Kozey, Staudenmeyer, & Freedson, 2011). There are also models based on actigraphy dates for estimate energy expenditure by artificial neural networks, using as input demographic variables, physiological variables, and accelerometers signal features that vary during physical activities (Rothney, Neumann, Be, & Chen, 2007)(Montoye & Begum, 2017). However, there is no clear evidence of the physiological variables influence on the outcomes of these calculation models. For example, about the number of variables, or about the prioritization recommendations of specific variables to be inserted in the models.

A systematic review is proposed aiming to identify evidence of the physiological variables influence on energy expenditure estimation by actigraphy.

Hypothesis: Physiological variables have relevant influence on the outcomes in energy expenditure calculation methods based on actigraphy.

Objectives: Perform a systematic review to search evidence of physiological variables influence in energy expenditure estimation based on actigraphy, identifying (a) which physiological and "non-physiological" variables are inserted in energy expenditure calculation methods; and (b) identify evidence of relevant differences in outcomes by using specific physiological variables.

2. METHODS

This review will be composed by the following steps: studies identification, screening, eligibility (inclusion/exclusion), data extraction, assessment of methodological quality, data analysis, synthesis outcome, and results presentation.

2.1. Search strategy

The following electronic databases were searched: Academic Search Complete, Scopus, Science Direct, Web of Science, PubMed, and Informaworld by Francis & Taylor. For some combinations of terms were used database filters. The search strategy includes combinations of the following key-terms related to the theme: "energy expenditure", "actigraphy" "physiological variables", "variable", "equation", "estimation", "calculation", and "artificial neural network". The combinations and filters used on each database are presented in the Appendix. There were no publication date restrictions for the studies recorded.

The identification of studies has started in November 2017, conducted by two independent reviewers (ADL and JCCG) that plan to finish all the review in May 2018.

2.2. Screening Criteria

All collected record are screened considering all the following criteria:

- Original studies published in indexed journals were included;
- Articles languages will be restricted to English, Portuguese, Spanish and French;
- Studies on energy expenditure estimation that use actigraphy or similar movement sensors.

2.3. Inclusion Criteria

All the included articles have to fulfill the criteria:

- To be an original study published in indexed journals;
- To present actigraphy utilization;
- To present some energy expenditure calculation method applied;
- To present energy expenditure measurement with some *gold standard* method (direct calorimetry, indirect calorimetry by oximetry, or double labeled water method)
- To present the error between energy expenditure measured and calculated values;
- Were included studies with healthy people in working age, i.e. between 18 and 65 years old (according to the target working population).

2.4. Exclusion Criteria

Any of the following criteria result in study excluded. Therefore, were excluded:

- Studies about animal energy expenditure;
- Protocol studies, editorials, book chapters, opinion articles, abstracts, congress communications, and proceedings articles or abstracts.
- Studies about sleep behavior;
- Studies with diseased population;
- Studies with population outside working age (less than 18 years old and more than 65 years old were excluded);
- Studies that analyzed only one physical activity.

2.5. Primary outcomes

As main outcomes are expected:

- Actigraphy devices used in the studies;
- Energy expenditure calculation methods presented in the articles;
- Physiological variables included in the calculation methods;
- Errors between energy expenditure measured and calculated values.

2.6. Secondary outcomes

Other outcomes include:

- Other variables used in the studies;
- The most frequently variable used;
- Suitability of the technique to the different contexts;
- Devices signal features included as variables in calculation methods.

2.7. Data extraction and management

Titles and abstracts of the studies found were screened independently by two review authors to identify potential studies that meet the inclusion criteria. Articles were collected and managed using Mendeley as reference manager. The full texts of these studies were assessed for eligibility. The reading and inclusion/exclusion procedure will be conducted by two independent reviewers (ADL and JCCG). Excluded articles have been registered with respective reason on electronic forms. Any disagreement between them over the eligibility of particular studies will be resolved in a consensus meeting with a third reviewer.

