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SOFTWARE RELIABILITY ANALYSIS IN BIOMECHANICAL ANALYSIS: LITERATURE REVIEW

[1]* Eloisa Oliveira de Araújo, [2] Adson Durantt Duarte

[1, 2] Universidade do Estado do Amazonas - UEA, Manaus, AM

[1]* E-mail: eloisaraujo@outlook.com

ABSTRACT

A biomechanical analysis in order to identify risks and changes, observes the overload exposed to the body, as well as postures that can lead to injury. The use of tools helps to identify possible risks. The use of reliable and designed software becomes effective in the evaluation. This study aimed to investigate the reliability of the use of software in biomechanical analysis. A literature review of articles based on data from the last ten years was carried out on the PubMed, VHL, SciELO and PEDro data platforms, using Ergonomics, Kinovea, SAPO and reliability as search words, in Portuguese and English. The results found show that the use of the Kinovea software has over 90% reliability in biomechanical analysis and SAPO over 60% for biomechanical analysis and can be used as tools to identify possible risks that can lead to RSI / WRMSD. After the research, it can be concluded that the software Kinovea and SAPO for biomechanical analysis are reliable

KEYWORDS: Ergonomics; Kinovea; SAPO; Reliability

1. INTRODUCTION

Man spends a significant portion of his time in a work environment. The influence of this environment can be detrimental to the worker; however, work-related injuries are not always caused by occupational diseases or accidents, but it is still a topic discussed by researchers (Dul & Weerdmeester, 2012).

Due to the work period and the adopted posture, humans are susceptible to poor postures, which can lead to postural changes and the risk of injuries (Renner, 2005). However, ergonomics has contributed to this factor, assisting in optimizing the human fit to their workplace, thus reducing costs for the company, potential absences, and providing a better quality of life for the worker (Villela, 2006).

Postural changes can contribute to the onset of work-related diseases, such as MSDs (Musculoskeletal Disorders), Repetitive Strain Injury, and Occupational Diseases Related to Work. Identifying these potential risks is essential, especially in assessing the range of motion that the individual presents (Araújo et al., 2017).

Biomechanical analysis aims to identify measurements and joint angles present during an activity, serving as a parameter in identifying joint and/or muscle overloads present in the task. The use of software provides quantitative results for asymmetrical postures. The device used must be reliable and operated correctly (Furlanetto et al., 2011). Therefore, this study aims to investigate the reliability of using software in biomechanical analysis

1.1 BIOMECHANICAL ANALYSIS

The term biomechanics was adopted by scientists in the 1970s with the aim of describing the mechanical aspects of living organisms. Thus, biomechanics seeks to examine the forces acting on and within biological structures and the effects produced by these forces. The applied forces can be internal, produced by muscles, as well as external forces acting on the body (Amadio et al., 1999).

Occupational biomechanics is an area that encompasses the prevention of work-related injuries, improvements in working conditions, and the performance of tasks that workers undertake during their workday (Hall, 2017).

> "One of the fields of knowledge within the body of sciences embraced by ergonomics is occupational biomechanics, which concerns the physical interactions of the worker with their workstation, machines, tools, and materials, aiming to reduce the risks of musculoskeletal disorders" (Falcão, 2007).

A biomechanical analysis related to posture, mobility, and load transportation, occupational biomechanics can determine safety limits for the worker to perform tasks with the least possible risk to their physical integrity (Silva, 2015). Therefore, the analysis will determine whether a body segment or joint deviates from an ideal postural alignment, in the identification and location of body segments (Hidrata, 2002).

An analysis of human movement can be qualitative when evaluated directly through visual observation, and quantitative biomechanical analysis, performed through photographs, cinematography, electromyography, or any other technique that requires objective measurements (Paula, 2002).

Braz et al. (2017) mention that the use of tools to assess postural alignment can be essential for detecting bodily changes. Risks and postural changes can be identified through various assessment methods, and among them is photogrammetry, through two-dimensional analysis.

