Alison Alfred Klein, Angela Luiza Cunha Legey, Arlete Ana Motter, Estefani Santos Castro, Maria Lucia Leite Ribeiro Okimoto *

Comparative study of RULA evaluations using Kinebot software

Abstract Objective: to compare the use of the observational method, with the postural analysis using Kinebot software, of workers in manufacturing stations.
Background: The RULA (Rappid Upper Limb Assessment) is among the tools most used by ergonomists. Kinebot is a software that evaluates the worker through filming and digital recognition, capable of generating a volume of information and detail so superior to the methods currently used.
Method: 50 manufacturing positions from an industry in Paraná were selected, in which both methods were applied separately, to then compare the data obtained in the analyses, being the observations in the application the scores.
Results: Kinebot was much easy to apply, there was positive and weak correlation for trunk, neck, right forearm, left and right arm. For the variables left forearm and final action level, there was a positive and moderate correlation.
Conclusions: the subjectivity of a conventional method has its evaluation levels decreased with the expansion of technological tools. Kinebot has proved easier and with the results being RULA-compliant.

Keywords RULA, Musculoskeletal disorders, Kinebot, Ergonomics tools, Working Posture Analysis.

* **Alison Alfred Klein** is PhD student at the Post Graduate Program in Design, Federal University of Paraná.
<alison.klein@ufpr.br>
ORCID: 0000-0001-7725-9959

Angela Luiza Cunha Legey Master Degree at the Post Graduate Program in Collective Health, Federal University of Paraná.
<angelalegey@gmail.com>
ORCID: 0000-0002-4295-4182

Arlete Ana Motter is Post Graduate at the Program in Collective Health, Federal University of Paraná.
<arlete.motter@gmail.com>
ORCID: 0000-0002-2585-207X

Estefani Santos Castro has a degree in Physiotherapy, Federal University of Paraná.
<steesantoscastro@gmail.com>
ORCID: 0000-0003-0608-6688

Maria Lucia Leite Ribeiro Okimoto is Professor at the Post Graduate Program in Design, Federal University of Paraná.
<lucia.demec@ufpr.br>
ORCID: 0000-0002-1968-1964

Estudio comparativo de evaluaciones RULA utilizando el software Kinebot

Resumen *Objetivo: comparar el uso del método observacional, con el análisis postural por medio del software Kinebot, de trabajadores en estaciones fabriles.*

Antecedentes: El RULA (Rappid Upper Limb Assessment) es una de las herramientas más utilizadas por los ergónomos. Kinebot es un software que evalúa al trabajador mediante filmación y reconocimiento digital, capaz de generar un volumen de información y detalle tan superior a los métodos utilizados actualmente.

Método: Se seleccionaron 50 puestos de producción de una industria de Paraná, en los que se aplicaron ambos métodos por separado, para luego comparar los datos obtenidos en los análisis, siendo las observaciones en la aplicación los puntajes.

Resultados: Kinebot fue mucho más fácil de aplicar, hubo correlación positiva y débil para tronco, cuello, antebrazo derecho, brazo izquierdo y derecho. Para las variables antebrazo izquierdo y nivel de acción final, hubo una correlación positiva y moderada.

Conclusiones: la subjetividad de un método convencional ha disminuido sus niveles de evaluación con la expansión de las herramientas tecnológicas. Kinebot ha demostrado ser más fácil y los resultados cumplen con RULA.

Palabras clave *RULA, Trastornos musculoesqueléticos, Kinebot, Herramientas de ergonomía, Análisis de postura de trabajo.*

Estudo comparativo de avaliações RULA utilizando o software Kinebot

Resumo *Objetivo: comparar a utilização do método observacional, com a análise postural pelo software Kinebot, de trabalhadores em estações fabris.*

Introdução: O RULA (Rappid Upper Limb Assessment) está entre as ferramentas mais utilizadas pelos ergonomistas. O Kinebot é um software que avalia o trabalhador por meio de filmagem e reconhecimento digital, capaz de gerar um volume de informações e detalhes tão superior aos métodos atualmente utilizados.

Método: Foram selecionados 50 postos fabris de uma indústria paranaense, em que os dois métodos foram aplicados separadamente, para então comparar os dados obtidos nas análises, sendo as observações na aplicação os escores.

Resultados: O Kinebot foi muito fácil de aplicar, houve correlação positiva e fraca para tronco, pescoço, antebraço direito, braço esquerdo e direito. Para as variáveis antebraço esquerdo e nível de ação final, houve correlação positiva e moderada.

