METHOD FOR STRESS DETECTION IN INDUSTRIAL ASSEMBLERS USING SMARTWATCH SENSORS

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ABSTRACT

Goal: The purpose of this study is to present a method to quantitatively identify the levels of stress of employees during work using the technology of smart watches with sensors measuring vital signs and, from this data, deepen the discussion on the relationships between the levels of physical and cognitive complexity of the activities and their influence on the stress resulting from these works.

Theoretical reference: Use of literature through research on similar methods already applied in immersive training, dissertations, articles, and national standards. For this purpose, the Systematic Bibliographic Review (SBR) was used, which is “a scientific method for searching and analyzing articles in a given area of science”.

Method: To achieve the objectives proposed in this work, a methodology with ten steps was developed. Four different workstations of an optical connector assembly company were selected to assess the stress levels of assemblers, using smart watch sensors, during their work activities. The workstations were evaluated for their physical load, through ergonomic analysis and for their cognitive load, through mental load classification. All data were statistically correlated.

Results and conclusion: Based on the statistical analysis of the data, it can be seen that the higher the level of complexity, the higher the average levels of stress presented. There is a direct influence on the level of stress and activities with greater complexity and related to physical (ergonomic) demands. The level of demand for carrying out activities, motivated by skills, rules and knowledge, mainly because they are related to decision-making, is related to the stress levels of employees, and can thus directly affect their mental health.

Research implications: Through the results presented, we realized that reducing the demands of decision and reasoning during the activities requested at work, the company will be able to promote a reduction of the possible levels of stress of its employees, if this action does not impact on the reduction of their motivation for work.

Originality/value: The method presented in this article differs from the others by comparing the different physical and mental demands with the stress levels measured with the use of smart watches during the activities of assembly line workers. It can be used to evaluate the effectiveness of an activity alternation approach, such as rotation, which can have a positive impact not only to minimize physical overloads but also to reduce levels of mental stress at work.

Keywords: Mental Workload, Ergonomics, Activity Complexity, Stress Level.

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MÉTODO DE DETECÇÃO DE TENSÕES EM MONTADORES INDUSTRIAIS QUE UTILIZAM SENSORES DE RELÓGIOS INTELIGENTES

RESUMO

Objetivo: O objetivo deste estudo é apresentar um método para identificar quantitativamente os níveis de estresse dos funcionários durante o trabalho usando a tecnologia de relógios inteligentes com sensores que medem sinais vitais e, a partir desses dados, aprofundar a discussão sobre as relações entre os níveis de complexidade física e cognitiva das atividades e sua influência no estresse resultante desses trabalhos.

Referência teórica: Uso da literatura através de pesquisa sobre métodos similares já aplicados em treinamento imersivo, dissertações, artigos e normas nacionais. Para isso, foi utilizada a Revisão Bibliográfica Sistemática (SBR), que é "um método científico para buscar e analisar artigos em uma determinada área da ciência".

Método: Para atingir os objetivos propostos neste trabalho, foi desenvolvida uma metodologia com dez etapas. Quatro diferentes estações de trabalho de uma empresa de montagem de conectores ópticos foram selecionadas para avaliar os níveis de tensão dos montadores, usando sensores de relógio inteligente, durante suas atividades de trabalho. As estações de trabalho foram avaliadas pela carga física, pela análise ergonômica e pela carga cognitiva, pela classificação de carga mental. Todos os dados foram correlacionados estatisticamente.

Resultados e conclusão: Com base na análise estatística dos dados, observa-se que quanto maior o nível de complexidade, maiores são os níveis médios de estresse apresentados. Há uma influência direta no nível de estresse e atividades com maior complexidade e relacionadas a demandas físicas (ergonômicas). O nível de procura para a realização de atividades, motivadas por competências, regras e conhecimentos, principalmente porque estão relacionadas com a tomada de decisões, está relacionado com os níveis de stress dos trabalhadores, podendo assim afetar diretamente a sua saúde mental.

Implicações da pesquisa: Com os resultados apresentados, percebemos que reduzindo as demandas de decisão e raciocínio durante as atividades solicitadas no trabalho, a empresa poderá promover a redução dos possíveis níveis de estresse de seus funcionários, se essa ação não impactar na redução de sua motivação para o trabalho.

