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SOFTWARE RELIABILITY ANALYSIS IN BIOMECHANICAL ANALYSIS: LITERATURE REVIEW

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Abstract

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

Keywords: Ergonomics; Kinovea; TOAD; Reliability.

1. INTRODUCTION

Man spends much of his time in a work environment. The influence of this environment can be harmful to the worker, however, it is not always that work injuries are caused due to occupational diseases or work accidents, but it is still a subject discussed by researchers (Dul & Weerdmeester, 2012).

Due to the period of work and posture adopted, men are susceptible to vicious postures, which can lead to changes in posture and the risk of injuries (Renner, 2005). However, ergonomics has contributed to this factor, helping to improve the quality of the man to his workplace, thus reducing costs to the company, possible leaves and providing a better quality of life to the worker (Villela, 2006).

Postural changes can contribute to the emergence of work-related diseases, which are RSI/WMSD, Repetitive Strain Injury and Work-Related Occupational Diseases. Noting these

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possible risks is fundamental, especially in identifying the range of motion that the individual presents (Araújo et al., 2017).

Biomechanical analysis aims to identify the joint measurements and angulations present during an activity, being a parameter in the identification of joint and/or muscle overloads present in the task. The use of software has shown quantitative results for postural asymmetrics. The device used must be reliable and executed correctly (Furlanetto et al., 2011). Thus, this study aims to investigate the reliability of the use of software in biomechanical analysis.

1.1. Biomechanical analysis

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

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

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

A biomechanical analysis related to posture, mobility and load transport, occupational biomechanics can determine the safety limits for the worker to perform the tasks with the least possible risk to his 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, 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 body alterations. Risks and postural changes can be identified through several 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 the verification of postural changes and biomechanical assessment, such as the SAPO and Kinovea software, which are more useful and reference for postural analysis in Work Ergonomics Analysis (AET) and forensic examinations.

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 device has the ability to analyze, compare, measure and evaluate a posture, through images or videos.

"Kinovea is a free software application for analyzing, comparing and evaluating sports and training, especially suitable for physical education teachers and coaches. Some advantages of this program are: observation, measurement, video comparison" (Valdivia et al., 2013).

The Kinovea tool features search functions for video files, folders, and cameras. In addition, they provide annotations such as labels and numbers, lines and arrows, curves, markers, magnifying glass (FIGURE 1). The program provides a comprehensive module for webcams and cameras compatible with ultraviolet C (UVC) radiation, so that you can watch the broadcast in real time (Elwardny et al., 2015).

Figure 1. Kinovea software in biomechanical analysis

Source: www.link.springer.com/chapter

With the choice of video or image, the program allows the user to perform edits of magnification, rotation, mirror, compare and superimpose two images. After analysis, the software makes it possible to export the data to a spreadsheet with the results found, thus demonstrating better data extraction and organization (Charmant, 2020).

