Safety On: a new survey methodology for occupational diseases. A Preliminary study of the incongruous postures of employees in manufacturing and service companies

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Abstract

Musculoskeletal Disorders (MSDs) stand as a prominent cause of injuries within modern industries. Earlier research has successfully established a causal linkage between MSDs and awkward working postures. Therefore, the development of a robust tool assessing workers' postures is of paramount importance in preventing MSDs. The Rapid Upper Limb Assessment (RULA) stands as one of the most widely adopted observational methods for evaluating working postures and their associated risks of MSDs in industrial settings. This preliminary study aims at designing and validating a novel tool capable of preventing incongruous postures among workers. The methodology leverages a wrist-worn sensor, facilitating the continuous monitoring of incongruous postures adopted by workers. The data collected through this sensor-based approach are subsequently evaluated using the RULA method. The findings from the RULA assessment highlights incongruous postures dominant among computer operators and individuals working in both the service and industrial sectors.

Introduction

Occupational hazards that may lead to musculoskeletal disorders (MSDs) are a significant concern for technical operators in the service and production sectors. In Italy, protective measures for workers exposed to manual handling of loads and awkward postures primarily involve health surveillance protocols. These measures are tied closely to the nature of the work, which frequently requires employees to maintain obligatory postures for long time intervals, resulting in biomechanical stress on the musculoskeletal system and increasing the risk of symptoms manifesting in various anatomical districts. MSDs involve injuries affecting muscles, tendons, ligaments, and nerves. They are sometimes referred to as Repetitive Strain Injuries (RSI), Cumulative Trauma Disorders (CTD), or Repetitive Motion Injuries (RMI). MSDs develop as a consequence of repetitive, forceful, or awkward movements that exert strain on joints, ligaments, and other soft tissues. Specific MSD injuries include Low Back Strain, Neck Strain, Tendonitis, Carpal Tunnel Syndrome (CTS), Rotator Cuff Syndrome, and Tennis Elbow.

In recent years, there has been a growing effort to study and mitigate MSDs. These disorders pose significant challenges for modern industrialized countries, impacting not only short-term outcomes such as cost reduction and productivity enhancement, but also long-term benefits, including improved employee motivation, reduced staff turnover, decreased sick leave, and lower insurance costs. Recent studies have explored uncomfortable working postures using various methods. Literature has documented several risk assessment methodologies, including Ocra, Reba, Rula, Niosh, and Mapo. Among these approaches, the RULA (Rapid Upper Limb Assessment) method stands out for its ability to swiftly analyze hand-arm movements and assess ergonomic risks.

RULA was developed to provide a rapid evaluation of individual workers' exposure to ergonomic risk factors associated with upper extremity MSDs. This ergonomic assessment tool takes into account the biomechanical and postural demands placed on the neck, trunk, and upper limbs by job tasks. RULA employs a systematic process to assess the required body posture, force exertion, and repetition associated with the task being evaluated. A single-page worksheet is used to evaluate body posture, muscle use frequency, and forceful exertions. Existing methodologies primarily rely on checklists and the analysis of short work activity videos or images. Currently, there is a lack of methods that enable continuous posture monitoring tailored to individual workers, based on their job requirements and anthropometric characteristics. The primary objective of this study is to design and test a tool capable of consistently monitoring and preventing incongruous worker postures, addressing this notable gap in current occupational health and safety practices.

Material and Methods

The study was organized into three phases:

1. Planning and Design of the Survey: This phase involved the creation of specific data acquisition codes and the design of the survey instrument.
2. Harmonization of the Instrument at Upper Limb Limit Angles: In this stage, efforts were spent in synchronizing the instrument with the upper limb's limit angles.
3. Testing: the study run specific tests on a homogeneous group of workers to demonstrate the working assumptions.

The first part of the experimentation identified the instrument taken as the reliable sensor for the assessment of incongruous arm and hand postures. The instrument has 3-axis accelerometers and gyroscope, and it can monitor the positions on the XYZ axis, allowing the analysis of wrist rotation and wrist bending (Pich and Roll).