Originalidade/valor: O método apresentado neste artigo difere dos demais ao comparar as diferentes demandas físicas e mentais com os níveis de estresse medidos com o uso de relógios inteligentes durante as atividades dos trabalhadores da linha de montagem. Pode ser usado para avaliar a eficácia de uma abordagem de alternância de atividade, como a rotação, que pode ter um impacto positivo não só para minimizar as sobrecargas físicas, mas também para reduzir os níveis de estresse mental no trabalho.

Palavras-chave: Carga de Trabalho Mental, Ergonomia, Complexidade de Atividade, Nível de Estresse.

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1 INTRODUCTION

According to Buzogi and Kim [1], the increase in mass customization in assembly processes has led to work with a higher level of complexity of activities. Where previously assembly line workers needed to routinely assemble and repeat products that were considered homogeneous, that is, with almost no variation, it is now observed that the so-called mixed model assembly has increased proportionally due to the greater demand for heterogeneous products, with a greater number of variables.

As consequence, the mental aspects of assembly work gained importance due to greater diversification in production lines with greater choice density during the assembly process. The overall complexity of a given assembly work process results from the sum of choices to be made at all stages over a limited time.
Each choice is based on an episode of information processing, including aspects of attention, interference control, inhibition, and behavioral execution. The more information contained in an assembly system, the greater the cognitive activity required to deal with the worker's uncertainty associated with each choice during task execution. The complexity of choosing the operator is defined in the average uncertainty or randomness (of the product). In an assembly line with different product variants, behavioral choices and adaptations are required over a given period, thus leading to a greater mental workload. [2]

There is a possibility that the increase in mental demand is related to the increase in levels of stress at work, triggering an increase in occupational diseases with an emotional background, such as Professional Exhaustion Syndrome (PES), also known as Burnout Syndrome. The World Health Organization (WHO) released a survey that almost 1 billion people lived, in 2019, with some kind of mental disorder and that one in five individuals had some level of mental health problem. Research has also shown that syndromes related to increased stress at work, such as PES, have increased significantly. [3]

Several factors may be contributing to the increase in stress levels resulting from activities carried out during work. One of the factors studied is related to the increase in mass customization in assembly processes, which leads to work that generally presents a higher level of complexity. [4]

Cognitive psychology studies the choice behavior of human beings and their emotional characteristics with the aim of understanding and helping people. There are some correlations with reaction time studies for a given stimulus. As shown in empirical studies, response times to a stimulus increase with an increasing number of stimuli or response alternatives considered. The greater the number of options to choose from, the more alternatives must be considered. The greater the complexity, the more time is needed to complete the task correctly. [5]

Further confirmation comes from perception research. Using eye tracking to gain insight into gaze behavior (fixations and registration) it is possible to make assumptions about the perceptual and cognitive basis of choice processes. With the increasing complexity of tasks and an increasing number of choices, there is a need for repeated and longer memorization of instructions. Through these longer and repeated memorization processes, informational noise is reduced, stress on working memory is relieved, and new resources are made available. [1]

Both lines of research show that the structure and number of cognitive processes are determined by the interaction of task resources, operator resources and working conditions.

The main objective of this work is to propose a method, which using data monitoring technology tracked by smart watches (smartwatches), made it possible to correlate the levels of mental stress (mental overload) of workers on assembly lines with levels of complexity of the tasks performed.

To achieve the objectives of the work, the following specifics are being proposed:

• Proposal of a method for assessing stress at work.
• Determining the levels of complexity of activities at jobs on an assembly line.
• Measure the Stress Levels of employees in different positions during a working day.
• Method evaluation correlating results obtained with gold standard mental load assessment (NASA TLX Questionnaire and SWAT Matrix).

2 METHODS

For this work, necessary actions were proposed so that all information relevant to working conditions was considered. (Figure 1)
Method for Stress Detection in Industrial Assemblers Using Smartwatch Sensors

Initial research through the methodology of Systematic Bibliographic Review (SBR) was used to observe publications related to the theme of this work.

