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Literature review

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Rapid upper limb assessment (RULA) in ergonomic assessment: A comprehensive review

Avaliação rápida do membro superior (RULA) na investigação ergonômica: uma revisão abrangente

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RESUMO | INTRODUÇÃO: A avaliação rápida de membro superior (RULA) é um método de pesquisa desenvolvido para uso em investigações ergonômicas em postos de trabalho onde distúrbios de membros superiores relacionados ao trabalho são relatados. Existem diversas pesquisas disponíveis sobre o uso de RULA na avaliação distúrbio osteomuscular relacionado ao trabalho (DORTs). Porém, até o momento não há nenhuma revisão compilada disponível sobre a pesquisa abrangendo os usos de RULA em avaliações ergonômicas. **OBJETIVO:** Compilar artigos relacionados com o uso de RULA na avaliação de DORTs entre trabalhadores de diversas áreas. **MATERIAIS E MÉTODOS:** A busca por artigos relacionados ao tema foi realizada nas bases de dados acadêmicas PubMed, Medline, CINAHL, PsycINFO e EBSCO. A coleta foi realizada até 22 de julho de 2019 usando as cinco palavras-chave, "ergonomia" "Musculoesquelético", "local de trabalho" e "avaliação rápida de membros superiores". Essas palavras-chave foram combinadas usando os operadores booleanos "AND", "OR" e "NOT". Adotou-se as recomendações do checklist PRISMA. **RESULTADOS:** Foram identificados 263 artigos. Após a remoção de 161 artigos duplicados, sobraram 102 artigos para as análises. Destes, 21 artigos foram excluídos pelo título e resumo e 81 artigos completos foram avaliados. Novamente, 68 artigos foram excluídos por não atenderem aos critérios de inclusão e, finalmente, 13 artigos foram incluídos na análise qualitativa abrangente. **CONCLUSÃO:** A aplicação mais ampla do RULA foi confirmada a partir desta revisão abrangente.

PALAVRAS-CHAVE: Ergonomia. Sistema musculoesquelético. Avaliação rápida do membro superior. Posto de trabalho.

ABSTRACT | INTRODUCTION: RULA (rapid upper limb assessment) is a survey method developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported. There are various researches available regarding the use of RULA in assessing work-related musculoskeletal disorders (WRMSDs). But till date, there is no compiled review available regarding the comprehensive research on the uses of RULA in various ergonomic assessment. **OBJECTIVE:** To compile the availability of article related to the uses of RULA in assessing WRMSDs among workers from various fields. **MATERIALS AND METHODS:** The articles related to RULA in ergonomic assessment were searched using the reputed academic databases, including PubMed, Medline, CINAHL, PsycINFO, and EBSCO from inception to July 22, 2019 using the five keywords, "ergonomics," "musculoskeletal," "workplace," and "rapid upper limb assessment." These keywords were combined using the Boolean operators "AND," "OR," and "NOT." **RESULTS:** A total of 263 articles (n=263) were identified. After the removal of 161 duplicate articles, 102 articles were screened for the analysis. Among then, 21 articles were excluded and 81 full-text articles were assessed for eligibility. Again 68 articles were excluded due to not meeting the inclusion criteria and finally 13 articles were included in the qualitative comprehensive analysis. **CONCLUSION:** The wider application of RULA has been confirmed from this comprehensive review.

KEYWORDS: Ergonomics. Musculoskeletal. Rapid upper limb assessment. Workplace.

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Introduction

Well-being is defined as not only the absence of disease and reduced physical functioning, but the presence of positive physical, mental, and psychosocial states of being[1]. The work-related musculoskeletal disorders (WRMSDs) results in early retirement, reduce in production and regular absent from work[2]. With the invention of computers, it has become an integral part of work places which includes, education institution, banking sector, communication sector, etc. Due to the regular use of computers, there is an increasing prevalence of upper quadrant symptoms with computer usage. Neck and shoulder are the most prone areas for developing orthopaedic symptoms among the people who use computer. Working office environment and psychological factors related to work are the modifiable risk factors for developing work related musculoskeletal disorders. The orientation of workstation with computers is one of the physical aspect of work environment that influences the upper quadrant symptoms[3].

