Fatigue Detection Post Physical Activity: A Review

Ashish Sharma*, Gaurav Sethi

School of Electronics and Electrical Engineering, Lovely Professional Univerisity, Jalandhar, India

*Corresponding author

doi: https://doi.org/10.21467/proceedings.114.13

Abstract

Construction work is purely effortful and the prevention of injuries at construction job sites is essential for encouraging worker's well being and health which is generally overlooked at the construction sites. World's construction industry is one amongst those having unsatisfactory work health issues. A large number of laborers and construction workers have to undergo fatigue risk at their job place as fatigue increases the risk of injury among construction workers. This paper describes the current state of the art of the research carried out in case of fatigue assessment after performing some physical activity providing an insight into fatigue, its detection and an overview of the causes of risk fatigue and its countermeasures. A number of subjective and objective fatigue assessment approaches have been used that have further stimulated the inclusion of latest and advanced approaches for fatigue detection. Although individual's knowledge regarding the fatigue detection approaches has enhanced, there is as yet minimal research in the field of fatigue detection post physical activity at construction sites. This article provides a novel deep action recognition approach using deep extension based equilibrium with capsule auto encoder network for the detection of physiological fatigue among construction workers. The proposed method was tested on the dataset collected at the local construction sites in the form of videos.

Keywords: fatigue, construction workers, physical activity.

1 Introduction

The construction and labour sites record a considerable number of on-site injuries in India and abroad. Also, another major cause of nonlethal injuries that is caused mainly due to having a break from construction work, as well as a huge counterbalance costs and medical costs with frequent work dysfunctions (1). Fatigue is one of the major causes for accidents happening in the construction sites. The construction industry often exposes workers to massive workloads, extended work timings, and iterative tasks making body fatigue unavoidable (2,3). Physical fatigue can also birth to continual health problems as well as task related body and joint disorders, inveterate fatigue problems, and immune system dysfunctions (4,5). Thus, fatigue detection and assessing technology that permit for mediation in advance of fateful effects to workers' protection, fitness, and efficiency are worth studying. Fatigue in general terms is defined as the reduction in the transient performance of the muscles to employ optimal force after undergoing a physical activity. Fatigue is a symptom, not a condition. Fatigue develops moderately in steps over a time period for works that do not demand continued employment of maximum possible force. As per a study on construction workers, a worker undergoes five to six hours of average walking in individual time shift and around 40-44% of the individual carrying out these jobs are reported to be exhausted due to body fatigue (6).

Traditional approaches to assess the physical exposure experienced by the workers at construction sites are generally based on ocular observation carried out by a skilled observer or it may rely on any other subjective approaches such as questionnaires. However, as per the nature of fatigue detection, certain fatigue indicators may vary among different workers with distinct social and ethnic backgrounds (7,8). This is the reason that subjective techniques of fatigue detection are generally implemented to the task specific environment and the target individuals.

Proceedings DOI: 10.21467/proceedings.114; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-8-8

Physical and body related measurements, encompassing pulse rate, oxygen intake and outer body temperature are employed to conquer the limitations of subjective detection methods (9,10). As above said method may be clumsy and difficult to implement, sometimes secondary measures have been implemented to assess physical exhaustion, enhanced jerk, and joints related issues (11). These detection methods are based on motion data collected using optoelectronic sensors, which is the pioneering approach for non-invasive physical locomotion capture in different studies (12,13). Practically, the above technique is limited to employ as it requires great skillfulness, a huge processing cost and it is also a difficult task to deploy these methods on most job sites(12).