The following keywords were used: occupational stress and mental load, to start the search on the Scopus Platform and 309 publications were found. By applying the filters: open access, limiting publications from 2018 to 2023 and only articles completed in English; 44 eligible articles were obtained.

Next, a search was carried out with the keywords: complexity of activities, also on the Scopus Platform where 66,161 references were found. By applying the filters: open access, limiting publications from 2018 to 2023 and only articles completed in English; 8,487 eligible articles were obtained.

A new search was carried out with the keywords complexity of activities and smart watches, 14 articles were found; of these, only 7 articles related stress monitoring in different occupational areas.

Figure 1 - Methodological Approach
Source: Prepared by the authors (2023)
Research by evaluating levels of stress at work pointed to qualitative methodologies using questionnaires such as the NASA Task Load Index and the SWAT Matrix for mental load assessment through a Likert scale. Both are considered the gold standard in assessing stress at work.

Only 7 articles using work-related stress monitoring by smart watch sensors were found. As these sensors and the algorithms used to quantify the stress level are relatively recent technologies, there is a great opportunity for scientific projects to attest to the effectiveness of these equipment, including correlating them with the qualitative methodologies mentioned above.

The bibliographic review showed that there are still few works related to the subject. The opportunity to quickly monitor stress in the work environment can bring many benefits in strategies to improve working conditions. Thus, it was decided to use the smart watch as an analysis tool in this research.

As the object of this research was to survey levels of stress and mental load in the work environment; the authorization and collaboration of a company, manufacturer of optical connectors, was necessary, which allowed the voluntary collection of data from employees.

All confidentiality and image preservation requirements that could contravene the rules of the General Law for the Protection of Personal Data (LPPD) and the company's Compliance program were complied with and observed.

All the movements and activities carried out in each workstation of a connector assembly line were described using the MTM methodology [8], as well as the pre-definition of the times that each movement should take for a person considered to be averagely trained to perform them.

Based on process time data obtained in the previous step using the MTM methodology, the workstations then underwent a detailed ergonomic assessment using the Ergonomics Assembly Work-sheet method (EAWS) [9].

The MTM TiCon4® software was used to observe the ergonomic score of each station. The results found in a quantitative way can be considered as the physical load to which the employee is exposed during the period of work in each position.

In this stage of the work, each of the described activities carried out within a cycle was scored based on the Rasmussen model [10].

The table below (Table 1) shows the degrees of complexity were scored based on the type of requirement of the activity, observing the behaviors to be carried out according to:

- **Skill**, which would be the level of muscle control used to perform the activity. It's basically an automatic reproduction of the gestures in the operations system.
- **Rule**, which would be the first level of conscious control of the procedure. The collaborator uses rules, adopts procedures, observes the signs, and correlates with an already stipulated standard.
- **Knowledge** would be the most complex level of conscious control, in which the employee adopts strategies for solving problems based on previously acquired mental models.

<table>
<thead>
<tr>
<th>TYPE OF ACTIVITY</th>
<th>COMPLEXITY REQUIREMENT</th>
<th>ACTIVITY SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKILLS</td>
<td>MUSCLE CONTROL</td>
<td>1</td>
</tr>
<tr>
<td>RULES</td>
<td>PROCEDURES</td>
<td>2</td>
</tr>
<tr>
<td>KNOWLEDGE</td>
<td>DECISIONS</td>
<td>3</td>
</tr>
</tbody>
</table>

*Source: Prepared by the authors (2023)*
The scoring method was based on the work model published by Martins and Meja [11] stipulating points for each type of behavior observed in the activity.

In this stage of the work, the 4 (four) workstations were selected that presented different levels of complexity according to the model described by Rasmussen and of ergonomic risk evaluated by the EAWS method [8] based on the movements described through the MTM time analysis methodology according to table below (Table 2).

Aiming to observe if there really is an increase in the mental load as the levels of complexity of the activities increase; the selected stations had complexity scores with greater variation (from 3 to 21 points). Based on the score obtained, two of the selected stations were of low complexity (named as: SIMPLE), one of them considered medium complexity (named SEMI-COMPLEX) and one of high complexity (named as COMPLEX).