Falcão et al. (2018) report that the use of validated and reliable software can assist in checking postural changes and biomechanical evaluation, such as the SAPO and Kinovea software,

which are more useful and referenced for postural analysis in Work Ergonomics Analysis (AET) and legal expertise

1.2 SOFTWARE KINOVEA

The Kinovea software was created and developed by Joan Charmant (2018), and over the years, it has been used by physical education professionals, physiotherapists, coaches, and students. This tool has the capability to analyze, compare, measure, and evaluate a posture through images or videos.

> "Kinovea is an open-source software application for the analysis, comparison, and evaluation of sports and training, particularly suitable for physical education teachers and coaches. Some advantages of this program include video observation, measurement, and comparison" (Valdivia et al., 2013).

The Kinovea tool features functions for searching video files, folders, and cameras. Additionally, it provides annotations such as labels and numbers, lines and arrows, curves, markers, and a magnifying glass (Figure 1). The program offers a comprehensive module for webcams and cameras compatible with ultraviolet C radiation (UVC), allowing real-time monitoring (Elwardny et al., 2015).

Figure 1. Kinovea Software in Biomechanical Analysis

Source: www.link.springer.com/chapter

With the selection of the video or image, the program allows the user to perform edits such as zooming, rotation, mirroring, comparing, and overlaying two images. After analysis, the software provides the option to export the data to a spreadsheet with the found results, thereby demonstrating better extraction and organization of the data (Charmant, 2020).

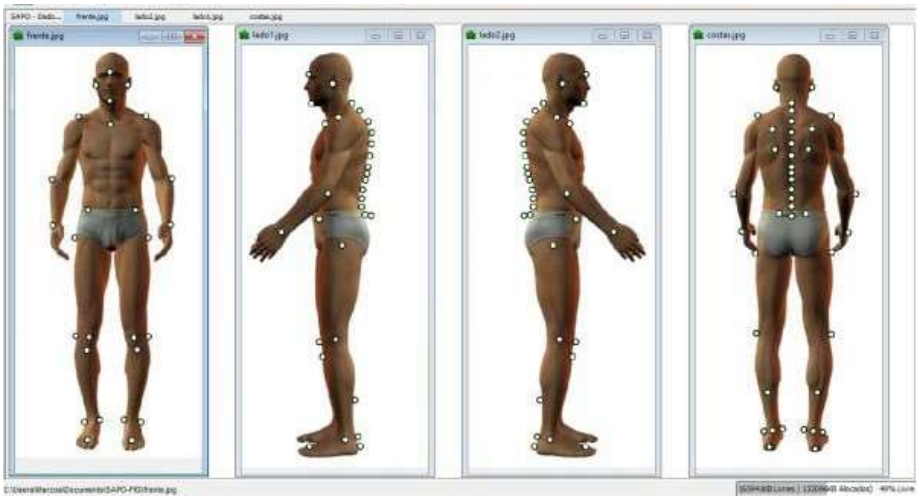
1.3 SOFTWARE SAPO

O Software para Avaliação Postural (SAPO) é um programa livre e de código aberto projetado para procedimentos científicos, permitindo a medição de distâncias, posturas e ângulos. Ele foi desenvolvido por uma equipe multiprofissional da UNIFESP e USP com o objetivo de auxiliar na análise postural, inclinação e equilíbrio (Cerveira, 2020).

> "Software de Avaliação Postural (SAPO) focuses on the development of open-source software for postural assessment, the development of metrological studies on computerized postural assessment, the creation of scientific tutorials on postural assessment and software, and the establishment of a database with results from assessments conducted by collaborating centers. The software is a computer program that utilizes digitized photographs – biophotogrammetry of individuals, enabling the measurement of postural deviations" (Nery, 2009).