Conclusões: a subjetividade de um método convencional tem seus níveis de avaliação diminuídos com a expansão das ferramentas tecnológicas. O Kinebot provou ser mais fácil e com resultados compatíveis com RULA.

Palavras-chave *RULA, Distúrbios musculoesqueléticos, Kinebot, Ferramentas de ergonomia, Análise da postura de trabalho.*

Introduction

Work-related musculoskeletal disorders develop over time, have in its causes the work and the environment in which it is performed. Working conditions, context and personal aspects increase the risk of developing these disorders, therefore their origin is multifactorial and usually affect trunk, neck, upper limbs and lower limbs (Dimate et al., 2017; Couto, 2019).

The 2018 Brazil's Health Yearbook, from the Brazilian Ministry of Health, points out that between 2007 to 2016, 67,599 cases of Work-Related Musculoskeletal Disorders (DORT) were recorded. The same study points out that there is significant growth in the period, from 3,212 cases in 2007 to 9,122 in 2016 (Brazil, 2019). They are one of the main causes of absenteeism and treatments, resulting in considerable costs for companies and overloading the health system. There are several strategies aimed at improving working conditions, through models proposed by the World Health Organization, in which it seeks to protect and promote the health, safety and well-being of workers (WHO, 2010).

The conception and maintenance of an appropriate work environment are the objectives of ergonomics, which acts to improve worker performance, reduce stress and fatigue (Mohammadipour, 2018). The application of ergonomics is important in areas where manual activities directly affect the physical and mental health of workers, because it studies posture and human movement, important aspects to determine the risk of musculoskeletal disorders in the workplace (Junnior et al., 2017).

To evaluate working conditions, several authors guide the implementation of the EWA methodology (ergonomic analysis of work) being performed in conjunction with the worker, also evaluating work posture, and may or may not use ergonomic tools and proposing actions to improve the working condition (Vidal, 1985; Couto, 1995, 1998 and 2019; Guérin, 2001; Ferreira, 2015).

In order to improve the approaches of EWA, researchers have developed many instruments for the evaluation of ergonomic condition, but these new methods are sometimes expensive and invasive requiring in their use training and high technical knowledge, which departs them from the real working conditions. Commonly these tools use direct observation and collect their data in tables where their formulas are applied, example of these methods are RULA, REBA, OWAS and the NIOSH equation, all easy to use, low cost and of wide application. However, in real practice, because they depend on the analysts, about 13% of the evaluations present serious errors that totally invalidate the result, and in about 15% of the cases the errors generate super estimation or underestimation of the risks on work causing musculoskeletal disorders (Diego-Mas et al., 2017).

Among the tools used by ergonomists in evaluations with physical demands, one that stands out is the Rapid Upper Limb Assessment (RULA), developed in 1993 by McAtamney and Corlett, which constitutes an observational instrument. Its objective is to analyze whether workers are exposed to risk factors in the upper extremities during work performance. The instrument evaluates three factors: posture of different areas of the body, load or strength exercised and muscle activity (Gómez-Galán et al., 2020). To be of rapid use, it was divided into segments, groups A and B. Group A includes the arm, forearm and wrist, while Group B includes the neck, trunk and legs. This ensures that all posture is recorded (Mcatamney; Corlett, 1993).

The filming of the work posture for postural analysis is a standard tool in ergonomics, because it allows dividing a work cycle into different key elements, denoted as subtasks. The amount of time spent during each of these subtasks can also be deducted as a percentage of the work cycle (Armstrong et al., 2014). To use instruments such as RULA, were implemented specific software recording in video (Manghisi et al., 2017).

Thus, observational instruments are widely used in industry, especially because they do not require complex configurations and enable the use to evaluate a wide range of tasks. However, data collection is obtained through subjective observation or simple estimation of angles projected in videos, that is, subject to inaccuracy or partiality by different observers. Video-based systems have been introduced to overcome these limitations, they do not restrict or disrupt the natural movements of workers, but it remains difficult to obtain 3D information and place cameras in appropriate positions in congested workplaces (Plantard et al., 2015).

The KINEBOT (Kinebot, 2020) is a software that evaluates the worker through filming and digital recognition using artificial intelligence algorithm, has an analysis capacity superior to observational and manual capacity, because it works at 30 frames per second, that is, the work cycle is evaluated 30 times every second, generating a volume of information and details extremely superior to the methods currently used. Therefore, the present study aims to compare the postural analysis obtained by the RULA observational method, with the analysis through Kinebot software, of workers in jobs in a manufacturing company.