In the developing countries such as India, a relatively new concept in an essential component of most enterprises is ergonomics[4]. Human health can be protected and various health risks can be prevented by understanding ergonomics[5]. Implementing modifiable workstations is an important step in application of ergonomics. By concentrating on core ergonomic principles, the musculoskeletal problems can be reduced and the productivity of workers can be increased[6]. The effective ergonomic designs make the employee to deliver his task effectively by making tools and environment effectively. Employee's job satisfaction and work efficiency can be increased by good ergonomic design. Thereby, the amount spent for workers on their health expenses and absent from job due to their health conditions can be minimized. "Appropriating the duty to the worker" can be made possible only by ergonomics and hence, this could act as the appropriated terminology for defining ergonomics.

The WRMSDs of the upper limb can be investigated by the survey method known as, RULA (rapid upper limb assessment). No special equipment is required for RULA in providing a quick assessment of the postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body. There are various researches available regarding the use of RULA in assessing WRMSDs. But till date, there is no compiled review available related to the uses of RULA in assessing WRMSDs among workers from various fields. Hence, we aimed to draft the comprehensive review on the uses of RULA in ergonomic assessment on various fields.

Methods

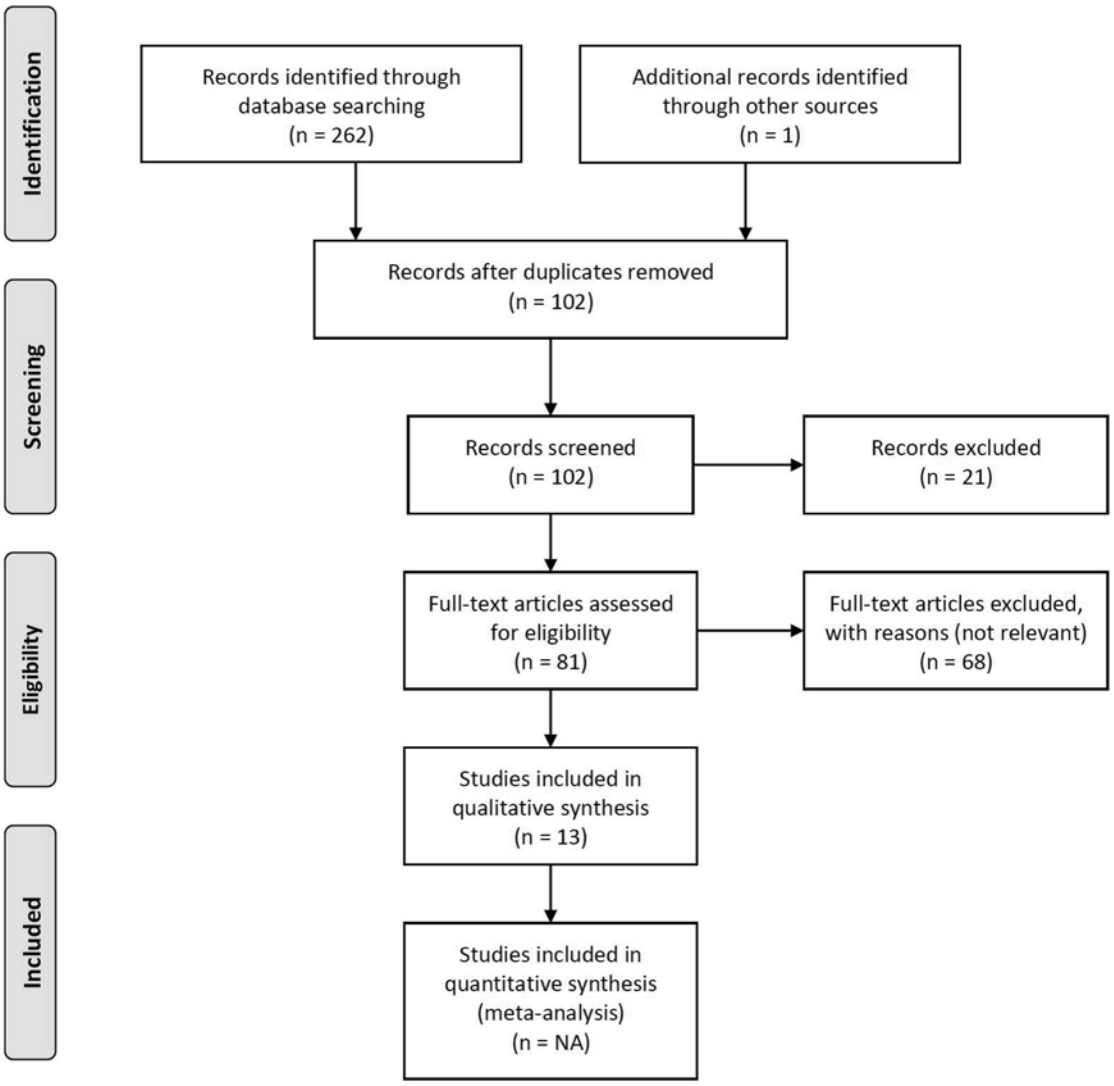
Origin of RULA

RULA was devised by McAtamney L and Nigel Corlett E to evaluate the exposure of individuals workers to ergonomic risk factors associated with upper extremity MSD and to aid in ergonomic investigations of workplaces where work-related upper limb disorders are reported[7]. The European Community Directive on the minimum safety and health requirements and the UK Guidelines on the prevention of work-related upper limb disorders are fulfilled by RULA. The action list can be generated from the coding system in assisting the intervention level required to minimize the risk of WRMSDs due to physical loading among the workeres[7]. RULA has its application among various study population.

Information Source:

The articles related to RULA in ergonomic assessment are searched the reputed academic databases from inception to July 22, 2019. In addition, the reference sections of the extracted articles were manually searched for any articles missed by the electronic search. Academic databases, including PubMed, Medline, CINAHL, PsycINFO, and EBSCO, were used to extract relevant studies. The primary author (A.K.) conducted the electronic search using the keywords encompassed within five primary key terms: "ergonomics," "musculoskeletal," "workplace," and "rapid upper limb assessment." These keywords were combined using the Boolean operators "AND," "OR," and "NOT." The second author (S.K.), assisted in excluding irrelevant articles, which was not related to the aim of the study. The details of the articles searched, screened, included and analysed is displayed in PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart in Figure 1.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart of the comprehensive review