2 Fatigue, Fatigue Characterictics and Corresponding Fatigue Detection Methods

2.1 Fatigue and Its Characteristics

Defining fatigue in terms of composite interplay of the biological phenomena, physiological processes, and behavioral demonstration is a tedious task. Authors in (14) define fatigue as functional organ failure. Excessive energy consumption may be the leading cause for such a functional organ failure. Fatigue in other words may be called as a decay in efficiency and productivity due to partial healing from last physical activities (15). As per (16), fatigue is defined as a fall in any tissue 's ability to apply force as a result of carrying out a physical activity. Author in (17) proposed to differentiate acute and chronic fatigue. Acute fatigue is generally related to an individual cause, and exists in healthy individuals, is sensed generally as normal, has a rapid start and short but severe course, is generally relieved by taking rest, diet, exercise, and stress management, and has a minute effect on the daily performance. But, chronic fatigue, is specified as having an unspecified function, and it mainly affects persons with poor clinical health, having random causes. Chronic fatigue may worsen with any further physical or mental activity and there is little improvement even after taking a rest. Ream et. al (18) defined fatigue as: "A subjective, unpleasant symptom which incorporates total body feelings ranging from tiredness to exhaustion creating an unrelenting overall condition which interferes with individuals' ability to function to their normal capacity".

After overall discussion, we can now view physical fatigue as a knowledge about lessened capacity for performing physical activity due to lack in the resources required to do so.

2.2 Fatigue Detection Methods

The detection of fatigue has always been a tedious task for researchers. Often the assessment of fatigue is related to conditions where fatigue is observed, thereafter curbing the generalization of the results and observations. Detecting fatigue has been a tedious task not merely because of its pervasive nature but also because fatigue is a symptom and, as such, its subjectivity presents additional detection difficulties. As per the statement provided the author in (19) "The absence of an overall definition of fatigue preempts any scientific basis for measuring the condition, because logically, that which cannot be defined cannot be measured, and is not understood. The absence of a relevant means to detect and measure fatigue have seriously limited efforts to synthesize common knowledge about fatigue. Numerous efforts to detect and measure fatigue have evolved in the present state-of-the-art despite all above concerns. Early work in fatigue detection was aimed at fatigue in the workplace and was undergone by industrial psychologists and military scientists. Generally healthy population was targeted for these studies at a specific time for detection.

Although, several techniques have now been evolved for fatigue detection and measurement, but the findings can be variable in nature and is dependent upon a number of intrinsic and extrinsic factors. Intrinsic factors account mainly for attributes like body health and experience. Extrinsic factors may include cumulative workload and task complexity. There are several methods of fatigue detection used for laboratory studies and field studies. Under this study, we will focus on the measures that can be deployed in field studies.

2.3 Subjective Methods

In the subjective approach of fatigue detection, the system relies on the surveys and questionnaires based on self perceived exertion scales, conducted on selected and suitable subjects. A consent for the same is taken from the subjects. Although these have the advantage of being inexpensive, they lack reliability (20). Benjamin et al. performed a study on fatigue detection in an office environment. The study design was guided by a specific theory of change. Authors expected that training would increase office ergonomic knowledge and that would help workers to restructure their workspace, which in turn would further influence working postures and behaviours. Here, the authors collected the dataset through online mode after a training method named 'theory of change" as shown in fig. 1. Data collection occurred two months and one month before the change employed and two, six, and twelve months after the change theory practice. A short daily symptom survey was conducted at the start, middle and end of each day in a 5-day workweek. The level of pain or discomfort was rated by the subjects on a scale of 0 for no pain to 10 for extremely severe pain for different body parts.