The program provides the option to open a "New Project" and "View Projects" for editing and/or adjustments to previously made projects. When initiating a project, information about the subject under analysis should be described, and different images can be selected for each view (frontal, right lateral, left lateral, and posterior), separately (Figure 2) (Souza et al., 2011).

Figure 2. Software for Postural Assessment (SAPO) - Frontal view, left lateral view, right lateral view, and posterior view.



Source:http://pesquisa.ufabc.edu.br/bmclab/sapo

Os resultados após a análise do SAPO são gerados por um relatório que apresenta os marcadores estabelecidos pelo pesquisador e a angulação encontrada. No relatório, quando o sinal é positivo, significa que o lado esquerdo é mais elevado (medidas na vista anterior e inclinação à direita), e quando o sinal é negativo, indica que o lado direito é mais elevado (inclinação à esquerda). No entanto, para ambos os acrômios e as duas espinhas ilíacas anterossuperiores, é padronizado que a inclinação à direita é determinada por sinal positivo, e à esquerda, por sinal negativo (Cerveira, 2020; Marques, 2014).

2. METHODOLOGY

This is a literature review of scientific articles with data collected from the past ten years, indexed in databases including PubMed (US National Library of Medicine National Institutes of Health), SciELO, PEDro (Physiotherapy Evidence Database), and BVS (Virtual Health Library). The search aimed to investigate the reliability of using software in biomechanical analysis, using descriptors such as software, ergonomic, reliability, and their specific English and Portuguese correlates identified in Health Sciences Descriptors (DECS): ergonomic

assessment, equipment, supplies technology, software validation, and in the Medical Subject Headings (MESH): programs, computer, tools, applications.

For the search in the PubMed, BVS, PEDro, and SciELO databases, the terms were combined and/or isolated using "AND" in the search strategy ((Kinovea) AND (reliability) AND (ergonomics)).

Inclusion criteria consisted of clinical trials, randomized or non-randomized, observational or experimental studies that included research using Kinovea or SAPO as software for biomechanical analysis. Exclusion criteria included studies prior to 2010, reviews, and duplicate articles.

3. RESULTS AND DISCUSSION

In this research, a literature review was conducted to investigate the reliability of using software in biomechanical analysis. Using the established descriptors, 246 articles were identified. After applying the inclusion and exclusion criteria, five articles were selected to compose the results, as described in Table 1.

Table 1. Selected Articles

AUTHOR/ YEAR	OBJECTIVE	RESULTS	CONCLUSION
SOUZA et al. (2011)	Assess the inter-examiner (IE) and intra-examiner (IA) reliability of the angular measurements proposed by the postural assessment software (SAPO) v.0.68.	The inter-examiner reliability (IE) of the 20 measured angles resulted in 2 being classified as not acceptable, 1 as acceptable, 1 as very good, and 16 as excellent. In the assessment of method repeatability by the same evaluator, 2 angles measured by examiner A were significantly different in two measurements, as well as two angles by examiner B and one angle by examiner C.	It was concluded that the angles proposed by the SAPO protocol demonstrated reliability in the evaluation among different examiners for measuring body segments.
DIVÍ et al. (2019)	To determine the validity of the Kinovea software compared to AutoCAD, and its intra and inter-examiner reliability in obtaining coordinate data; and to compare their results from four different perspectives and evaluate intra-rater reliability in each perspective.	The results indicate that Kinovea is reliable when measuring within the perspective range of 90º to 45º and at a distance of 5 m from the recorded object. However, the differences found among the four tested perspectives suggest that Kinovea is better employed at 90º than at 45˚.	Kinovea is a free and reliable tool that produces valid data, providing an acceptable level of accuracy in angular and linear measurements obtained by scanning the x and y coordinates axes.
FERNÁNDEZ et al. (2014)	Analisar a validade e confiabilidade de um	O coeficiente bivariado de produto-momento de Pearson	O método HSC-Kinovea éextremamente prec iso,