Table 2 - Data from Workstations Where Collections Were Carried Out

<table>
<thead>
<tr>
<th>WORKSTATION</th>
<th>LEVEL OF COMPLEXITY</th>
<th>COMPLEXITY CLASSIFICATION</th>
<th>SWAT RESULT</th>
<th>NASA RESULT</th>
<th>STRESS AVERAGE [SMARTWATCH]</th>
<th>ERGONOMIC SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Take the cable from the box</td>
<td>3</td>
<td>SIMPLE</td>
<td>11,99</td>
<td>15,25</td>
<td>48,75</td>
<td>42</td>
</tr>
<tr>
<td>2 - Insertion</td>
<td>9</td>
<td>SIMPLE</td>
<td>15,83</td>
<td>14,68</td>
<td>45,60</td>
<td>22</td>
</tr>
<tr>
<td>3 - Polishing</td>
<td>23</td>
<td>COMPLEX</td>
<td>15,75</td>
<td>15,86</td>
<td>52,18</td>
<td>15,7</td>
</tr>
<tr>
<td>4 - Optical Test</td>
<td>17</td>
<td>SEMI-COMPLEX</td>
<td>16,08</td>
<td>16,90</td>
<td>58,7</td>
<td>27,5</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2023)

To correlate the physical load with the mental load of a workstation, workstations with different levels of ergonomic risk determined by the score obtained in the ergonomics evaluation with the EAWS method were selected.

The selected stations had the following characteristics:

- WORKSTATION 1 – Take the Cable from the Box
  - The first job selected (Figure 2) performs the activity called Take the Cable from the Box and has the lowest level of complexity among the activities, considered SIMPLE.
  - It has an EAWS ergonomic evaluation score of 42 points, which is considered moderate, as it is necessary to move different loads and some postures with spine flexion.
  - The employee works standing up moving loads ranging from 0,500 kg to 5.6 kg.
  - The work cycle is short, with a certain repeatability of the movements.

Figure 2 – First Workstation - Take the cable from the box
Source: Prepared by the authors (2023)
• WORKSTATION 2 – Insertion

The second selected workstation (Figure 3) performs the activity called Insertion, where the optical fiber is inserted into the ferrule (internal part of the connector). This activity has a low level of complexity, it is also considered SIMPLE.

It features a 22-point EAWS ergonomic assessment score, considered to be in excellent ergonomic condition. The employee works sitting down during the entire process and only performs movements without the use of manual force.

There is no cargo movement in this activity. The cycle time is longer than the previous post and there is a certain repeatability of the movements.

![Figure 3 – Second Workstation - Insertion](image)

*Source:* Prepared by the authors (2023)

• STATION 3 – Polishing

The third selected station (Figure 4) performs the activity called Polishing, in which the employee performs a series of procedures with a piece of equipment called a Polisher, with the objective of fine finishing the optical fiber of the connector.

This activity is considered COMPLEX, due to the need to know the different stages of the process, meeting quality standards and technical specifications. To perform a complete cycle, the employee takes approximately 9 minutes, with a cycle considered long (542.2 seconds).

It has an EAWS ergonomic evaluation score of 15.7 points, considered good ergonomic condition. The employee works standing up during the entire process and only performs movements without the use of manual force and with some small shifts during the activity.
• STATION 4 – Optical Test

In the fourth selected workstation (Figure 5) the employee performs the activity called Optical Test, which consists of using a test equipment in which the conductivity parameters of the optical fiber are tested.

This activity is considered SEMI-COMPLEX because a higher level of knowledge of the acquired process is required so that some decisions are taken with assertiveness.

It has an EAWS ergonomic evaluation score of 27.5 points, considered good ergonomic condition. The employee works standing up throughout the process and performs movements with some use of manual force to move the cables.
2.1 Apply Mental Load Assessment (NASA and SWAT) in Selected Workstations

In this stage of the work, two questionnaires were applied to the operators of the selected stations to assess mental load, considered the gold standard: the NASA TLX Questionnaire - Task Load Index [6] and the SWAT Matrix - Subjective Workload Assessment Technique [7].

In the NASA questionnaire [6], collaborators indicate the “weight” that certain subjects have in relation to mental load, such as: Mental Demand, Physical Demand, Time Demand, Performance, Effort and Frustration.