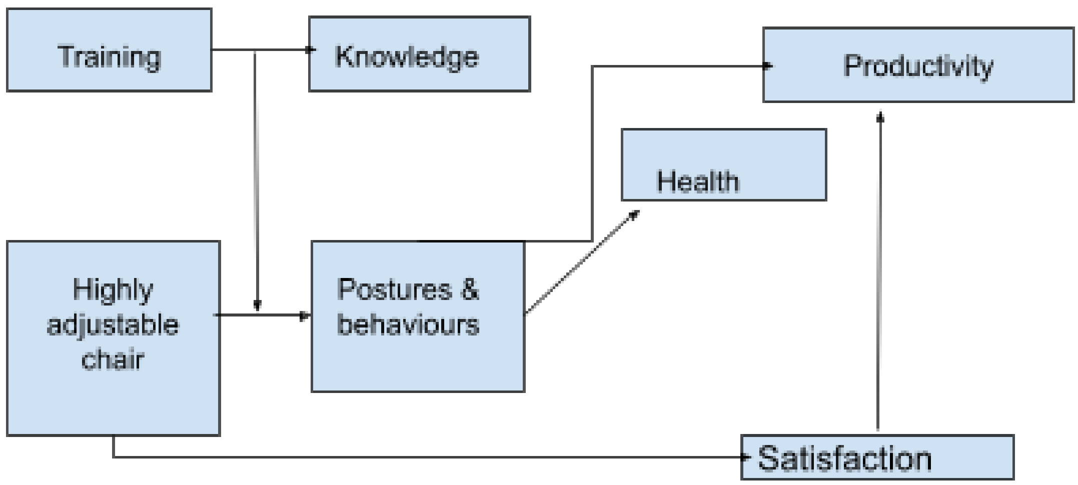


Fig. 1. Theory of change (21)

The sum of all the ratings by an individual subject ranging from 0 (no pain anywhere in the body) to 90 (extremely severe pain in full body) was considered as the primary variable. In the questionnaire, thirty different covariates and potential co founders were observed. After performing primary and secondary hypothesis, the fatigue was observed as per fig. 2.

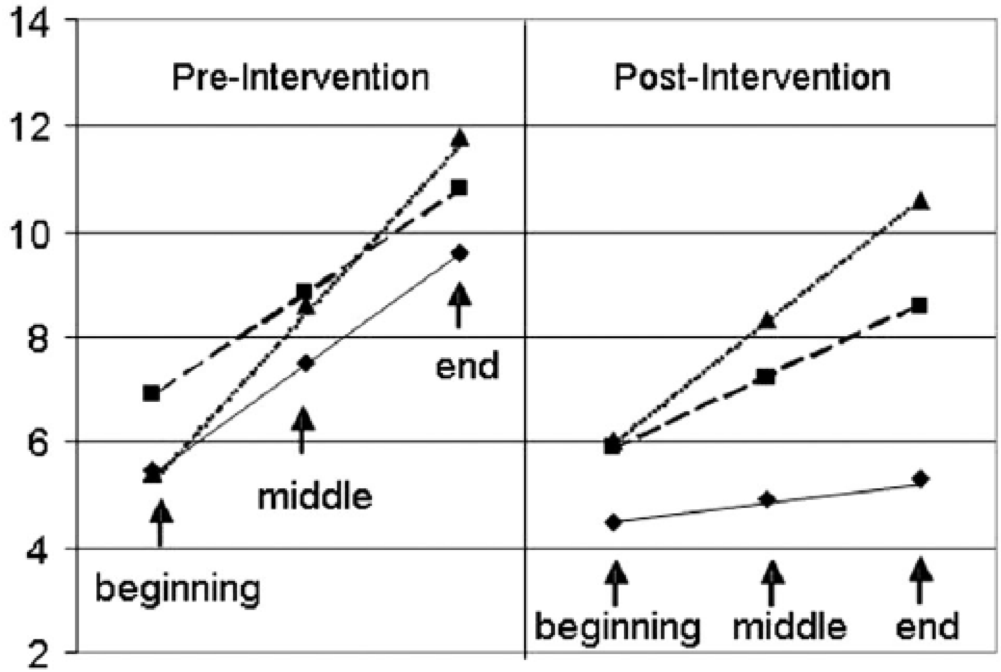


Fig. 2. Bodily pain at the beginning, middle, and end of the day before and after training (21)

Park et. al conducted another study on each five working days of a selected week. Authors surveyed working hours of the subjects for complete weeks and observed body health etc. during the last month. Secondly, subjective fatigue before leaving for work in the morning at residence and during afternoon performing work at office was surveyed. And lastly the stress by self reported questionnaire was surveyed. Authors deployed fatigue questionnaire and the stress questionnaire. The subjects were inspected for pre study health conditions. The subjective fatigue was observed two times at home before leaving to work in the morning and during duty time in the afternoon.

Authors used One way analysis of covariance (ANCOVA) to adjust for differences in different age groups. It was concluded after performing this research that JAIH subjective fatigue questionnaire was able to distinguish between fatigued and non-fatigues subjects. Several other subjective fatigue detection studies have been conducted so far and it can be concluded that these methods are easy and inexpensive but lack reliability.

