EEG recording during locomotion: a methodology review

P. F. Custódio [1,2], E. van Wegen [2], P. Praamstra [3], J. Harlaar [2,4], F. Steenbrink [1]

[1] Motek Medical B.V.

[2] Research Institute MOVE, VU University Medical Center

[3] Department of Neurology, Radboud University Nijmegen Medical Centre

[4] Department of Rehabilitation Medicine, VU University Medical Center Amsterdam

Background

Due to methodological limitations of neuroimaging techniques, studying the role of cognitive processes during locomotion is a challenge (Makeig et al. 2009).

Recently, electroencephalography (EEG) has been used to study the supraspinal mechanisms during human gait and has been reported as feasible (Holtzer et al. 2014). However, there is debate about the influence of muscular artifacts on the EEG data (Castermans et al. 2014).

The aim of this review is: i) to provide more information on state-of-the-art EEG methodologies (EEG data processing) used to study gait control in humans; and ii) to summarize the EEG outcomes used.

Methods

The search of studies was done on PubMed from 2000 up to March 31, 2015. **The search terms included were**: (i) adults or young; (ii) electroencephalography and (iii) gait, walking or locomotion. Exclusion criteria were: non-human studies, studies with infants or newborns and case reports.

Results

A total of **126 articles** were found and **39 articles** were included in the qualitative syntheses.

We identified three main areas of focus in the literature: **validation of EEG methodologies**, **brain cortical activity** during gait and **population groups** comparison .

In Figure 1 you can see the filtering methods and algorithms used for the data processing and the measurement outcomes used in the literature.

16 out of the 19 articles of the first category concluded that it was feasible to record EEG or to obtain comparable EEG outcomes during gait and standing still.

Commonly, the first step of EEG signal processing consists of basic filters (e.g. high-pass, low-pass and the Notch filters).

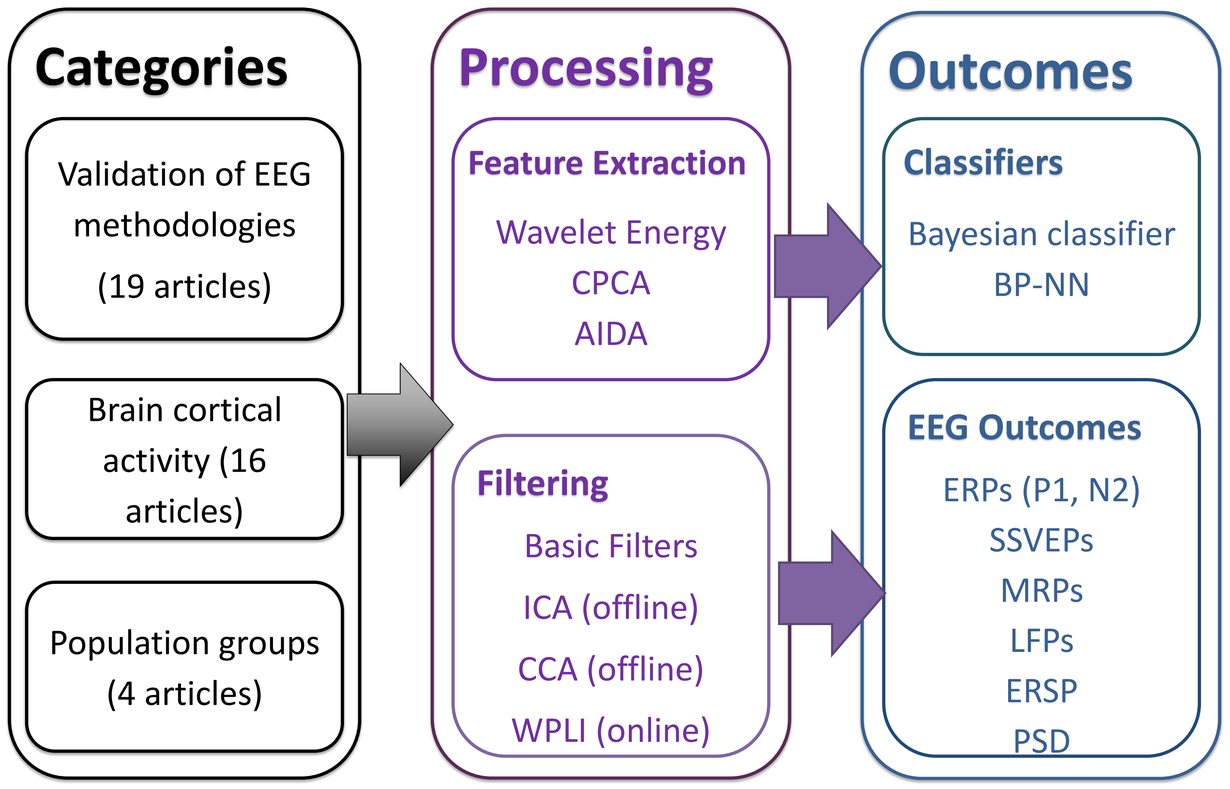

Fig. 1 Flow diagram representing the three stages during this review. First we identified articles that focused on those categories, secondly, we summarized the EEG data processing methodologies used, and lastly the EEG outcomes used.

The **most used advance processing methodology** followed a similar approach to Gwin et al. (2010), **applying an ICA** (13 articles) to find the muscular artifact components and remove them. Both ICA and CCA are algorithms used in **offline processing** of the data, while WPLI was used in **online processing**, useful for brain computer interfaces (BCIs) with real-time feedback.

The most used EEG outcomes were **ERSD** and **PSD in beta and alpha frequency bands** (14 articles). One of the most striking results is the beta desynchronization patterns on the motor cortex correlated with the gait cycle.

Conclusion

The increased interest in this field (35 articles are from 2011 onwards) shows that there is **neurophysiological evidence** that the brain has a dynamic control during stepping and gait.

This research is of particular interest for understanding motor neurological diseases like Parkinson's disease (6 articles) and rehabilitation in spinal cord injuries (1 article).

Abbreviations: classwise principal component analysis (CPCA); approximate information discriminant analysis (AIDA); back propagation neural networks (BP-NN); independent component analysis (ICA); canonical correlation analysis (CCA); weighted phase lag index (WPLI); steady-state visual evoked potentials (SSVEPs); event-related potentials (ERPs); movement-related potentials (MRPs); local field potentials (LFPs); event-related spectral perturbation (ERSP); power spectral desynchronization (PSD).