Method

The study was based on videos of work cycles recorded by physiotherapists who specialize in ergonomics at a manufacturing company. The researchers selected 50 manufacturing stations from a Paraná industry in the white line manufacturing industry, the company has about 1,030 jobs, and were randomly chosen through a raffle. These posts were evaluated by both the RULA method and the Kinebot software (using the free license provided to researchers). The sample consisted of male and female workers in the manufacturing area of a company, with daily working hours between 6 and 8 hours.

Initially the researchers were trained by the Kinebot developer on its use and application, as well as the operation of its platform. The videos of the posts were then inserted into the Kinebot platform by an independent researcher, to tabulate the data by the software. Then, the researchers applied both methods in isolation, so as not to occur contamination of the information, resulting in the tabulation of the data through the two methods. Finally, the data obtained in both analyses were compared, comparing the observations of the application and the score referring to the trunk, neck, left forearm, right forearm, left arm and right arm, in addition to the analysis of the final score, through the levels of action, obtained by the two methods.

Application of the RULA method

The application of RULA method was following the criteria of the pioneer study (Mcatamney; Corlett, 1993). Where the body of the method is divided into segments, groups A and B. Group A includes the arm, forearm and wrist, while Group B includes the neck, trunk and legs. For the next step, a scoring system was developed to include additional load in the musculoskeletal system caused by excessive static, repetitive movements, and the requirement to exert strength or maintain an external load. These scores are calculated for each of groups A and B, forming scores C and D, respectively (Mcatamney; Corlett, 1993).

For the development of the overall score, both the C score and the D score are incorporated into a large single score whose magnitude provides a guide to the priority of subsequent investigations, based on the estimated risk of injury, due to musculoskeletal load. Finally, the scores are divided and summarized in action levels, the following being:

- **Action level 1:** Score 1 or 2 indicates that posture is acceptable if it is not maintained or repeated for long periods of time.
- **Action level 2:** Score 3 or 4 indicates that investigations are needed and changes should be made
- **Action level 3:** Score 5 or 6 indicates that investigations are needed and what changes should be made soon.
- **Action level 4:** Score 7 indicates that investigations are necessary and that changes should be made immediately.

Kinebot application

The Kinebot (www.kinebot.com.br – v. 1)is a software that evaluates the worker through filming and digital recognition. The tool has a capacity of analysis superior to observational and manual capacity, because it works at 30 frames per second, that is, the work cycle can be evaluated 30 times every second, generating a volume of information and details extremely superior to the methods currently used. Another advantage of the software, is to allow the analysis of which moment of the work cycle happen the inadequate postures.

The application of Kinebot occurs simply and quickly, the videos of the workstations were recalled, leaving exactly a cycle of work, after they were released on the platform, with the identification, after the system process the data and responds with the processed and the information of the RULA notes and other information generated by the software. In the final analysis report, the software delivers to the evaluator, both the angulation and the frequency of each movement, for each joint of the body.

To generate the report, the ergonomist needs to select the tool that he wants to apply for the analysis (in the case of the present study, the RULA method) and the type of report he wants to generate (motion analysis). Next, it is necessary to fill in the essential information about the workplace (company, sector, job and date of data collection). The parameters that the software asks the ergonomist to finalize the report are as follows:

- **Parameters on Force/Load score:** Load less than 2 kg (intermittent); load from 2 kg to 10 kg (intermittent); load from 2 kg to 10 kg (static or repetitive); or load greater than 10 kg of repetitive load or blows.
- **Leg position:** Legs and feet supported and with equal load distribution or legs without support.
- **Repetition:** Number of times the duty cycle is repeated per minute.

At the end of this stage, the software delivers to the evaluator, both the angulation and the frequency of each movement, for each joint of the body, in case the RULA method is chosen, the regions of the body that the report generated for us were: trunk, neck, left forearm, right forearm, left arm and right arm. At this stage, the ergonomist can also put the comments he wants on the analysis and thus generate the PDF in the report. Containing the final action level:

- **Action level 1:** Acceptable - Acceptable posture if not repeated or maintained for long periods.
- **Action level 2:** Mild risk - Investigate; possibility of requesting changes; changes should be made.
- **Action level 3:** Medium risk - Investigate; make changes quickly.
- **Action level 4:** High risk - Immediate change.

Statistical analysis

The Shapiro Wilks test was used to verify the normality of data distribution. To investigate correlations between the total RULA and KINEBOT scores, Kendall’s correlation coefficient was used both to compare the values for trunk, neck, arm and forearm alone, and for the level of final action. The correlation magnitude was graded as follows: R<0.30= weak;

0.4<R<0.6= moderate; R>0.70= strong. The Software SPSS Statistics for Windows, version 22.0 was used to perform statistical analysis and the significance level was established at $p < 0.05$, (Mohammadipour et al., 2018 and Rodrigues et al., 2017).