Selection criteria

The following criteria had to be satisfied for inclusion in the review: published original research evaluating RULA in adults and children. Studies were excluded if the studies are from language other than English language.

Data collection and analysis

All abstracts obtained were assessed independently by A.K. and S.K. for inclusion. There were no instances of disagreement between reviewers, so arbitration by a third person was not necessary. Data extraction was performed by A.K. and S.K.

Quality assessment

Quality assessment were not performed as the studies included in this comprehensive review was heterogeneous and RULA is an outcome scale.

Results

A total of 262 articles were identified through database searching and additional one article was identified through other sources. Thus, total 263 articles were identified. After the removal of 161 duplicate articles, 102 articles were screened for the analysis. Among then, 21 articles were excluded due to inappropriate to the study objective (n=12) and study design (n=9). 81 full-text articles were assessed for eligibility and by that 68 articles were excluded due to not meeting the inclusion criteria. Finally 13 articles were included in the qualitative comprehensive analysis. The details of the study included in this comprehensive review describing the application of RULA among different types of workers are described below.

RULA among banking sectors

Globalization, liberalization and other worldwide proceedings are the tremendous change, the 21th century, the banking sector is witnessing. In order to provide the impetus for reform and adaptation to a competitive advantage in multinational companies as environment, the globalization and privatization among Indian banking sector plays a crucial role. The increased risk factors at workplace for developing WRMSDs in upper limb has been documented. There are the potential causes of occupational stress and related disorders among employees in the banking sector of India. The validity and reliability of RULA among the bank employees' using computers were established by Kumar and Kamath in 2019[8]. Total 301 Participants were recruited in their study, in which 170 participants were males, and other 131 were females. Concurrent validity of RULA with the criterion measure Rapid entire body assessment (REBA) is found to be good as measured by spearman's rank correlation test, ρ=0.91 ($p<0.001$). Intra-and inter-rater reliability of RULA is found to excellent with ICC=0.92 (0.90-0.94) and 0.91 (0.89-0.93) respectively. Thus they have established the validity and reliability of RULA among the bank employees' using computers. There exists good validity and excellent reliability among them[8]. Hence, RULA can be effectively used among the bank employees' using computers.