2.4 Objective Methods

Objective approaches of fatigue detection are based on physiological processes (movement of different body parts) and are more reliable. The on-site implementation of these systems is a cumbersome and expensive task. In the current state-of-the-art fatigue detection and physical exertion assessment has been implemented mostly by using Electromyography (EMG) and with the inception of cheap and reliable wearable motion sensors it has been performed using inertial measurement units (IMUs).

In (22), the authors have performed the task using EMG. The study was performed on ten female participants. None of the subjects were reported for any kind of motor health issues. The study was performed on the production-line workers. The task was to pick a product followed by visual control and then placing it back as illustrated in fig. 3.

Proceedings DOI: 10.21467/proceedings.114
Series: AIJR Proceedings
ISBN: 978-81-947843-8-8
ISSN: 2582-3922

Fig. 3.Task performed in [22]. (a) picking the product; (b) visual control; (c) placing the product.

The speed of the sprayer was used as the measure for work pace. The task was performed by the subjects for 1 week with 9 hours a day working period. The subjects were allowed a 10 minute short break every hour. There was a lunch break for 30 minutes. Measurements were carried out on Monday and Friday.

Detection of fatigue was carried out using EMG. It was observed by authors that the amplitude of EMG increased during the day time. Local perceived discomfort increased in the upper body during duty time. Fig. 4 shows the EMG test contraction method used in (22).

Fig. 4. Electromyography test contraction method (22)

Karg et. al, 2014, performed another study by employing optical markers to record the data set. The data acquisition took place at the Tokyo University of Agriculture and Technology, Tokyo. A set of 35 passive optical markers were used to capture a dataset with 10 motion cameras. The subjects performed squat exercise. Seven subjects provided with the description of the experiments performed repeated sets of five squats. After a set of five squat exercises each time, the extent of fatigue of each subject was recorded on a 6 points Likert-scale. Table 1 shows an illustration of every level employed in (24).

TABLE II. DIFFERENT FATIGUE LEVELS AND THEIR DESCRIPTION

Level	Fatigue	Fitness
1	Not tired at all	Not fit at all
2	Not really tired: can do many more	Barely fit
3	A little tired: can do a few more	Practice sport sometime
4	Tired: can do a little more	Practice sport often
5	Very tired: can hardly endure more	Practice sport regularly
6	Extremely tired: cannot endure more	Athlete

It was observed by the authors that fatigue during squat exercises influenced different body parts and joints. A Hidden Markov Model technique was applied to incorporate the findings that the fatigue keeps on increasing continuously.

Another study incorporated in (20) was based on the use of sensors on different body parts. Inertial Measurement Units (IMUs) were used to capture whole body kinematics of the subjects. The study was performed at the Canadian Masonry Design Centre, where 32 male workers with distinct experience levels in bricklaying job were observed. Different IMU units were placed as shown in fig. 5.

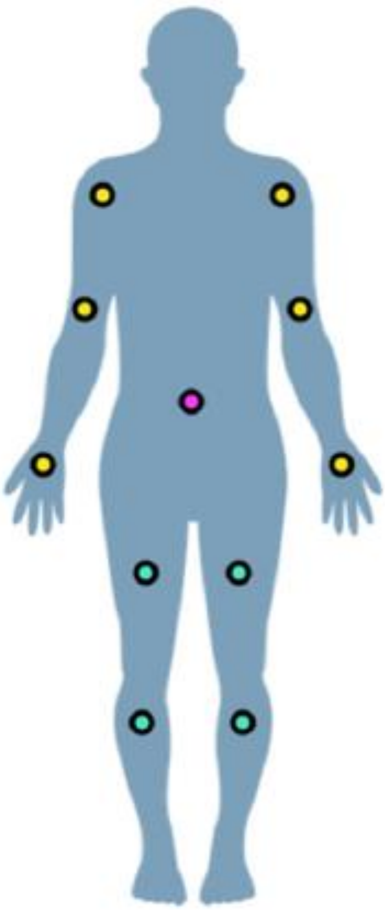


Fig. 5. Positioning of different IMU units in (20)

Proceedings DOI: 10.21467/proceedings.114
Series: AIJR Proceedings
ISBN: 978-81-947843-8-8
ISSN: 2582-3922

The data collected was processed using MATLAB. The fatigue here was observed in terms of jerk (rate of change of acceleration) values. The resultant acceleration of the eleven body segments were calculated out of their cartesian components. It was observed that the jerk values kept on increasing with fatigue.