ESP32 240MHz dual core, 600 DMIPS, 520KB SRAM, Wi-Fi
Flash Memory: 4MB
Alimentazione: 5V @ 500mA
LCD: 0.96" , 80*160 TFT LCD, ST7735S
Accelerometer: MEMS MPU6886
MIC SPM1423
RTC BM8563
PMU AXP192

Figure 1. The instrument used and specific characteristics.

The speed of data acquisition was adjusted according to the advancement of the experiment. In the first phase, 7-8 data acquisitions were performed per second. In the last test phase, one acquisition is made per second. The number of specialized workers subject of our study was 30 individuals. The subjects worked for service companies with the qualification of video terminal workers or functions for the use of computers or IT tools (tablets, push-button panels, smartphones). In the second part of the experiment, the data analysis method was developed. The limit angles for the wrist, hand and arm deriving from the RULA method were evaluated, as shown in Figure 2.

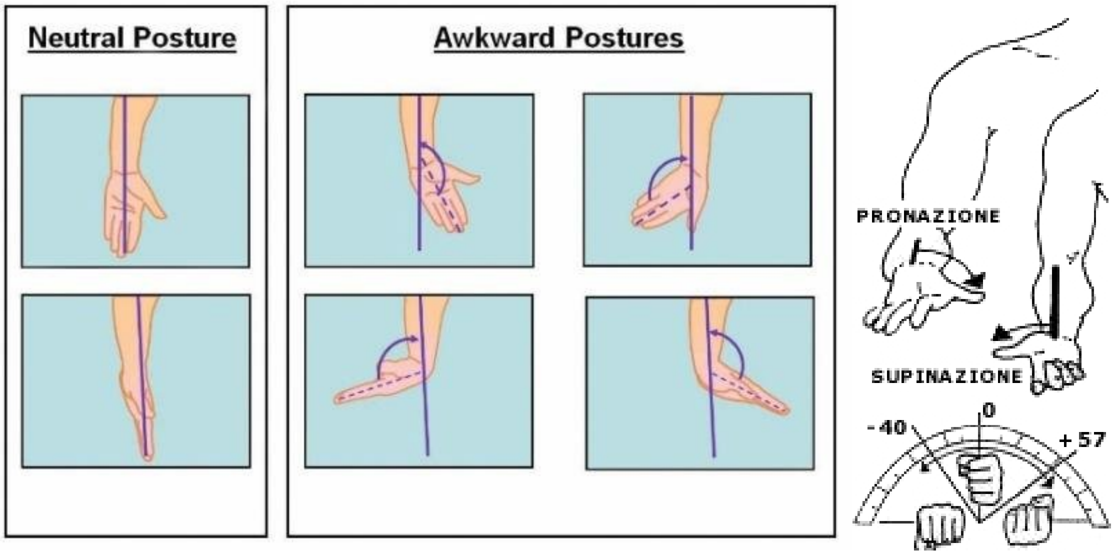

Figure 2. Graphical examples of position and limit angles of the upper limbs, hand arm wrist.

The limit angles have been applied to office workers and workers who use computers or other data entry and computation systems as shown in Figure 3.

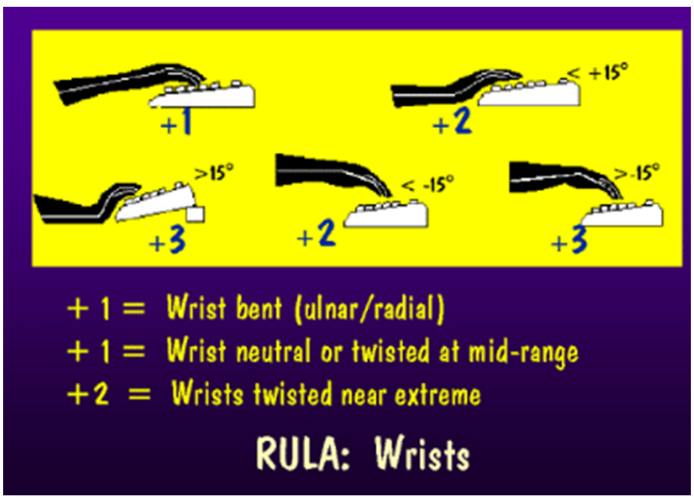

Figure 3. A graphical illustration of the limit angle in office work.