RULA among the smartphone users

RULA can be used in assessing ergonomic risk assessment among the smartphone users. The number of smartphone users globally is increasing at lightning speed. A correlational study was performed to evaluate the correlation between any self-reported musculoskeletal disorders and the level of ergonomic risk[9]. To determine the presence of any musculoskeletal disorders among the smartphone users, 30 participants were asked to complete specifically tailored questionnaire. The participants posture while performing seated smartphone texting task were recorded by video. Three independent researchers evaluated the video sequences to report the level of ergonomic risk using RULA tool. The postural risk of computer users developing WRMSDs has been widely assessed by an observation-based screening tool. RULA. But till date, it has not yet documented among the smartphone users. The risk of using smartphone and its associated postures are identified by RULA. The ergonomic risks from using smartphone to text phone was well established by the RULA tool scores. Majority of the smartphone users had found to report the Grand Total Score of 6 for both sides (left side: 80.00%, right side: 90.00%). This emphasises the the need for further exploration and modifications (Action Level 3). Surprisingly, not even single smartphone users had reasonable RULA Grand Scores of 1 or 2. The Chi-Square test established the association between WRMSDs and its associated ergonomic risk. among the smartphone users and statistically significant ($p<0.05$) association was reported by Fisher's exact test. Significant correlation was established between right RULA Grand Score and WRMSDs at neck ($\chi2$ = 9.424; p value = 0.009) and in similar way, Significant correlation was established between right RULA Grand Score and WRMSDs at upper back ($\chi2$ = 31.717; p value <0.001). RULA Score B (combination of neck, trunk and leg postures) and RULA Score D (combination of Score B, muscle use and force scores for group B) were also significantly correlated with neck musculoskeletal disorders ($\chi2$ = 19.286 at p value<0.001 and $\chi2$ = 9.310 at p value = 0.002 respectively). The high ergonomics risk among the smartphone users was confirmed by RULA results. Posture and muscle use are the two potential risk factors for WRMSDs among the smartphone users. The combined postures of neck, trunk and leg postures had a serious effect on WRMSDs on neck. These factors should be considered while investigating and designing ergonomic interventions among smartphone users in future[9].

RULA among school children

In a digitally driven school environment, the ergonomic assessment among learners could be documented by RULA[10]. Musculoskeletal discomforts and modifications in posture are increased among the adolescents using computers. The cascade effect of this technology-induced, non-active lifestyle leads to abnormal posture, pain, repetitive strain injury and dysfunctional movement patterns. RULA was used in the computer-related ergonomic intervention on posture and ergonomic behaviour among the adolescents in a school environment. Grade 8 learners (n = 127) were recruited randomly from two randomly selected private schools in Johannesburg to participate in the controlled trial. A computer usage questionnaire and RULA were administered at baseline, 3 and 6 months post-intervention. Intervention group was provided with participatory educational programme while the control group was not provided with standard intervention. Statistical intervention was performed using the intention-to-treat analysis for reporting the missing data. Between group analysis were performed at baseline, 3 months and 6 months on computer usage questionnaire on position and type of computer and RULA[10]. There is significant reduction in the intervention group ($p<0.001$) at 6 months of post-intervention. The school children in AL 3 has significantly decreased 26.2% at baseline to 14.8% in the intervention group while in control group, RULA scores were worsened. In intervention group, no participants were observed in action level (AL)[4]. Although the learners were still not in an 'acceptable' range of postural positions, there was a significant ($p<0.001$) increment were observed between the pre-intervention and post-intervention stage among the learners. But they were still in an 'acceptable range.' The sustenance of ergonomic intervention were noted even over 6 monts post-intervention. Their findings demonstrate the effect of an ergonomic intervention and its sustainability over 6 months. The early identification of poor posture and positive impact in decreasing the poor posture among the school children following intervention is the clinical contribution of the study[10].