3 Proposed Method for Fatigue Assessment

Subject based assessment of fatigue for different actions of workers like loading or unloading building materials, mixing building materials, pitching action etc. is carried out. Fig 6 below presents an overview of different steps in the proposed methodology for fatigue detection (fig 6):

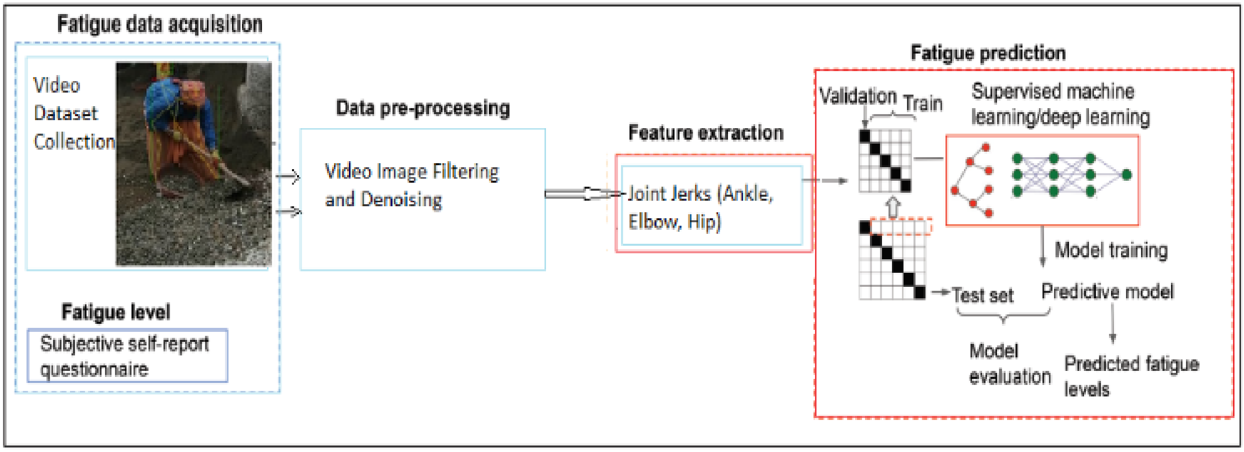
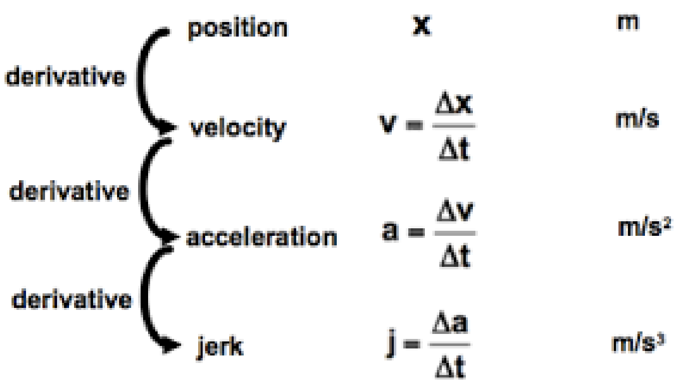


Fig. 6.An overview of the proposed method

The fatigue dataset is collected at a construction site using a high resolution motion camera from multiple angles and at a predefined distance so as to have uniformity in the dataset. The number of subjects used for the study so as to have maximum accuracy. A subjective questionnaire is required to be filled by the subject before being part of the study and only those subjects are chosen who are having no chronic illness that may lead to inaccurate results. The dataset video images are preprocessed using suitable filtering and denoising techniques. Filtering usually refers to the method of removing some redundant information as per the requirements of image processing, and preserving the useful information. By filtering the images are made more suitable for ocular as well as objective assessment systems as per the application. Images are left blurry when these are attacked by some noisy components. Sometimes the noise is introduced at such a level that it may destroy the useful information and affect further feature extraction from these images.