Results

Of the selected posts, two of them had the videos compromised being excluded from the research so that the final sample totaled 48 job posts.

Regarding data collection through both methods, the practicality of the software was remarkable in comparison to the application of the RULA tool, the time it took to apply the RULA method was longer than the time of application of the Kinebot method, and the RULA method generated greater doubts during its application, given its subjectivity. In addition, the RULA delivered a conventional evaluation by scoring each group, evaluating a static posture (the one that was most visualized during the work cycle). While the Kinebot a percentage of time on each note, which evaluated the entire cycle.

Table 1 shows the percentages found in each of the action levels of both the RULA method and the Kinebot software. It can be observed that the predominant level of action in the evaluated jobs was, the action level 2, both for the RULA (78%), and for the Kinebot (88%). This considers it a mild risk to the job. The level least detected by the methods was 1, being 2% for both methods, this percentage was also found for level 4, in regards to the Kinebot software .

Table 1. Results of the final score of RULA and KINEBOT (n=48).

Levels of Action	N (%) RULA*	N (%) KINEBOT
1	1 (2%)	1 (2%)
2	37 (78%)	42 (88%)
3	7 (14%)	4 (8%)
4	3 (6%)	1 (2%)

Going for the descriptive analysis, the final level of action of both methods remained as action level 2 (RULA = 2.25 ± 0.601; KINEBOT = 2.10 ± 0.424). The lowest mean, for both methods, was for the right forearm (RULA= 1.40 ± 0.494; KINEBOT = 1.65 ± 0.189) and the highest mean for Right Arm (RULA= 2.38 ± 1.104; KINEBOT = 3.35 ± 0.372). These and the other descriptive values are found in Table 2.

Table 2. Descriptive analysis.

Data described as mean ± standard deviation.
Shapiro-Wilk test for normality and homogeneity of the sample with p> 0.05 for samples with normal distribution.
* RULA = Rapid upper limb scale.

Variables	**RULA***	**KINEBOT**
Sample number (n)	(n=48)	(n=48)
Trunk	1.77 ± 0.778	2.03 ± 0.351
Neck	1.79 ± 0.743	3.22 ± 0.361
Left Forearm	1.44 ± 0.501	1.71 ± 0.203
Right Forearm	1.40 ± 0.494	1.65 ± 0.189
Left Arm	2.33 ± 1.09	3.02 ± 0.442
Right Arm	2.38 ± 1,104	3,35 ± 0,372
Final score	2,25 ± 0,601	2,10 ± 0,424

Table 3 shows the correlation between the RULA method and the Kinebot software for the variables: trunk, neck, right and left forearm, right and left arm and final action level. The results demonstrate a positive correlation, that is, the higher the level of action for RULA, the greater it was for Kinebot, for all variables. Furthermore, there was a weak and positive correlation for trunk, neck, right forearm, left and right arm. As for the variables left forearm and final action level, there was a positive and moderate correlation between RULA and Kinebot (R = 0.36 and p <0.00, R = 0.58 and p <0.00, respectively).

Table 3. Correlation between variables.

Kendall test performed to correlate the samples.
* Significance level p <0.05.
** Positive and moderate correlation for final action level between RULA and KINEBOT

Variables	**Correlation**	
Trunk	R = 0,13	p= 0,26
Neck	R = 0,21	p= 0,07
Left Forearm	R = 0,36**	p < 0,00*
Right Forearm	R = 0,12	p = 0,38
Left Arm	R = 0,08	p = 0,47
Right Arm	R = 0,18	p = 0,11
Final score	R = 0,58**	p < 0,00*

Discussion

The results suggest a weak correlation between the variables neck, trunk, arms and forearms, this may be related to the level of subjectivity of the RULA method, since the tool allows the observation of only one work posture, in addition to allowing the score only in whole numbers, while the Kinebot software evaluates the entire work cycle, delivering in the final report the percentage of time in each position, that is, the score varies and the final value can be delivered in decimals, added to this fact that while RULA evaluates a posture Kinebot evaluated postures thousands of times within the cycle. Regarding the final action level, there was a moderate correlation between the tools.

Taking into account the aforementioned method for applying each of the tools, it is possible to observe that the RULA tool takes around 5 to 10 minutes of application per worker, moreover, if the workstation is congested and the applicator has doubts, the time can vary, taking even longer and making it even more subjective. In the Kinebot software, the delay time is on average 2 minutes, counting the time to put the video for analysis in the system and the generation of the final report.