The discomfort and school children's posture while using computers were evaluated using RULA[11]. Researcher have recruited sixty-eight children with mean age of 9 years and 6 months. During their regular 15-25 min computer session at school, their computing posture was observed using RULA. The level of perceived discomfort was recorded with the help of modified visual analogue scale (VAS) at the site of discomfort with body discomfort chart (BDC)[11]. In accordance with RULA, the Computer tasks were examined and were classified as Action Level (AL) 1 (acceptable) to 4 (needs immediate change). Surprisingly, un acceptable level was adopted by majority of the children while using computers. The percentages of level among the children reported by RULA while assessing their posture with reference to the levels, AL1, AL2, AL3 and AL4 were 0%, 60%, 38% and 2% respectively. Their research concluded, that the body discomfort is associated with poor posture while using the computers. Children who reported discomfort had a greater mean RULA grand score of 5.0 is associated with reported body discomfort than the children who did not report discomfort mean RULA grand score of 4.4. Children's posture is also impacted by the type of computer task. Overall for examining the children's computing posture, RULA emerged as a apt method[11].

To assess the children's computing posture, RULA has been established as the reliable method[12]. RULA is reported as one of the fast observation method to analysis posture. As the reliability of RULA in assessing children's (among pediatric population) computing posture, is not yet established, this reliability study has been executed. Hence the aimed at investigating the inter-rater and intra-rater reliability of RULA among the pediatric population using computers. Six raters who trained in using RULA were employed in assessing the posture from the 24 video recordings presented at random to the raters, on two different occasions. They were asked to establish the reliability of RULA by this procedure. Greater intra-rater reliability of RULA over inter-rater reliability was reported and during both, the reliability was found to moderate to good. The reliability of RULA was reported to be more reliable among the older children (8-12 years) than while assessing the younger children aged between 4 and 7 years. Thus, RULA has been emerged as the reliable ergonomic tool among older children than the younger children[12].

RULA in biomechanical assessment

Among the Brazilian-Portuguese, only very few observational methods for analysis of biomechanical posture analysis are available. Hence, researchers were interested in establishing the interpretability, reliability and construct validity of Brazilian version

of RULA with Strain Index (SI)[13]. researchers aimed at adapting the Brazilian version of RULA cross-culturally and to test the measurement properties of RULA with SI. Cross-cultural adaptation was established by the guidelines proposed by, Beaton et al. and measurement properties of Brazilian version of RULA was established according to COSMIN guidelines. They evaluated the task that required static and dynamic posture of upper limbs. At the end of the reliability study, the Brazilian version of RULA was found to have good intra-rater reliability of, k = 0.00-0.93, and SI range from poor to excellent with, ICC2,1 = 0.05-0.99. But, the Brazilian version of RULA was found to havepoorintra-rater reliability of, k = -0.12-0.13, and SI range from poor to moderate with, ICC2,1 = 0.00-0.53. Good agreement was observed for intrarater (75%-100%) and interrater (42.24%-100%) while using the Brazilian version of RULA and good agreement was observed with SI also[13]. Acceptable internal consistency was reported with the Brazilian version of RULA of Cronbach's alpha, α=0.88. But low internal consistency was observed with SI Cronbach's alpha, α=0.65 The construct validity of, ρ (rho) = 0.61 were found between Brazilian version of RULA and SI, in wrist/hand-wrist posture) and ρ (rho) = 0.39 in strength/intensity of exertion. The cultural equivalence for the Brazilian Portuguese version of RULA have been confirmed[13]. Very poor to almost perfect reliability was reported with Brazilian version of RULA and SI. The Brazilian version of RULA had better internal consistency than the SI. The reproducibility of Brazilian version of RULA is not guarantee even after mandatory training regarding the use of the observation method of biomechanical exposure, Brazilian version of RULA[13].