	método alternativo (método HSC-Kinovea) para medir o tempo de vôo e a altura do salto vertical usando uma câmera Casio Exilim FH-25 (HSC) de alta velocidade e baixo custo.	mostrou uma correlação quase perfeita entre os valores de tempo de vôo obtidos pelo método HSC-Kinovea e aqueles obtidos usando a plataforma de RI. Além disso, o método HSC-Kinovea explicou 99,5% das diferenças obtida pela plataforma de RI	confiável e válido para medir o tempo de vôo de saltos verticais. De fato, a precisão teórica desse método é muito, enquanto o sistema IR possui uma precisão teórica de 61,8 mm para o mesmo tempo de vôo.
FERREIRA et al. (2010)	Estimar a precisão do software de avaliação postural (PAS/SAPO) para mensuração de ângulos e distâncias corporais, bem como as confiabilidades inter avaliador (IEA) e intravaliador (IAA)	A confiabilidade IEA foi excelente para 41% das variáveis e muito boas para 35%. Dez por cento das variáveis apresentaram confiabilidade aceitável e 14% foram definidos como não aceitáveis. Para confiabilidade IAA, 44,8% das medições foram considerados excelentes, 23,5% eram muito bons, 12,4% eram aceitáveis e 19,3% eram considerados inaceitáveis.	O software de avaliação postural foi acurado na mensuração dos ângulos e distâncias corporais e deve ser considerada uma ferramenta confiável para avaliação postural.

Source: Own Author

The use of reliable and validated software ensures researchers obtain accurate results, enabling error-free studies with variables attributed to the research. Cinematography is employed to gather data on body position, velocity, and acceleration through video, and the Kinovea and/or SAPO software aids in measuring angular movements, angular velocity, and angular acceleration (Simsic et al., 2014).

Fernández et al. (2014) sought to investigate the validity and reliability of the HSC-Kinovea method through biomechanical analysis of flight time and vertical jump height in 25 subjects. The recording was done in non-professional conditions without a tripod or lighting, by a single researcher. The video was analyzed by two evaluators and subsequently processed using the Kinovea software.

However, Diví et al. (2019) aimed to determine the validity and reliability of Kinovea and AutoCAD through lower limb analysis during walking from four perspectives. AutoCAD was used to design the geometric figure, recorded at angles of 90º, 75º, 60º, and 45º, with 4 frames analyzed. Frame calibration in Kinovea, digitization, and export to a spreadsheet with the results were performed.

Fernández et al. (2014) and Diví et al. (2019) calculated the intraclass correlation coefficient (ICC) and Pearson's bivariate product-moment correlation coefficient (r). Tests such as the Kolmogorov-Smirnov and Shapiro-Wilks were employed for data distribution and statistical normality analysis (Souza et al., 2011; Fernández et al., 2014; Ferreira et al., 2010; Lopes et al., 2013).

The results showed a correlation between the HSC-Kinovea method and the RI platform (both with values: $r=0.997$ and $p<0.0001$). Kinovea explained 99.5% ($r2= 0.995$ and $p < 0.0001$) of the differences obtained by the RI platform (Fernández et al., 2014). Similarly, ICC=1, 95% and $p<0.0001$ were found in three observers (Diví et al., 2019).

Fernández et al. (2014) and Diví et al. (2019) support the use of Kinovea software due to its user-friendly nature, not requiring expertise in video analysis, providing a precise and reliable means for technicians and coaches to assess accurate, valid, and reliable data. Authors report Kinovea as a tool used in specific analyses such as upper limbs, lower limbs, and assisting in identifying biomechanical risks during task execution (El-Raheem et al. 2015; Silva et al., 2019; Veiga et al., 2014).

The SAPO/PAS software can also be used in postural analysis. Ferreira et al. (2010) assessed the software's accuracy in measuring angles and distances and its reliability, using

physiotherapists not regularly using the software for analysis.