In the assessment by the SWAT Matrix [7], the employee points out factors such as Cognitive Demands and Task Complexity, Health Consequences, Task Characteristics, Temporal Organization and Work Pace. The following results were obtained at each workstation:

- **STATION 1** – Take the cable from the box.
  When applying the mental load SWAT matrix, the post reached a score of 11.99 with the employee's perception that the factors; consequences for health and pace of work, are the ones that most interfere with their mental load during the activity. This was the lowest result found among the 4 stations evaluated.
  Using the NASA Mental Load Assessment, a weighted rating of 16.26 points was obtained. With the classification of the employee with the greatest influence on this result, the physical demand and in second, frustration, associated with the low requirement of knowledge to perform the activity. Contrary to the result of the evaluation by the SWAT Matrix, the NASA result found here was the second highest among the evaluated stations.

- **STATION 2** – Insertion.
  When applying the mental load SWAT matrix, the post reached a score of 15.83 with the employee's perception that the factors; temporal organization and cognitive demands and complexity of the tasks are the ones that most interfere with their mental load during the activity. This was the second highest value found in jobs evaluated by this method.
  Using the NASA Mental Load Assessment, a weighted rating of 14.86 points was obtained. With the classification of the employee with the greatest influence on this result, first was performance and second was mental demand, associated with the concentration required to perform the activity. It was the lowest value found among the evaluated stations, suggesting less stress.

- **STATION 3** – Polishing.
  When applying the mental load SWAT matrix, the post reached a score of 15.76 with the employee's perception that the factors; temporal organization, work pace and task characteristics are the ones that most interfere with their mental load during the activity.
  Using the NASA Mental Load Assessment, a weighted rating of 15.86 points was obtained. With the classification of the collaborator with the greatest influence on this result, the mental demand and in second place the demand for time, required to perform the activity.

- **STATION 4** – Optical Test.
  When applying the mental load SWAT matrix, the post reached a score of 16.08 with the employee's perception that the factors; cognitive demands and complexity of the tasks, and consequences for health, are the ones that most interfere with their mental load during the activity.
  Using the NASA Mental Load Assessment, a weighted rating of 16.93 points was obtained. With the classification of the employee with the greatest influence on this result, the mental demand and secondly the demand for time, required to perform the activity.

The results found in this post were the highest among all evaluated in both methods, suggesting agreement here.
2.2 Gathering Data at Workstations

In the data collection stage, the collaborators received information about the purpose and importance of the study and were invited to participate voluntarily. Each participant informed the number of their CPF (Brazilian Individual Taxpayer Registration Number) and signed next to the collected data proving the verification of the information.

To reduce the noise in relation to the reliability of the data and as most of the employees of this company are women, the evaluation was exclusively female.

Collaborators who intentionally agreed to participate in the research were approached during their work activities when asked how long they had been performing that activity; only collaborators who were at least thirty minutes in the activity were evaluated. This followed by a minimum time at the workstation was defined so that the effects of activities (physical or mental) on the employee could be really perceived.

Currently, there is a wide range of smart watches on the market that monitor stress through heart rate sensors that use an algorithm to estimate the level of stress through the difference in the data collected over a given period. Some devices report greater reliability in the data monitored through more accurate sensors.

Some devices implement stress measurement through electrodermal sensors, which detect small electrical changes in the skin. By monitoring cortisol levels, which is a hormone associated with concentration problems, insomnia, and heart disease, according to the manufacturers, these devices are even capable of predicting stress up to an hour in advance.

For this work, the selected device was the Amazfit® smart watch, model GTR 3 Pro (figures 6 and 7), which is the third generation of the equipment and presents improvements in the sensor system, suggesting greater accuracy in data collection. This equipment was also selected because it presents a lower cost-effectiveness compared to other equipment offered on the market with the same type of technology.

The employees were then asked to “wear” the stress level measurement device with data sensors they resisted, where the following factors were observed:

- Heart Rate (HR)
- Stress Level
- Blood Oxygen (Saturation - SpO2)
- Breath Rate

![Figure 6 – Used Smartwatch (Amazfit GTR 3 Pro)](source: Prepared by the authors (2023))
Following the manufacturer's instructions, the smart watch (https://www.amazfit.com/br/gtr3-pro) was “dressed” on the employee at the width of a finger from the wrist and tightened as tightly as possible. The employee was then asked to keep the arm immobile for 45 seconds, the time necessary for the 4-health information to be recorded (HR, Stress Level, SpO2 and Breathing Rate).