The tool was configured and applied to early testers. This experimental phase made it possible to:

- define the correct position on the operator's wrist.
- define and detect the limit angles.
- correlate and verify automatic measurements to test measurements.
- define three levels of risk (described later in this section).

Three levels of risk deriving from the average of the samplings carried out have been defined:

- **low level:** the operator does not assume awkward postures for a long time, there is no anomalous behavior that could cause occupational diseases. They are represented by the green color; the level corresponds to a low and acceptable risk.
- **medium level**: it is necessary to carefully monitor the worker, some inappropriate postures are detected which could generate occupational diseases in the future. This level is represented by the yellow threshold and represents moderate risk.
- **high level**: there is an incorrect working condition. The worker assumes incongruous, prolonged positions. The risk level is represented by the red color and corresponds to a high, unacceptable risk level which produces occupational disease.

In the second phase the correctness of the measurements was verified. Tests were carried out (100 tests for 3 repetitions). The tests correlated the detector data (angle) with the data measured manually by an operator with a goniometer and analysis plan (Figure 4).

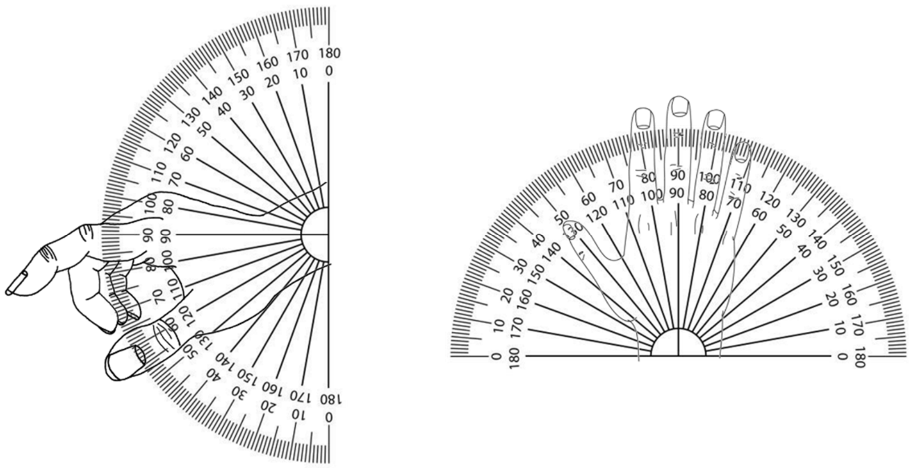

Figure 4. Analysis table for the validation of the measures.

Results

The experimentation was carried out on 7 production and service companies for a total of 100 operators selected out of a sample of 200 operators to whom the sensor was applied. The first result obtained, which can be seen in Table 1, is the definition of the limit angles for different types of tasks.

Table 1. Example of values tested on x-axis and on roll

employed	
Roll	x
40	-45
16,5	-20
12,5	-15
12,5	15
-16,5	20
-40	45

The average sampling duration was two hours. The sensor battery lasts for 8 hours, however, the average operators used the sensor for a two hour work cycle (Figure 5).