However, Souza et al. (2011) aimed to evaluate the application of the SAPO software's postural assessment protocol in inter and intra-examiner evaluation with 24 subjects. The photogrammetry protocol was followed with a plumb line, 3 meters away from the camera on a tripod at the subject's average height.

SAPO is a reliable tool for postural analysis in both intra-rater and inter-rater agreement, with good or excellent ratings of 75% and 64.8%, respectively. It is accurate for angle and distance measurements. Out of 29 variables, only 4 were unacceptable (ICCs<0.70) in inter-raters, and intra-rater reliability ICCs ranged from 0.157 to 0.837 (Ferreira et al., 2010). The ICC reliability and reproducibility found by Souza et al. (2011) for the 20 measured angles were only 2 were not acceptable.

Based on the results, SAPO software, aimed at analyzing postural asymmetries, is reliable when performed by experienced or inexperienced examiners, being a precise and useful tool. However, limitations were found during the present study due to the scarcity of studies focusing on the reliability and validity of software in postural analysis, necessitating further research addressing the features and elucidation related to the topic (Souza et al., 2011; Ferreira et al., 2010).

4. CONCLUSION

A thorough analysis of biomechanics in task execution is essential to highlight musculoskeletal changes based on the angular movement of segments and the risks the assessed individual may face. The use of Kinovea and SAPO software aims to analyze the angles, speed, and posture that an individual adopts during an activity, proving to be useful. Once validated, these analyses become reliable for assessment. Thus, it is concluded that the use of software in biomechanical analysis enhances the research's reliability due to the statistical data resulting from the tool and the performed analysis.

5. REFERENCES

Abd El-Raheem, R. M., Kamel, R. M., & Ali, M. F. (2015). Reliability of using Kinovea program in measuring dominant wrist joint range of motion. Trends in Applied Sciences Research, 10(4), 224.

Amadio, A. C., Costa, P. H. L., Sacco, I. C. N., Serrão, J. C., Araújo, R. C., Mochizuki, L., & Duarte, M. (1999). Introdução à biomecânica para análise do movimento humano: descrição e aplicação dos métodos de medição. Revista Brasileira de Fisioterapia, 3(2), 41-54.

Balsalobre-Fernández, C., Tejero-González, C. M., del Campo-Vecino, J., & Bavaresco, N. (2014). The concurrent validity and reliability of a low-cost, high-speed camera-based method for measuring the flight time of vertical jumps. The Journal of Strength & Conditioning Research, 28(2), 528-533.

Braz, R. G., Goes, F. P. D. C., & Carvalho, G. A. (2008). Confiabilidade e validade de medidas angulares por meio do software para avaliação postural. Fisioterapia em Movimento (Physical Therapy in Movement), 21(3).

Cerveira, F. (2009). SAPO. Recuperado em 12 de junho de 2020, de http://www.luzimarteixeira.com.br/sapo/.

Charmant, J. (2004) Kinovea. Recuperado em 12 de junho de 2020, em: https://www.kinovea.org/.

Da Silva, L., Forcelini, F., Varnier, T., Gontijo, L. A., Merino, G. S. A. D., & Merino, E. A. D. Análise dos riscos físicos da operação de checkout: uma proposta conceitual de posto de trabalho. Human Factors in Design, 8(16), 119-137.

De Araújo, E. O., Estrázulas, J. A., Guerreiro, A. L. L., & Estrázulas, J. A. (2017). Avaliação postural de trabalhadores de campo de uma empresa de distribuição de energia do Amazonas. Lecturas: Educación Física y Deportes, 22(231).

De Paula, A. H. (2002). Teoria da análise biomecânica, através da observação visual. Revista Digital–Buenos Aires: ano, 8.

Dul, J. & Weermeester, B. (2012). Ergonomia Prática. (3nd ed., pp.) São Paulo: Blucher.

Elwardany, S. H., Eleiny, K. E. A., & Arabia, S. (2015). Reliability of Kinovea computer program in measuring cervical range of motion in sagittal plane. Open Access Library Journal, 2(09), 1.