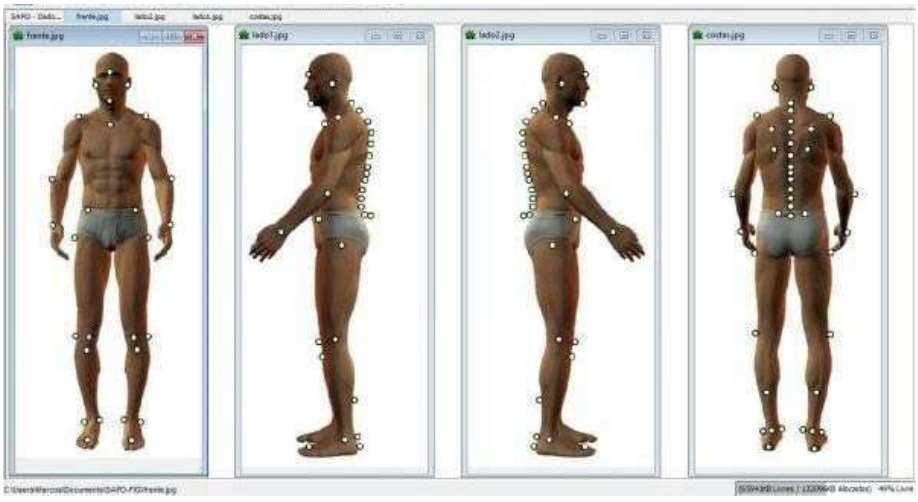
1.3. Software SAPO

Postural Assessment Software (SAPO) is a free and open source program for scientific procedures, which allows the measurement of distances, postures and angles. It was developed by a multiprofessional team from UNIFESP and USP with the purpose of assisting in postural analysis, inclination and balance (Cerveira, 2020).

"Postural Assessment Software (SAPO) focuses on the development of free software for postural assessment, development of metrological studies on computerized postural assessment, creation of scientific tutorials on postural assessment and software, and creation of a database with results of assessments made by collaborating centers. The software is a computer program that makes use of digitized photographs – biophotogrammetry of individuals, making it possible to measure postural deviations" (Nery, 2009).

The program provides opening a "New Project" and "View Projects" in case of editing and/or adjusting projects already made. When a project begins, the information about the subject under analysis should be described, and different images can be selected for each view (front, right side, left side and rear), separately (FIGURE 2) (Souza et al., 2011).

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



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

The results after analysis of the SAPO are generated by a report, which presents the markers established by the researcher and the angle found. When the sign is positive in the report, the left side is higher (measured in the front view and right slope), and the negative sign, the right side is higher (left slope). However, the two acromions and the two anterior superior iliac spines, it is standardized that the inclination to the right is determined by a positive sign, and to the left, by a negative sign (Cerveira, 2020; Marques, 2014).

2. METHODOLOGY

This is a literature review of scientific articles with a search for data from the last ten years, indexed in the databases of PubMed (US National Library of Medicine National Institutes of Heath), SciELO, PEDro (Physiotherapy Evidence Database) and VHL (Virtual Health Library). The search was conducted with the purpose of investigating the reliability of the use of software in biomechanical analysis, through the descriptors: software, ergonomic, reliability and its specific correlates in English and Portuguese identified in the Health Sciences Descriptors (DECS): ergonomic assessment, equipment, supplies technology, software validation and in Medical Subject Headings (MESH): programs, computer, tools, applications.

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

Clinical trials, randomized or not, observational or experimental studies that included research using Kinovea or SAPO as software for biomechanical analysis were used as inclusion criteria. Exclusion criteria include studies prior to 2010, reviews, and duplicate articles.

3. RESULTS AND DISCUSSION

In this research, a literature review was carried out in order to investigate the reliability of the use of software in biomechanical analysis, through the established descriptors, 246 articles were found, after applying the inclusion and exclusion criteria, five articles were selected to compose the results, being described in Table 1.

AUTOR/ANO	OBJETIVO	RESULTADOS	CONCLUSÃO
SOUZA et al. (2011)	Verificar a confiabilidade inter examinadores (IE) e intra examinadores (IA) das medidas angulares propostas pelo software de avaliação postural (SAPO) v.0.68.	A confiabilidade IE dos 20 ângulos mensurados, 2 foram classificados como não aceitáveis, 1 como aceitável, 1 como muito bom e 16 como excelentes. Na avaliação da repetibilidade do método, por um mesmo avaliador, 2 ângulos mensurados pelo examinador A foram significativamente diferentes em duas medidas, também dois ângulos pelo examinador B e um ângulo pelo examinador C.	Concluiu-se que os ângulos propostos pelo protocolo SAPO mostraram-se confiáveis após avaliação entre diferentes examinadores para mensurar os segmentos corporais.
DIVÍ et al. (2019)	Determinar a validade do software Kinovea em comparação com o AutoCAD, e sua confiabilidade intra e inter examinadores na obtenção de dados de coordenadas; E comparar seus resultados em quatro perspectivas diferentes e avaliar a e confiabilidade intra avaliador em cada perspectiva.	Os resultados mostram que Kinovea é confiável ao medir na faixa de perspectiva de 90º a 45º e a uma distância de 5 m do objeto registrado. No entanto, as diferenças encontradas entre as quatro perspectivas testadas sugerem que o Kinovea é melhor empregado a 90º de 45˚	Kinovea é uma ferramenta gratuita e confiável que produz dados válidos, fornecendo um nível aceitável de precisão nas medições angulares e lineares obtidas por digitalização dos eixos x e y coordenadas.
FERNÁNDEZ et al. (2014)	Analisar a validade e confiabilidade de um 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.	O coeficiente bivariado de produto-momento de Pearson 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	O método HSC-Kinovea é extremamente preciso, 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% eramconsiderados 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: Author Himself