The resultant joint and muscle jerks are extracted from the video images using some suitable model for the calculation of pixel jerk in the consecutive images. The jerk j from image pixel positions can be calculated as given below



Fatigue is predicted by training the regression models. Any suitable training model like Random Forest (RF) or Convolutional Neural Network (CNN) is used. The test dataset is classified between fatigued and non-fatigued subjects.

4 Conclusion

After having a review of research carried out in fatigue detection it can be concluded that in using subjective as well as objective approaches, there is always a requirement of large data sets. There is always a variation in the collected parameters in terms of demographic and other individual differences in the development. Although the objective approach is much more reliable and accurate, it also adds in the cost. This study also concludes that work exposes individuals to fatigue that they would rarely experience without work. A significant population across the world is exposed to fatigue risk due to their busy work schedules and other non-work related causes. So, there is always a need to assess fatigue effectively for fatigue risk management.

References

[1] K. Yang, C. R. Ahn, and H. Kim. "Validating ambulatory gait assessment technique for hazard sensing in construction environments." Automation in Construction, vol. 98, pp. 302-309, Feb. 2019.

[2] A. Aryal, A. Ghahramani, and B. Becerik-Gerber, "Monitoring fatigue in construction workers using physiological measurements," Automation in Construction, vol 82, pp.154-165, oct. 2017.

[3] L. Zhang, "Jerk as a Method of Identifying Physical Fatigue and Skill Level in Construction Work." Master's thesis, University of Waterloo, 2019.

[4] E. Valero, A. Sivanathan, F. Bosché, and M. Abdel-Wahab, "Analysis of construction trade worker body motions using a wearable and wireless motion sensor network," Automation in Construction, vol 83, pp .48-55, Nov. 2017.

[5] Z. Maman, S. Yazdi, L. A. Cavuoto, and F. M. Megahed, "A data-driven approach to modeling physical fatigue in the workplace using wearable sensors," Applied ergonomics,vol. 65, pp. 515-529, Nov. 2017.

[6] A. J. Dittner, S. C. Wessely, and R. G. Brown, "The assessment of fatigue: a practical guide for clinicians and researchers," Journal of psychosomatic research, vol. 56(2), pp. 157-170, Feb. 2004.

[7] L. S. Aaronson, C. S. Teel, V. Cassmeyer, G. B. Neuberger, L. Pallikkathayil, J. Pierce, ... and A. Wingate, "Defining and measuring fatigue," Image: the journal of nursing scholarship, vol. 31(1), pp. 45-50, Mar. 1999.

[8] Y. Zhu, R. R. Jankay, L. C. Pieratt, and R. K. Mehta, "Wearable sensors and their metrics for measuring comprehensive occupational fatigue: a scoping review," In Proceedings of the Human Factors and Ergonomics Society Annual Meeting, Vol. 61,pp. 1041-1045, Sept. 2017

[9] S. Hwang, J. Seo, J. Ryu, and S. Lee, "Challenges and opportunities of understanding construction workers' physical demands through field energy expenditure measurements using a wearable activity tracker," Construction Research Congress, pp. 2730-2739, 2016.

[10] U. C. Gatti, S. Schneider, and G. C. Migliaccio, "Physiological condition monitoring of construction workers," Automation in Construction, vol. 44, pp. 227-233, Aug. 2014.

[11] S. A. A. N. Bolink, H. Naisas, R .Senden, Essers, H. Heyligers, I. C. Meijer, and B. Grimm, "Validity of an inertial measurement unit to assess pelvic orientation angles during gait, sit–stand transfers and step-up transfers: Comparison with an optoelectronic motion capture system," Medical engineering & physics, vol. 38(3), pp. 225-231, Mar. 2016.