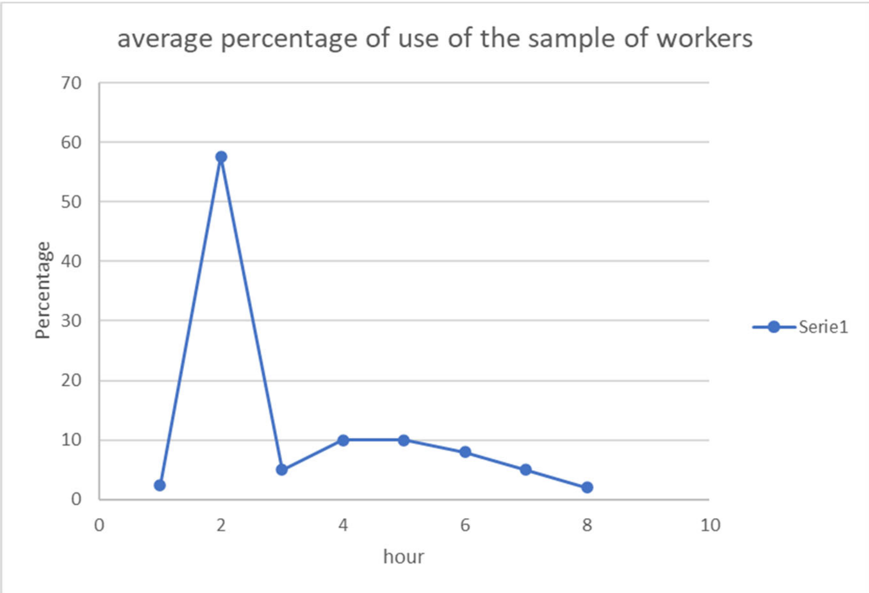

Figure 5. Average percentage of use of the sample of workers.

The reason for limiting sensor usage to only two hours is connected to its current lack of ergonomic features, making it uncomfortable for eight-hour work shifts. The most significant finding was the absence of a significant difference among operators based on gender or age. It is important to note that the sensor was designed for left-handed use, but due to the limited number of left-handed individuals available for statistically valid tests, all operators in our study were right-handed. Figure 6 presents the average results observed during the four-month observation period.

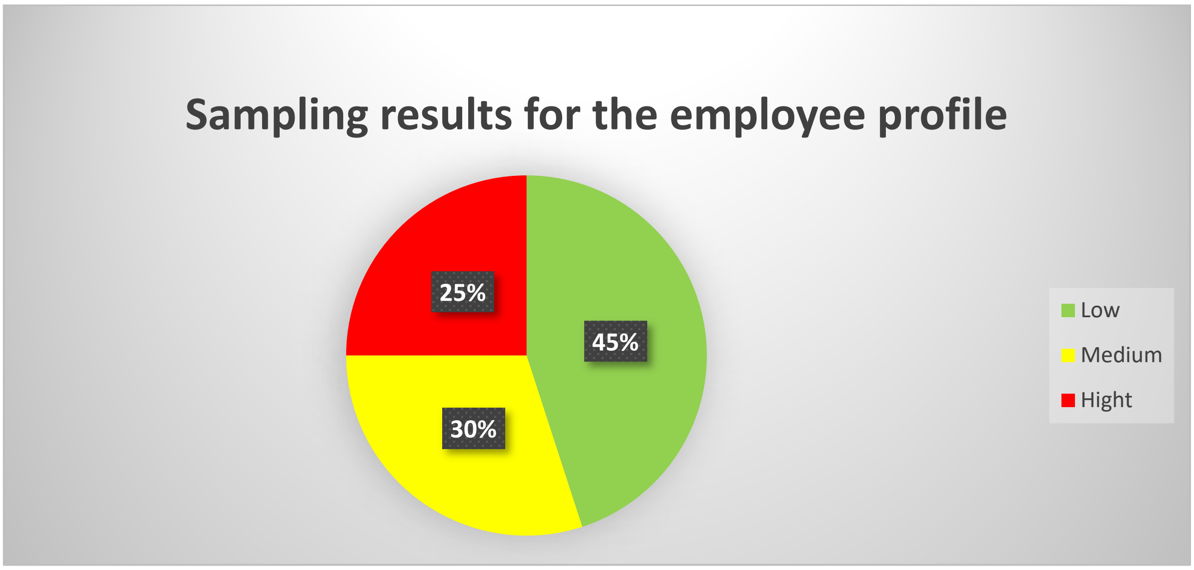

Figure 6. The per cent distribution of the results.

