

Inertial measurement units' features to assess gait quality in aging or pathological states : a systematic review.

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1 Research Questions

- What methods and context are used to evaluate gait quality in ageing or pathological states using inertial sensors?
- How is care improved by gait evaluation in ageing or pathological states using inertial sensors?
- Which parameters should one extracts from inertial sensors to assess gait in ageing or pathological states?

2 Research Protocol

2.1 Search Strategy

Methods for Literature Search : An electronic database search of titles and abstracts will be performed in August, 31st 2016 to identify articles analysing gait using inertial sensors among healthy elderly or subjects diagnosed with any pathology. Three databases (Pubmed, Cochrane, EMBASE) will be used as references for published articles. The search will be performed for articles published between January, 1st 2014 to August, 31st 2016 using the following key words : ‘Gait’ with ‘inertial measurement unit’, ‘IMU’, ‘inertial sensor’, ‘accelerometer’ or ‘gyrometer’. The following outlines the complete combination of search terms that was used to search the titles and abstracts for all three databases : (Gait[Title/Abstract] AND (inertial measurement unit[Title/Abstract] OR IMU[Title/Abstract])) OR inertial sensor[Title/Abstract] OR accelerometer[Title/Abstract] OR gyrometer[Title/Abstract])

Inclusion criteria All articles, published from January, 1st 2014 to August, 31st 2016, obtained through these searches will be included in the systematic review. All articles will be considered regardless of language used and all full papers will be retrieved when possible (full articles that are not in open access will be bought).

Exclusion criteria We will import data to Zotero® and all articles will be reviewed (title, abstract and main text when needed) to discard articles that do not meet the six following criteria :

1. HUMAN criterion : all animal studies will be discarded ;
2. GAIT criterion : all studies quantifying other activity than gait (eg stair climbing, standing, running, prone locomotion) or addressing general physical activity (step count, walking bout length...) will be discarded ;

3. IMU criterion : all studies using other sensors than inertial sensors (eg GaitRite, force plates) will be discarded ;
4. PARAMETER criterion : all studies than do not compute any parameter to quantify gait but focus on walking segmentation or event detection (U-turn, FOG) or gait recognition from raw data or use of the IMU as a feedback tool will be discarded ;
5. PATHOLOGY or AGING criterion : all studies including young (<65 years old) healthy people will be discarded ;
6. COMPARISON criterion : all studies than do not compare subjects but focus on methodological issues (eg IMU methodology and validation, sensor placement methodology and validation, parameter computational algorithm validation) or material issues (robotics and prostheses) will be discarded.

3 Paper Review Process

Potentially eligible studies will be screened for eligibility independently by two review authors (AV and DR) relying on the title, abstract as well as full text. If discrepancies happen between the reviewers, they will discuss until a consensus is reached. Papers that are eligible will be subjected to data extraction and quality assessment.

3.1 Quality Assessment :

Besides, a quality assessment will be performed by using a 20-item quality checklist for longitudinal studies which we adapted from Hubble et al (2015) by altering one item and adding three more items to better fit the requirements of our aim (supplemental material). Each article will be assessed twice (by the two assessors in random order), each reviewer being blind to the score given by the other. Disagreements will then be discussed and the mean of both scores will be chosen as the final score if no agreement is to be found.

3.2 Data Extraction and Analysis :

Upon selection of the articles for inclusion, references will be imported to excel for data extraction. One assessor (AV) will extract and collate information regarding :

- the subjects included in the study : whether they are elderly or persons diagnosed with a pathology, their number, the classification used for diagnosis, disease severity ;
- the type of study : in laboratory environment or ambulatory, longitudinal or cross-sectional ;
- the aim of the study : risk assessment or diagnosis or differential diagnosis or evaluation of treatment or prognosis ;
- the protocol used in the study : step detection method, type and location of the inertial sensor(s), methodology for gait assessment including floor type, speed, and exact sequence of steps, specific condition added (dual task) ;
- the features computed : method used to extract the parameter (spatial analysis, temporal analysis, temporo-spatial analysis, frequential analysis, chaos theory, complexity analysis, fractal, phase plot analysis, energetic analysis), parameter description, parameter unit, parameter value ;
- the statistical analysis : test for normality, test used, whether correction for multiple comparison was applied, confounding factors, parameter significance.

Except for those concerning values of the features, when data are not available in the main text, we will look in the supplemental materials for more detailed information. When data on the sensors (frequency, provider) are not available even in the supplemental materials, we will look for the specs on precedent articles for the same author or on the Internet using sensor references.

supplemental material : 20-item quality checklist

Reporting

1. Is the hypothesis/aim/objective of the study clearly described? (1 point)
2. Are the main outcomes to be measured clearly described in the Introduction or Methods section? (1 point)

If the main outcomes are first mentioned in the Results, the score should be 0.

3. Is the protocol clearly described? (2 points)

Add 1/2 point for each of the four element specified : ambulatory or distance or time of walk, the sequence of steps (U-turn, sit-to-stand transition), sensor type and frequency, sensor position.

4. Are the step and segment detection methods clearly described? (1 point)

If the methods are only specified as 'automatic' or 'by hand' without more explanation, the score should be 0.

5. Are the number of trials and steps included in the analysis clearly specified? (1 point)
6. Are the characteristics of the patients included in the study clearly described? (1 point)

In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given.

7. Are the distributions of principal confounders in each group of subjects to be compared clearly described? (1 point)
8. Are the main findings of the study clearly described? (1 point)
9. Does the study provide estimates of the random variability in the data for the main outcomes? (1 point)
10. Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001? (1 point)

External validity

11. Were the subjects asked to participate in the study representative of the entire population from which they were recruited? (1 point)

The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source populations from which the patients are derived, the score should be 0 (unable to determine).

12. Were those subjects who were prepared to participate representative of the entire population from which they were recruited? (1 point)

The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.

13. Was there validation of the sensor used? (1 point)

If the sensor is self-made and no analysis of reliability has been made in either the article or a precedent one, the score should be 0.

Internal validity - Bias

14. If any of the results of the study were based on ‘data dredging’, was this made clear? (1 point)

Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then score 1.

15. Were the statistical tests used to assess the main outcomes appropriate? (1 point)

If no test for normality or no post-hoc corrections has been made when needed, only 1/2 point should be given. If both criteria fail, score should be 0.

16. Were the main outcome measures used accurate (valid and reliable)? (1 point)

For studies where the outcome measures are clearly described, the score should be 1. For studies which refer to other work or that demonstrates the outcome measures are accurate, the score should be 1.

Internal validity - Confounding (Selection Bias)

17. Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population? (1 point)

18. Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time? (1 point)

19. Was there adequate adjustment for confounding in the analyses from which the main findings were drawn? (1 point)

This question should be scored 0 for trials if the main conclusions of the study were; i) based on analyses of treatment rather than intention to treat; ii) the distribution of known confounders in the different treatment groups was not described; or iii) the distribution of known confounders differed between the treatment groups but was not taken into account in the analyses. In non-randomised studies if the effect of the main confounders was not investigated or confounding was demonstrated but no adjustment was made in the final analyses the question should be scored 0.

Power

20. Did the study have sufficient power to detect a clinically important effect where the probability value for a difference being due to chance is less than 5