According to the manufacturer of the smart watch, the stress level is calculated based on heart rate variability (hvd) using an algorithm and has the following classification of results (Table 3):

<table>
<thead>
<tr>
<th>STRESS LEVEL CRITERIA</th>
<th>RELAXED</th>
<th>NORMAL</th>
<th>MIDDLE</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40 - 59</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 - 79</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80 - 100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A total of 160 measurements were carried out, 40 in each of the selected workstations. Measurements were carried out at different times and shifts over several days to achieve greater diversification of employees.

The collaborators were also asked whether they were in their premenstrual period, as this factor could have some influence on the level of stress found. The statistical correlation of the evaluated data does not demonstrate significance in relation to this specific factor and for this reason it was not further approached in this work.

The following results were obtained at each workstation (Table 4):

- **STATION 1** – Take the cable from the box.
  - The average score measured by stress monitoring through smart watch sensors was 48.75 points, considered within the normal range according to the scale provided by the manufacturer. The mean heart rate was 85.93 bpm (beats per minute).
- **STATION 2** – Insertion.
  - The average score measured by stress monitoring through smart watch sensors was 45.6 points, considered within the normal range according to the scale provided by the manufacturer. The mean heart rate was 80.9 bpm (beats per minute).
• STATION 3 – Polishing.
  The average score measured by stress monitoring through smart watch sensors was 53.7 points, considered within the normal range according to the scale provided by the manufacturer. The mean heart rate was 84.1 bpm (beats per minute).

• STATION 4 – Optical Test.
  The average score measured by stress monitoring through smart watch sensors was 52.18 points, considered within the normal range according to the scale provided by the manufacturer. The mean heart rate was 85.60 bpm (beats per minute).

<table>
<thead>
<tr>
<th>WORSTATION</th>
<th>STRESS AVERAGE (SMARTWATCH)</th>
<th>AVERAGE HEART RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Take the cable from the box</td>
<td>48.75</td>
<td>85.9</td>
</tr>
<tr>
<td>2 - Insertion</td>
<td>45.60</td>
<td>80.9</td>
</tr>
<tr>
<td>3 - Polishing</td>
<td>52.18</td>
<td>84.1</td>
</tr>
<tr>
<td>4 - Optical Test</td>
<td>53.7</td>
<td>85.6</td>
</tr>
</tbody>
</table>

**Table 4** – Stress Average x Average Heart Rate
**Source:** Prepared by the authors (2023)

### 2.3 Data Stratification and Statistical Correlations

At this stage of the research work, the data were stratified into four spreadsheets differentiating each of the stations analyzed and submitted to statistical analysis using the Minitab Statistic® software for data correlation.

The results of the statistical analysis of the data collected by the stress level monitor used in this research showed, according to the probability graph (Graph 1), that there is a significant difference in the levels of stress collected in each job.

The higher the level of complexity of a job, that is, of mental demand, classified as Simple, Semi-Complex and Complex, the higher the level of stress measured.

**Graph 1** – Probability of Stress Levels by Workstations
**Source:** Prepared by the authors (2023)

Analyzing the stress data in the probability graph, in the stations considered of low complexity, classified as "Simple" such as the "Remove cable from the Box" and "Insertion" stations, the level of stress in the activity performed sitting (Insertion), with less physical
demand, presented lower stress levels than the activity performed standing and with greater ergonomic demand.

It is noticed that the stress averages increase in relation to the “Optical Test” and “Polishing” stations, which present a higher level of complexity. (Graph 2)

![Graph 2](image)

**Graph 2** – Stress Values by Workstations

**Source:** Prepared by the authors (2023)

The difference obtained from the average stress levels found, between the more complex jobs, in this case the job called “Optical Test” and the less complex one “Getting the Cable from the Box” was 10%. The difference in relation to the second rank considered less complex, the “Insertion” rank, was 15%. This trend presented in the data demonstrates that the mental demand of an activity may be related to the level of stress presented by the operators. (Graph 3)

Correlations of Oxygen Saturation and Respiration Rate data did not obtain significant data in comparison between the evaluated jobs.