A high percentage of workers operate through incorrect postures (25%) for almost all the sampling. From an preliminary analysis (Figure 7), it is possible to associate the incorrect positions with the final part of the working day.

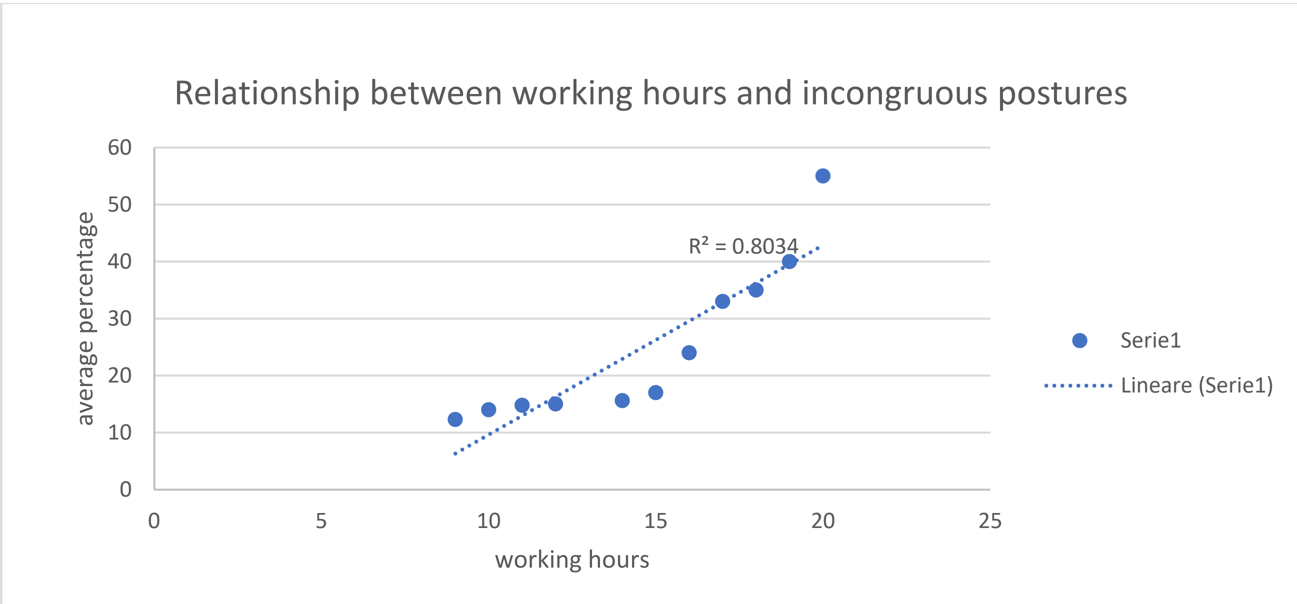

Figure 7. The relationship between working hours and incongruous postures.

The analysis demonstrates that a precise and real-time detection of job positions represents a widespread and little-evaluated problem. The standard methods are very often subjective and represent only a small part of the work activity during the observation.

Concluding remarks

This work is the starting point for a comprehensive analysis of the incongruous postures during working time. Currently, the routine instruments can only monitor the sensorized limb. Improvements in the ergonomics of the instrument should be introduced. The next experimental stage will involve the integration of an alarm signal to alert operators, thereby reducing their exposure time to the risk of occupational diseases. The statistical basis of this study was limited to workers who use keyboards, tablets, smartphones. Expanding the statistical universe of respondents could encompass individuals whose job involves more extensive use of their hands and upper limbs, such as warehouse or production line workers. Additionally, exploring other analytical methods, such as the Ocra index or the Reba method, remains a key opportunity for further studies.

References

Working at height. International Labor Organization, https:// www.ilo.org/global/topics/labour-administration-inspection/resources-library/publications/guide-for-labour-inspec tors/working-at-height/lang--en/index.htm (2023, accessed 9 December 2022).

LEGISLATIVE DECREE No. 81 dated 9 April 2008, Implementation of Article 1 of Law No. 123 of 3 August 2007, regarding the protection of health and safety in the work place. (OJ General Series no. 101 of 30-04-2008 - Ordinary Suppl. no. 108).