RULA among the computer users

The validity of using RULA among the computer workers were established[14]. It was reported that, the WRMSDs during typing is commonly associated with abnormal body posture. To prevent the occurrences of WRMSDs, its prevalence should be identified at early stage by a valid, rapid and reliable instrument. Hence, we aimed to establish the concurrent validity of mRULA with the established criterion measure RULA for the computer users. One observation of mRULA was correlated with another observation with RULA among 29 right handed workers who use computer. Those observation were repeated for six times with an interval of 60-minutes. At the end of the study, they have reported significant correlation of, r=0.6 for mouse and r=0.7 for keyboard and no significant differences were noted between the observations. Thus, mRULA is found to be valid and one observations is sufficient to assess the risk factors for WRMSDs[14].

RULA in quantifying abnormal posture

Abnormal posture can be quantified by using RULA. The most common and the worst postures can be reported in a task by an event-based method of RULA[15]. the posture distributions observed in a task were reported by a time-based method[15]. For the time-based posture analysis method, a 'click-on-screen' posture data entry method was developed to make the observation process faster and thereby, to minimize the categorization bias of possible posture. The work posture among the study cohort of 733 subjects in a prospective epidemiological study to report the WRMSDs among the upper extremity and the work posture among them were estimated by the above two methods. By computing the data obtained from the two posture analysis, the composite posture indices using a modified RULA method were established. Modified RULA was able to distinguish the jobs between two working postures with large differences[15].

RULA among dentists

A study was conducted among 60 dental students' to establish the difference in two seating posture while sitting in Bambach saddle seat against the conventional seats and to identify which seating posture prone more risks to developing WRMSDs.16 RULA was administered to them at baseline and at the end of ten weeks to establish the impact of two different seats. The study was executed at the School of Dentistry, University of Birmingham in 2006[16]. Second year bachelor of dental surgery students were inducted into to the study. They were selected using random sampling method and randomly allocated into two different seats (30 Bambach Saddle Seats and 30 conventional seats). Bachelor of dental surgery students were given preliminary training regarding the use of dental seats. After ten weeks after the post intervention, their seating posture were observed, photographed and assessed with the help of RULA[16].

RULA among the truck drivers

Neck and trunk loading among the professional truck drivers can be appropriately evaluated by RULA[17]. The risk factors related with WRMSDs affecting the neck and trunk during sitting posture among the truck drivers who collect rubbish and the vehicle which wash roads were evaluated using RULA. Two sets of truck drivers were compared one who sits in standard posture compare with one who sits with stooped posture. There were a significant association between RULA trunk and neck score and all self-reported pain ache and discomfort. RULA neck scores were statistically more significant reflecting high loading of the neck. The study displayed that loading of the spine can be assessed using RULA[17]. Professional truck drivers is observed to have high incidence of spinal disorders. Among the spine, cervical and lumbar are the common region gets affected and it results in increased rate of morbidity and early retirement age. The results confirmed that significant changes in neck posture affects the neck score due to increased neck loading. These posture were compared with the truck drivers using an adjustable and a non-adjustable seat[17].

RULA in examining relationship between physiological and psychological parameters among working population

Fountain LJ conducted a study on 20 subjects to compare and examine physiological and psychological parameters like perceived discomfort and job satisfaction in the working population[18]. The variables used in this study were surface electromyography, rapid upper limb assessment, self-reports of discomfort and job attitude. A thirty minute typing task in three different postures was used. There was no change in any of the variables except for perceived discomfort. The study also demonstrated that RULA was able to distinguish "high risk" workers susceptible to WRMSDs[18].

