Systematic Review on the Use of Electroencephalogram in Detecting Work Fatigue

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Abstract

Fatigue is one of the causes of occupational accidents and injuries especially among motor-vehicle users and those working in high risk jobs. For over many years there were attempts to quantify and objectify fatigue using an electroencephalogram (EEG). This systematic review is to the study protocols used and explore the results obtained to potentiate EEG's ability as a fatigue prevention-screening tool. We used the PRISMA statement method to identify, collate and classify the articles for review from PubMed database. Three investigators, independently, using predefined criteria, assessed selection of the articles. They assessed its quality following a standard set of information too. Of the 962 articles, scanned only 24 articles met the criteria and showed acceptable quality. Almost no papers attended to the sampling method. However, their variable measurements and analysis are appropriate according to respective objectives. EEG recording is an objective assessment and readily duplicated but we could not perform meta-analysis due to inadequacy in standardized methods of data collection and analysis. Nevertheless, the EEG changes showed consistency in findings whereby theta and alpha wave bands are the best indicators in fatigue detection. Hence: making EEG a potential screening tool for fatigue.

Keywords: Electroencephalogram • Fatigue • Workers

Introduction

Fatigue is a condition affecting both the mental and physical state of a person carrying out prolonged work, which can be either active or mundane. Fatigue experienced by normal people is a condition that can disappear with adequate rest. In the working population, fatigue is a common complaint with approximately 20% reporting rate [1]. The Maastricht Cohort Study carried out in 1998 Netherlands claimed prolonged fatigue was common among workers at around 21.9% transecting over 12 sectors and work trades [2].

There is a multitude of effects of fatigue in relation to work. Those effects and subsequent consequences of fatigue such as risky behaviours, risky work practices, and various addictions but more importantly accidents and injuries, are not only detrimental to the workers and their life but to their employers too. Employers would have to then deal with absenteeism, prolonged medical leave, and disciplinary problems. Such issues are also economically counterproductive for the employer's business [3]. A fatigue commercial passenger vehicle driver or pilot can make potentially fatal errors, which could cost lives. Patients treated by fatigue doctors could have been mismanaged or even potentially mistreated causing death [4]. These hazards are fatigue related, as fatigue constitutes reduced cognitive ability (decision-making and response time). During fatigue, there is decrease in physiological arousal, slowed sensorimotor functions, and impaired information processing, and impaired workers' ability to respond effectively in emergencies or unusual situations [5].

Many studies have been conducted using the electroencephalogram (EEG), which is an instrument used to detect bioelectrical brain waves (extracellular current flow). Electroencephalogram signals are indicated to be very predictive and reliable tool to detect alertness levels [6] and could be used in preventing fatigue related errors or as a trigger in counter-measure instruments [7]. These changes can be explained by analyzing the four types of brain waves detected by EEG. They are delta (0 to 4 Hz), theta (4 to 8 Hz), alpha (8 to 13 Hz), and beta (13 to 20 Hz) [8]. Delta waves are more frequent during sleep. An early stage of drowsiness indicated by an increase in theta waves. Alpha waves reflect a relaxed wakefulness state and decrease with concentration, stimulation or visual fixation, a state where the worker is fatigued enough to fall asleep [8,9].

The objective of this systematic review is to explore the use of various experimental designs and research methods in the collection of EEG data for detecting and evaluating work fatigue. From this exploration, further inspection of the results in the reviewed articles, are explored. The inspection of the result collates the common findings found in work fatigue evaluation. The results of this review could then provide a deduction of usefulness of using EEG as a tool for detecting and evaluating work fatigue.

Methods

Search Strategy

We searched the PubMed online database using the terms "electroencephalogram" and "fatigue", without setting the limit on publication dates of the articles due to its limited numbers. PubMed is a source of clinical and health linked research study articles only. Many studies of EEG and fatigue are found in other search engines too but are not clinically/health linked or attuned. This study wishes to select articles of studies within the clinical field under the framework of occupational health. All articles obtained from the search were screened and filtered using the PRISMA reporting method as shown in Figure 1 [10, 11].

The search result was screened for duplicates and removed. The cleaned titles were screened by three independent reviewers according to relevancy and shortlisted. The second level of screening was by reviewing the articles abstract for relevance. Any discrepancy was solved by majority consensus between the three reviewers. Full texts were retrieved from the final list of articles. Applying a set of inclusion and exclusion criteria, the three reviewers further screened and selected the eligible articles for full review.

Inclusion and exclusion criteria

The articles selected for systematic review included those of human studies only and must be in English. Title of the studies must be of clinical or health concern under the frameworks and concepts of occupational health. We also chose to include studies that use the following algorithms of EEG spectral analysis: absolute power and relative power of all brain waves, and the formulas: $(\alpha + \theta)/\beta$ and α/β [12]. The studies should have objectives to study fatigue among workers at different working conditions with contributing attempts for developing countermeasure protocols, prevention of accidents and relevant to occupational health [13,14]. Studies of fatigue carried out on non-specified occupation were also considered.

We excluded articles related to diseases caused by fatigue and chronic fatigue syndrome. Studies about fatigue but did not use EEG were excluded. The objectives that do not share this review's objective to identify the suitability of EEG in the detection of fatigue were excluded. We also excluded in addition, articles that did not come with an abstract or full text. We also removed articles using other than the specified algorithms and those attempting to create newer algorithms. Studies that induced fatigue using non-occupational or work-related methods such as alcohol were also excluded. Lastly, studies that are engineering based and not clinically related were also excluded.