Falcão, F. S. (2007) Métodos de avaliação biomecânica aplicados a postos de trabalho no pólo industrial de manaus (am): uma contribuição para o design ergonômico. (Dissertação) Universidade Estadual Paulista. Faculdade de Arquitetura, Artes e Comunicação, Bauru-SP.

Falcão, T. J. M, Costa, E.B., & Silva, L.D. (2018) Uma ferramenta de apoio a análise de risco biomecânico de trabalhadores em ambiente informatizado. (Dissertação de Mestrado) Universidade Federal de Alagoas.

Ferreira, E. A. G., Duarte, M., Maldonado, E. P., Burke, T. N., & Marques, A. P. (2010). Postural assessment software (PAS/SAPO): validation and reliabiliy. Clinics, 65(7), 675-681.

Furlanetto, T. S., de Oliveira Chaise, F., Candotti, C. T., & Loss, J. F. (2011). Fidedignidade de um protocolo de avaliação postural. Journal of Physical Education, 22(3), 411-419.

Guzmán-Valdivia, C. H., Blanco-Ortega, A., Oliver-Salazar, M. Y., & Carrera-Escobedo, J. L. (2013). Therapeutic motion analysis of lower limbs using Kinovea. Int J Soft Comput Eng, 3(2), 2231-307.

Hall, S. J. (2017) Biomecânica Básica. (7nd ed.) Rio de Janeiro: Guanabara Koogan.

Hirata, R. P. (2002) Análise biomecânica do agachamento. (Tese de Doutorado) Escola de Educação Física e Esporte da Universidade de São Paulo.

Lopes, M. D. M., Castelo Branco, V. T. F., & Soares, J. B. (2013). Utilização dos testes estatísticos de Kolmogorov-Smirnov e Shapiro-Wilk para verificação da normalidade para materiais de pavimentação.

Marques, A. P. (2014) Manual de goniometria (3nd ed.). Editora Manole.

Nery, P. B. (2009). Análise da confiabilidade intra e interexaminador do software de avaliação postural-SAPO em escolares do município de Ribeirão Preto-SP (Doctoral dissertation, Universidade de São Paulo).

Puig-Diví, A., Escalona-Marfil, C., Padullés-Riu, J. M., Busquets, A., Padullés-Chando, X., & Marcos-Ruiz, D. (2019). Validity and reliability of the Kinovea program in obtaining angles and distances using coordinates in 4 perspectives. PloS one, 14(6), e0216448.

Renner, J. S. (2005). Prevenção de distúrbios osteomusculares relacionados ao trabalho. Boletim da saúde, 19(1), 73-80.

Silva, V. R. (2015). Cinesiologia e biomecânica. Rio de Janeiro: SESES, 88.

Simsic, A. A., Fabrin, S., Soares, N., Miranda, A. P. B., Regalo, S. C. H., & Verri, M. E. D. Análise de dominância dos membros superiores em testes incrementais mediante o potencial de ação e padrão angular. Lecturas Educación Física y Deportes. Buenos Aires. Disponível em:< http://www. efdeportes. com/efd195/dominancia-dos-membros-superiores-em-testes. htm>, acesso em, 23.

Souza, J. A., Pasinato, F., Basso, D., Corrêa, E. C. R., & Silva, A. M. T. D. (2011). Biofotogrametria confiabilidade das medidas do protocolo do software para avaliação postural (SAPO). Revista Brasileira de Cineantropometria & Desempenho Humano, 13, 299-305.

Veiga, R. K., Gontijo, L. A., Masiero, F. C., Venturi, J., & Odorizzi, W. (2014). Emprego da análise ergonômica do trabalho em atividade com máquina agrícola motorizada. Exacta, 12(1), 123-136.

Villela, A. (2006). Ergonomia! Ergonomics!. Rónai–Revista de Estudos Clássicos e Tradutórios, 27-29.