RULA on ergonomic intervention among biomedical scientists

Another study was executed to examine the impact of intervention related to ergonomics on working posture and WRMSDs among female biomedical scientists[19]. They have utilized Nordic musculoskeletal questionnaire (NMQ), body discomfort chart (BDC) and rapid upper-limb assessment (RULA) tools for the ergonomic evaluation. The study was executed under three phases, they are pre-intervention, intervention and post-intervention. Pre-intervention, 79% of female biomedical scientists exposed the prevalence of symptoms for three-months during pre-intervention while working in haematology/transfusion. Examining them by RULA revealed the grand score of 4 among the majority of (59%) postures while remaining 24% had the Grand total scores of 5 or 6. The greater frequency of poor postures was seen among female biomedical scientists working in haematology/ transfusion. Awareness regarding the risk factors, seminar and workplace change are the intervention prescribed to them. Baseline measurements were repeated during the post-intervention phase. WRMSDs related symptoms had reduced to 54% which included body discomfort also. 64% of female WRMSDs among female biomedical scientists have been improved after the ergonomic intervention and also resulted in reduced prevalence of WRMSDs.

RULA on computer mouse position

The most important input device used in the keyboard is mouse than the keyboard. The upper limb position with reference to the degree of shoulder flexion and abduction which impose strain on the muscles of deltoid and trapezius of the neck–shoulder complex in relation to other part of body. Cool and Kothiyal[20], examined the electromyographic relationship between the position of the use of mouse and the muscular activity around the neck and shoulder region. The various position of mouse and the resulted muscle activity around the muscles of shoulder, neck and arm due to the change in mouse position were examined. They explored that the 'best' posture for various mouse position was selected by each subjects in relation to other body parts. The upper arm was observed to be in the best posture in eight of ten (80%) subjects when the position of mouse was altered while two of ten (20%) subjects reported that their upper arm was found to be in standard position. The lower arm was observed to be in the best posture among all the subjects when the position of mouse was altered while two of ten (20%) subjects reported that their lower arm was found to be in standard position. The extreme position of the upper or lower arm does not results in 'best position' among any of the subjects recruited. Mouse

position and posture demonstrated highly significant correlation among them. In the extreme position the upper arm posture was significantly (p=0.0001) worse while modified posture resulted in significantly (p=0.0001) better posture. The study confirmed that there is no change in electromyographic activity in trapezius muscle while altering the mouse to various positions. By the removal of numeric keyboard, the working posture among the right handed mouse users is improved.

Discussion

To best of our knowledge, this article is the first comprehensive review to report regarding the application of RULA. The reason for the recent study in executing the application of RULA among the bank employees, is that the employee spent almost maximum part of working hours in-front of computers or laptops and importance of banking have impact in each and every sectors. The position of the computer while being used is an important predictor for developing musculoskeletal pain as this relates to the concept of ergonomic behaviour.10 Working long hours without rest on a laptop or computer puts considerable strain on position of trunk and neck flexion with hyperextension of the upper cervical spine[21].

RULA has its application in determining the posture among the bio-medical scients, school children, truck drivers, use of mouse, dentists and smart phone users. This review provides collective information of studies regarding the use of RULA since its first appearance on 1993. RULA has been successfully used in various studies for more than 25 years due to its simplicity.

The strength of the review is that this is the first comprehensive review on the application of RULA on various fields in assessing WRMSDs. The results of this review provide insight into current application of RULA internationally, and highlight gaps in knowledge that need to be addressed to ensure effective and equitable services among the works of various fields susceptible for WRMSDs.

A major limitation of the study is the observational nature of review. The results were heavily reliant on the accuracy and comprehensiveness of the primary report. Another limitation is associated with heterogeneity between studies. Heterogeneity between studies occurs because of variations in patients, disease and methodological characteristics. The number of studies included in this review is limited as only studies addressing the RULA in various fields are included. Another major limitation is the quality assessment of the study included in this review were not performed.

The reason for emphasising more on bank employees using computer is due to digitization in banking sector and this sector remains backbone of other all sectors. So, the employees working in the banking sector should be assessed properly for WRMSDs. For that, RULA can be used as an important assessment tool.

Conclusion

The extensive use of RULA in ergonomic assessment have been identified from the available literature. The wider application of RULA has been confirmed from this comprehensive review.

Author contributions

Kumar A and Kamath SU conceived and designed the study, conducted research, provided review materials, collected and organized data and wrote initial draft of article. Kamath S provided the logistic and technical support. All the two authors approved the final draft.

Competing interests

No financial, legal or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

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