All relevant data was extracted from articles to an Microsoft Excel table format in order to simplify article analysis and comparison. The extracted information include: authors, publication year, journal, population and sample characterization, study conditions (free-living, controlled or laboratory), used devices, energy expenditure calculation method, number/variety of activities selected for studies developing or presenting energy expenditure calculation methods, gold standard method used to compare outcomes, error due to differences between measured and calculated values.

2.8. Assessment of methodological quality

Risk of bias will be assessed individually for each study in the review. Five items have been defined i.e., gold standard method used (direct calorimetry, indirect calorimetry, or double labeled water method), equity of study sample by gender, study conditions (free-living, controlled or laboratory), reported criteria of data collection and processing, and number/variety of activities selected for studies developing or presenting energy expenditure calculation methods.

A score (i.e. 1, 2 or 3) will be assigned depending on the methods followed (a higher score means a higher risk of bias). This classification will be conducted by two reviewers (ADL and JCCG), disagreement will be resolved with the third reviewer (MAPV), and the scores of bias will be analyzed by all four authors but reviewed by the fourth (LBS).

3. STUDIES SYNTHESIS PLAN

Will be done a narrative and quantitative synthesis based on the outcomes reported, the risk of bias and quality of the studies. The main outcomes of studies characterization, calculation methods, physiological variables, movement variables, the summary of errors between the calculation methods and the gold standard methods will be synthesized on tables. If it will be possible and convenient, outcomes will be analyzed by separating studies according to the calculation method type (artificial neural network, activity counting approach, multivariate regressive equation, or other). The increase in accuracy and precision will be quantified for each type of technique (calculation method and equipment configuration), concerning the variables (weight, high, sex, age and others) activities (running, walking at different speeds, resting, standing, typing, etc).

4. DISCUSSION

Despite it is known that physiological variables are important to energy expenditure estimation by actigraphy, there is a lack of knowledge about the influence of these variables on the outcomes. This review aims to find evidence of physiological variables influence on energy expenditure calculations methods, identifying whether and which variables are possibly relevant in these calculation models. These results can indicate possibilities of new studies about physiological variables inclusion, relevance, and priority on these calculation methods. At the end of the result analysis it will be possible to state about the suitability of the actigraphy technique in the scope of occupation health and safe, being an accurate alternative to the normalized methods defined by ISO 8996:2004.

This review might have unintentional limitations, for example, the studies selection process may inadvertently exclude relevant studies; or insufficient quantity or quality of the included studies might be others limitation factors to answer the search question.

Future research fields will be indicated in the complete review article.

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Appendix: Databases search strategy. Search terms and combinations used to identify studies related to physiological variables in energy expenditure estimation by actigraphy.

Database: Academic Search Complete

1) "energy expenditure" AND actigraphy AND "physiological variables"
2) "energy expenditure" AND actigraphy AND variable
3) "energy expenditure" AND actigraphy AND equation
4) "energy expenditure" AND actigraphy AND estimation
5) "energy expenditure" AND actigraphy AND calculation
6) "energy expenditure" AND actigraphy
7) TI "energy expenditure" AND TI equation
8) "energy expenditure" AND "artificial neural network"

Database: Web of Science

1) **Tópico**:("energy expenditure") *AND* Tópico:(Actigraphy) *AND* Tópico:("physiological variables")
2) **Tópico**:("energy expenditure") *AND* **Tópico**:(actigraphy) *AND* **Tópico**:(variable)
3) **Tópico**:("energy expenditure" *AND* **Tópico**:(actigraphy) *AND* **Tópico**:(equation)
4) **Tópico**:("energy expenditure" *AND* **Tópico**:(actigraphy) *AND* **Tópico**:(estimation)
5) **Tópico**:("energy expenditure" *AND* **Tópico**:(actigraphy) *AND* **Tópico**:(calculation)
6) **Tópico**:("energy expenditure") *AND* **Tópico**:(actigraphy)
7) **Título**:("energy expenditure") *AND* **Título**:(equation)
8) **Tópico**:("energy expenditure") *AND* **Tópico**:("artificial neural network")