The use of reliable and validated software guarantees the researcher a reliable result, enabling a study without errors and with variables that can be attributed to the research. Kinemetry is used to obtain data on position, velocity and body acceleration through video,

performing this collection by the Kinovea and/or SAPO software, assists in the measurement of 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 the biomechanical analysis of the flight time and vertical jump height of 25 subjects. For analysis, the recording was carried out under non-professional conditions, without the use of a tripod and lighting, and was recorded by only 1 researcher. For video analysis, they were analyzed by 2 evaluators, and later analyzed by the Kinovea software.

However, Diví et al. (2019), sought to determine the validity of Kinovea and AutoCAD through the analysis of lower limbs during gait and its reliability, from four perspectives. The study used AutoCAD to project the geometric figure, with engraving at the angle of 90º, 75º, 60º and 45º, with 4 frames analyzed, the calibration of the frame was performed in Kinovea, scanned and exported to a spreadsheet with the results.

The study by Fernández et al. (2014) and Diví et al. (2019), calculated the intraclass correlation coefficient (ICC) and Pearson's bivariate product-moment correlation coefficient (*r).* For data distribution and analysis of statistical normalities, tests for data organization are indicated, using the Kolmogorov-Smimov test and the Shapiro-Wilks test (Souza et al., 2011; Fernández et al., 2014; Ferreira et al., 2010; Lopes et al., 2013).

The results found showed that the correlation of the HSC-Kinovea method and the RI platform (both presented values: *r=0.997 and p<0.0001). It was evidenced that Kinovea explained 99.5% (r2= 0.995 and p* < 0.0001) of the differences obtained by the RI platform (Fernández et al., 2014). In addition, ICC=1.95% and *p<0.0001 were found in the three observers (Diví et al., 2019).*

Fernández et al. (2014) and Diví et al. (2019) corroborate the use of the Kindivea software, as it is easy to use and does not require experience in video analysis, being a means of precision and reliability, so technicians and trainers can evaluate accurate, valid and reliable data. Authors report the Kinovea software as a tool used in specific analyses such as only in upper limbs, lower limbs, in addition to assisting in the identification of biomechanical risks during the execution of a task (El-Raheem et al. 2015; Silva et al., 2019; Veiga et al., 2014).

The SAPO/PAS software can also be used in postural analysis. The study by Ferreira et al. (2010) evaluated the accuracy of the software in measuring angle and distance, and its reliability, using physiotherapists who did not use the software regularly to perform the analysis.

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

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

Based on the results found, the SAPO software with the objective of analyzing postural asymmetries is reliable when performed by experienced or non-experienced examiners. Being an accurate and useful tool. However, limitations were found during the execution of the present study due to the scarcity of studies focused on the reliability and validity of the software in postural analysis, making it necessary to conduct further research to address the resources and elucidation focused on the subject (Souza et al., 2011; Ferreira et al., 2010).

4. Conclusion

A thorough analysis of the biomechanics in the execution of a task is essential, in order to highlight the musculoskeletal changes according to the angle of the movement of the segments and the risks that the evaluated person may present. The use of Kinovea and SAPO software aims to analyze the angles, speed and posture that an individual performs during an activity, thus proving useful. And when validated, they become reliable for analysis. Thus, it is concluded that the use of software to aid biomechanical analysis makes the research more reliable due to the statistical data resulting from the tool and analysis performed.

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