[12] C. M. Bauer, F. M. Rast, M. J. Ernst, J. Kool, S. Oetiker, S. M. Rissanen, ... and M. Kankaanpää, "Concurrent validity and reliability of a novel wireless inertial measurement system to assess trunk movement," Journal of Electromyography and Kinesiology, vol. 25(5), pp. 782-790, Oct. 2015.

[13] P. J. Berger, L. McCutcheon, M. Soust, A. M. Walker, and W. M. Wilkinson, "Electromyographic changes in the isolated rat diaphragm during the development of fatigue" European journal of applied physiology and occupational physiology, vol. 62(5), pp. 310-316, Sept. 1991.

[14] P. Gander, L. Hartley, D. Powell, P. Cabon, E. Hitchcock, A. Mills, and S. Popkin, "Fatigue risk management: Organizational factors at the regulatory and industry/company level," Accident Analysis & Prevention, vol. 43(2), pp. 573-590, Mar. 2011.

[15] A. J. Dittner, S. C. Wessely, and R. G. Brown, "The assessment of fatigue: a practical guide for clinicians and researchers," Journal of psychosomatic research, vol. 56(2), pp. 157-170, Feb. 2004.

[16] B. F. Piper, "Fatigue: current bases for practice. In Management of Pain," Fatigue and Nausea, pp. 187-198. Macmillan Education UK, 1989.

[17] E. Ream, and A. Richardson, "Fatigue in patients with cancer and chronic obstructive airways disease: a phenomenological enquiry," International journal of nursing studies, vol. 34(1), pp. 44-53, Feb. 1997.

[18] D. Eidelman, "Fatigue on Rest" and associated symptoms (headache, vertigo, blurred vision, nausea, tension and irritability) due to locally asymptomatic, unerupted, impacted teeth. Medical hypotheses, vol 5(3), pp. 339-346, Mar. 1979.

ISBN: 978-81-947843-8-8 ISSN: 2582-3922

[19] L. Zhang, M. M. Diraneyya, J. Ryu, C. T. Haas, and E. M. Abdel-Rahman, ”Jerk as an indicator of physical exertion and fatigue,” Automation in Construction, vol. 104, pp. 120-128, Aug. 2019.

[20] B. C. Amick III, M. M. Robertson, K. DeRango, L. Bazzani, A. Moore, T. Rooney, and R. Harrist, “Effect of office ergonomics intervention on reducing musculoskeletal symptoms,” Spine, vol. 28(24), pp. 2706-2711 Dec. 2003.

[21] T. Bosch, M. P. De Looze, and J. H. Van Dieen, “Development of fatigue and discomfort in the upper trapezius muscle during light manual work,” Ergonomics, vol. 50(2), pp. 161-177, Feb. 2007.

[22] J. Park, Y. Kim, H. K. Chung, and N. Hisanaga, “Long working hours and subjective fatigue symptoms, ”Industrial health, vol. 39(3), pp. 250-254, 2001.

[23] M. Karg, G. Venture, J. Hoey, and D. Kulić, “Human movement analysis as a measure for fatigue: A hidden Markov-based approach,” IEEE transactions on neural systems and rehabilitation engineering, vol. 22(3), pp. 470-481, Jan. 2014.

[24] F. A. Barbieri, Dos P. C. R. Santos, E. Lirani-Silva, R. Vitório, L. T. B. Gobbi, and J. H. Van Diëen, “Systematic review of the effects of fatigue on spatiotemporal gait parameters,” Journal of back and musculoskeletal rehabilitation, vol. 26(2), pp. 125-131, Jan. 2013.

[25] P. Gander, L. Hartley, D. Powell, P. Cabon, E. Hitchcock, A. Mills, and S. Popkin, “Fatigue risk management: Organizational factors at the regulatory and industry/company level,” Accident Analysis & Prevention, vol. 43(2), pp. 573-590, Mar. 2011.

[26] U. C. Gatti, S. Schneider, and G. C. Migliaccio, “Physiological condition monitoring of construction workers,” Automation in Construction, vol. 44, pp. 227-233, Aug. 2014