DECREE OF THE PRESIDENT OF THE REPUBLIC of 14 September 2011, no. 177, Regulation containing rules for the qualification of companies and self-employed workers operating in environments suspected of pollution or border ing on pollution, pursuant to Article 6, paragraph 8, letter g) of Legislative Decree no. 81 of 9 April 2008. (11G0219) (Official Gazette General Series n.260 of 08-11- 2011).

Grieco A, Occhipinti E, Colombini D, et al. Manual handling of loads: the point of view of experts involved in the appli cation of EC Directive 90/269. Ergonomics 1997; 40(10): 1035–1056.

Work-related musculoskeletal disorders & ergonomics. Centers for Disease Control and Prevention, https://www.cdc.gov/workplacehealthpromotion/health-strategies/musculoskeletal-disorders/index (2020, accessed 15 December 2022).

Hagberg M, Violante F. Current issues in case definitions for common musculoskeletal disorders in workers for clini cal practice and research. Med Lav 2007; 98: 89–93.

Italian Society of Occupational Medicine and Industrial Hygiene and Daniela Colombini. Linee Guida Per La Prevenzione Dei Disturbi E Delle Patologie Muscolo Scheletriche Del Rachide Da Movimentazione Manuale Di Carichi. Pavia: PI-ME, 2004.

Borg G. Psychophysical scaling with applications in physical work and the perception of exertion. Scand J Work Environ Health 1990; 16(Suppl 1): 55–58.

Zhao H, Nishioka T, Okada J. Validity of using perceived exertion to assess muscle fatigue during resistance exercises. PeerJ 2022; 10: e13019.

Jakobsen MD, Sundstrup E, Persson R, et al. Is Borg’s per ceived exertion scale a useful indicator of muscular and car diovascular load in blue-collar workers with lifting tasks? A cross-sectional workplace study. Eur J Appl Physiol 2014; 114(2): 425–434.

Romano C, Baracco A, Coggiola M, et al. Simplified method for identifying the risk of biomechanical overload. G Ital Med Lav Ergon 2005; 27: 346–350.

Nappi F, Caselli U, Rughi D, et al. Repeated movements of the upper limbs: the OCRA protocol. Roma: INAIL, 2017.

Ergonomics Programme. Occupational Safety and Health Administration, https://www.osha.gov/laws-regs/federalreg ister/1999-11-23 (1999, accessed 11 November 2022)

NIOSH Manual of Analytical Methods (NMAM) 5th Edition. Centers for Disease Control and Prevention, https:// www.cdc.gov/niosh/nmam/default.html (2014, accessed 25 November 2022)

Sauter M, Barthelme J, Müller C, et al. Manual handling of heavy loads and low back pain among different occupational groups: results of the 2018 BIBB/BAuA employment survey. BMC Musculoskelet Disord 2021; 22(1): 956.

Waxenbaum JA, Reddy V, Futterman B. Anatomy, back, intervertebral discs. Treasure Island, FL: StatPearls Publishing, 2022. https://www.ncbi.nlm.nih.gov/books/ NBK470583/

Terracchio A, Lecca L, Zerbo S, et al. Work activities at increased risk of traumatic injuries: an integrated preventive approach. EMBJ 2022; 17(30): 140–147.

Reddy GMM, Nisha B, Prabhushankar TG, et al. Musculoskeletal morbidity among construction workers: A cross-sectional community-based study. Indian J Occup Environ Med 2016; 20(3): 144–149.

Umer W, Antwi-Afari MF, Li H, et al. The prevalence of musculoskeletal symptoms in the construction industry: a systematic review and meta-analysis. Int Arch Occup Environ Health 2018; 91(2): 125–144.

E-fact 44 - Checklist for the prevention of manual handling risks. European Agency for Safety and Health at Work, https:// osha.europa.eu/en/publications/e-fact-44-checklist-prevention manual-handling-risks (2008, accessed October 2023).