![Graph 3](image)

**Graph 3** – Probability Graph of Heart Rate Levels by Workstation

**Source:** Prepared by the authors (2023)
As the evaluated population was exclusively female, the hypothesis arose that the menstrual period and its hormonal variations could be related to stress levels. Therefore, all participants were asked whether they were in the premenstrual period or not. These data were presented without a significant statistical correlation. Of the 160 measurements taken, only 31 were in premenstrual periods and the average of these was lower than that found in the entire sample, demonstrating that this factor does not seem to have a direct influence on stress at work.

By developing and applying the method for assessing the stress level of industrial assemblers through wearable devices, the first specific objective of this work was achieved and can be replicated for future research.

The methodology developed by Rasmussen to classify the complexity of activities was important to quantify the levels of complexity of jobs on an assembly line. This step was important to identify what the mental requirement would be for employees to carry out the activities in each job. It was, therefore, possible to achieve the second specific objective proposed in this work.

Using the MTM method to describe and determine the time of activities, it was possible to use the EAWS methodology and carry out quantitative ergonomic analyzes, thus identifying the physical demands of each job. These steps also made it possible to correlate physical overloads with stress data.

By quantifying the level of stress of employees at workstations, during the day and in real time, using a smart watch with vital data sensors, it was possible to achieve the third specific objective by quantitatively determining the levels of stress of workers during their specific activities.

Executing each step described above, it was possible to statistically correlate the data on the levels of complexity of the activities, the physical demands and the mental demands for carrying out the processes of assembling the fiber optic connectors. By using the assessments by the NASA and SWAT questionnaires of mental load at work, it was possible to compare with the data collected by the sensors of the smart watch and thus reach the fourth specific objective of this work.

It was observed, after presenting the results, that the methodology proposed in this study to correlate the levels of complexity of the activities and their possible relationships with the mental requirement was presented in a certain way effective, with a certain proximity to the data of the gold standard subjective evaluations, however, with the replication of the method, these data can be better evaluated. It was also shown that the sensor technology present in smart watches for individual monitoring of health data can become an ally for researchers to identify stress levels at work or in other situations of mental demand.

The joint use of quantitative methods to assess activity complexity levels, ergonomic analysis and stress levels provided more reliable data for statistical data crossing.

Based on the results obtained from the correlation of the data measured at the workstations during the activities with their complexity and the physical demand (ergonomics), one can perceive a direct influence relationship. The level of demand for carrying out activities, based on skills, rules and knowledge, especially those related to decision-making, is related to the stress levels of employees, and can thus directly affect their mental health.

It can be concluded, therefore, that by reducing the demands for decision and reasoning during the requested activities, the company will be able to promote a reduction in the possible levels of stress of its employees, however the important factor related to frustration at work, which is evaluated by the questionnaire NASA-TLX, can negatively interfere in this process.

The method proposed here can be used to evaluate the effectiveness of an activity alternation approach, such as rotation, which can have a positive impact not only to minimize physical overloads but also to reduce levels of mental stress at work.
The possibility of studies related to understanding the influences of workload on the mental stress of employees is very wide. The development of this work provided important information for the integration of subjects related to the different areas of knowledge.

Based on the information obtained in the development of the method proposed here, it is possible to use, mainly, the classification of activities complexity to associate the mental requirement in the risk score of an ergonomic evaluation. That is, there is the possibility of developing a new methodology for ergonomic evaluation that also scores, in addition to the physical conditions of work, the mental requirement.

This work also makes it possible to carry out studies, trying to observe and evaluate the use of equipment with artificial intelligence technology and deep learning (Deep Learning) that can contribute to the reduction of mental stress in employees of assembly lines.

The method proposed and used in this work may serve as a parameter for measuring the efficiency of this equipment on assembly lines in relation to the mental health of employees.

Another study proposal is related to the comparative observation between the methods of evaluating stress levels, such as, for example, wearable equipment that uses electrodermal sensors. The same method proposed here can be used to structure research and compare two or more technologies for measuring stress levels.

3 STATEMENTS

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