The forms of output of the tools also vary, while RULA brings its score from the tables created by the authors, on a sheet of paper, the Kinebot method brings in its report the graphs, dividing the body into head, trunk, right arm and left, right and left forearm. The graphs give a percentage of the time spent in the same position, taking into account each second of the work cycle, that is, it is possible to observe the variation of postures during the complete cycle, punctuating each one and transforming it into a percentage.

Observational methods are widely used in the industry, one of the best known is RULA, as it is an easy-to-apply method that does not require complex configurations and can be used to evaluate a wide range of tasks using only paper and pen, in environments, from offices to manufacturing. However, data collection is obtained through subjective observation or simple estimation of projected angles in videos / photos, as the analysis present in this study, that is, subject to imprecision or partiality by different observers (Plantard et al., 2015).

Some advantages of the RULA method include being a reliable method for use in repetitive tasks, especially in the upper limbs; applicable to workers in very different areas; the evaluator does not need experience to apply it during the observation phase (Gómez-Galán et al., 2020). However, as you evaluate a single movement at a time, you can consider a high-level risk for non-permanent postures. Furthermore, the left and right sides of the body are assessed independently and the time taken by the worker to complete the task is not taken into account. In the present study, both members were evaluated by the method, in isolation, taking into account the position that most of a work cycle was repeated.

Despite the limitations, the method remains widely used in ergonomics, mainly because it is a simple method to use. However, with the advancement of technology, studies have shown that RULA can be applied with the help of software (Gómez-Galán et al., 2020). These video-based systems were introduced to overcome the limitations of observational methods, they do not restrict or disturb the workers' natural movements (Plantard et al., 2015). What can be confirmed in the present study, the Kinebot software evaluated the work cycle as a whole, generating a percentage of time in each of the positions, in addition to not being dependent of the evaluator.

However, as noted by Lowe et al. (2019), when they published about the ergonomics assessment methods most used by professionals, a total of 405 certified ergonomists were consulted, and as a conclusion, it can be seen that ergonomics practitioners in general, have not increased the use of traditional direct measurement instrumentation for musculoskeletal risk factors in the past 12 years. Although there have been great advances in technology and its diffusion in the general population, ergonomists still use pencil and paper for quantitative assessment. The use of mobile device applications for ergonomic evaluation is in the initial adoption phase.

In a systematic review, carried out by Dimate and collaborators (2017), it was clarified that the application of the RULA method has limited use to detect the degree of biomechanical risk, results that can be attributed to its subjectivity and improved when used with the technology in its favor, as observed in the present study, in which the results of the application of the RULA demonstrated only a certain moment of work. What was evidenced in this research when one observes the volume of data that is generated by the conventional evaluation compared with the system.

To compare the RULA with the Kinebot, videos collected in real work situations were used, taking into account the movement of the worker, with the proper equipment of the station and its variances. However, this aspect may justify the difference found in the level of final action in some of these posts, since the videos were subject to congestion in the workplace and / or the inappropriate positioning of the video camera, which may have led to a moderate correlation. between the tools. However, the possibility of the analyst having evaluated when he applied the RULA tool an instant that was not decisive in the work cycle is instituted as more evident, reinforcing the perceptions that the analysis made analogously is influenced by the analyst.

It corroborates with the moderate correlation between the tools, the difference in the observation time between both, RULA being a subjective observational method, evaluating only one working posture, and Kinebot evaluating the entire work cycle, at 30 frames per second.

Future research correlating the RULA method with the Kinebot should be carried out, suggesting a greater number of job posts evaluated. It is also suggested the correlation between the two methods with other areas of work, such as offices, for example, that demand a high demand from upper limbs. Other research, with the association of musculoskeletal disorders, should also be carried out. In addition, different tools used by ergonomists and present in the literature, must be compared with the Kinebot software and validated.

Conclusions

The study compared the use of a widely known observational method, RULA, with a new method of postural assessment using the Kinebot software, the results of the level of action obtained by both suggest a moderate correlation between the tools. This result may be related to the subjectivity level of the RULA method, as this is a tool that allows the observation of only one work posture, in addition to allowing the score only in whole numbers, while the Kinebot software evaluates the entire work cycle, delivering in the final report the detailed percentage of time in each position, the level being generally graded in decimals. The application of Kinebot was faster and more accurate than the use of RULA. The evaluations with RULA proved to be dependent on the analyst whereas in Kinebot there is no intervention by the analyst. The study with Kinebot allows to map at which point in the work cycle the most inappropriate postures occur, whereas in RULA only one situation is mapped. Thus, it can be concluded that the use of Kinebot technology favors ergonomic analysis by showing more quickly and accurately a much larger volume of information.

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