Database: Science Direct

1) TITLE-ABSTR-KEY(**"energy expenditure"**) and TITLE-ABSTR-KEY(**actigraphy**) and TITLE-ABSTR-KEY ("**physiological variables**")
2) TITLE-ABSTR-KEY(**"energy expenditure"**) and TITLE-ABSTR-KEY(**actigraphy**) and TITLE-ABSTR-KEY(**variable**)
3) TITLE-ABSTR-KEY(**"energy expenditure"**) and TITLE-ABSTR-KEY(**actigraphy**) and TITLE-ABSTR-KEY(**equation**)
4) TITLE-ABSTR-KEY(**"energy expenditure"**) and TITLE-ABSTR-KEY(**actigraphy**) and TITLE-ABSTR-KEY(**estimation**)
5) TITLE-ABSTR-KEY(**"energy expenditure"**) and TITLE-ABSTR-KEY(**actigraphy**) and TITLE-ABSTR-KEY(**calculation**)
6) TITLE-ABSTR-KEY(**"energy expenditure"**) and TITLE-ABSTR-KEY(**actigraphy**)
7) TITLE("**energy expenditure**") and TITLE(**equation**)
8) TITLE-ABSTR-KEY(**"energy expenditure"**) and TITLE-ABSTR-KEY ("**artificial neural network**")

Database: Scopus

1) (TITLE-ABS-KEY ("energy expenditure") AND TITLE-ABS-KEY (actigraphy) AND TITLE-ABS-KEY ("physiological variables"))
2) (TITLE-ABS-KEY ("energy expenditure") AND TITLE-ABS-KEY (actigraphy) AND TITLE-ABS-KEY ("variable"))
3) (TITLE-ABS-KEY ("energy expenditure") AND TITLE-ABS-KEY (actigraphy) AND TITLE-ABS-KEY ("equation"))

4) (TITLE-ABS-KEY ("energy expenditure") AND TITLE-ABS-KEY (actigraphy) AND TITLE-ABS-KEY ("estimation"))
5) (TITLE-ABS-KEY ("energy expenditure") AND TITLE-ABS-KEY (actigraphy) AND TITLE-ABS-KEY ("calculation"))
6) (TITLE-ABS-KEY ("energy expenditure") AND TITLE-ABS-KEY (actigraphy))
7) (TITLE ("energy expenditure") AND TITLE (equation))
8) (TITLE-ABS-KEY ("energy expenditure") AND TITLE-ABS-KEY ("artificial neural network"))

Database: PubMed

1) (("Energy Expenditure") AND Actigraphy) AND "Physiological Variables"
2) (("Energy Expenditure") AND Actigraphy) AND "Variable"
3) (("Energy Expenditure") AND Actigraphy) AND "Equation"
4) (("Energy Expenditure") AND Actigraphy) AND "Estimation"
5) (("Energy Expenditure") AND Actigraphy) AND "Calculation"
6) ("Energy Expenditure"[Title/Abstract]) AND Actigraphy[Title/Abstract]
7) ("Energy Expenditure"[Title]) AND Equation[Title]
8) ("Artificial neural network") AND "Energy Expenditure"

Database: Informaworld by Francis & Taylor

1) [All: "Energy Expenditure"] AND [All: "Actigraphy"] AND [All: "Physiological Variables"]
2) [All: "Energy Expenditure"] AND [All: "Actigraphy"] AND [All: "Variable"]
3) [All: "Energy Expenditure"] AND [All: "Actigraphy"] AND [All: "Equation"]
4) [All: "Energy Expenditure"] AND [All: "Actigraphy"] AND [All: "Estimation"]
5) [All: "Energy Expenditure"] AND [All: "Actigraphy"] AND [All: "Calculation"]
6) [All: "Energy Expenditure"] AND [All: "Actigraphy"]
7) [Publication Title: "Energy Expenditure"] AND [Publication Title: "Equation"]
8) [All: "Artificial neural network"] AND [All: "Energy Expenditure"]