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Methods of posture analysis for computer workers

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Abstract

Computer users may develop musculoskeletal disorders due to the forces applied, muscle use, posture and wrist velocity and acceleration exposures during computer use. Work-related musculoskeletal disorders (WMSD) in computer users cause substantial worker discomfort, disability and loss of productivity. The aim of this study is to review systematically the relevant literature on the applicable posture analysis methods of computer workers. A bibliographic survey based on PRISMA statement methodology was performed. The research was carried out on five databases and scientific journals: Scopus, Medline, Web of Science, Springer link and PubMed between 2007 and 2017. The total number of papers obtained following the elimination of duplicates was 3650, and finally reached 12 using exclusion and eligibility criteria. A review on different approaches for computer workers posture was accomplished and noted that the simultaneous utilization of the different methods including video and sensors allows achieving better posture analysis, compared to the situation where only one of them was used individually.

1. INTRODUCTION

Work-related Musculoskeletal Disorders (WMSDs) are considered the third main reason for disability and early retirement in the U.S. and are also widespread in many occupations (Peppoloni et al., 2016). Musculoskeletal discomforts such as stiffness or pain in the neck, back, shoulder and wrist are common among computer users (Sharan et al., 2011). Previous studies demonstrated that approximately 76% of computer professionals reported musculoskeletal discomfort in various epidemiological studies (Sharan et al., 2011). Other studies have shown computer workers suffering from WMSDs during the last 12 months reported problem in the low-back pain (40.4%), upper back (39.5), Neck (38.6%), hand/wrist (36.8%) and shoulder (15.2%) (Choobineh et al., 2007; Moom et al.,2015). For as much as for the prevention of WMSDs, assessing posture is very important to determine what factors can be changed and also what must be done to test the efficacy of a workplace intervention in reducing WMSDs among computer workers. This study systematically reviews the relevant literature on the applicable posture analysis methods for computer workers. Research on human action recognition is receiving growing attention in a wide variety of disciplines (Chen et al., 2015).

Different methods and tools have been developed to assess exposure to the risk factors for WMSDs. They can be divided into three groups according to the measurement technique. They include the self-report, direct measurement and observational methods (Plantard et al., 2017).

Self-report methods are carried in different forms such as rating scales, questionnaires, checklists or interviews. However, they are not always reliable and could lead to biased interpretation. Because of this reason, this paper has focused on other methods for posture analysis. Direct methods, which are based on direct collection of data from sensors attached to the worker's body, are difficult to implement in real work situations. Moreover, wearing these devices may cause discomfort as well as influencing the postural behavior. Observational methods are consisted of directly observing the worker and the corresponding tasks, using methods such as the RULA(Rapid Upper Limb Assessment) (Plantard et al., 2017).

Applications of 2D and 3D biomechanical models are classified in the direct group and estimate compressive force on the low back, assess the strength requirements of jobs, use application of guidelines, application of strain index and threshold values to address distal upper extremity musculoskeletal disorders analyzed within such methods(Garg & Kapellusch, 2009). In particular, this kind of information will help practicing ergonomists with how physical stresses can be objectively quantified. The capabilities of these applications have raised significant interest among researchers aiming to measure postures in various contexts, from daily activities (e.g. walking, running,…) to complex work-related tasks (e.g. climbing, hammering, computer work,...) and from sport biomechanics and clinical purposes to rehabilitation and computer 3D animation.

Human action recognition involves automatically detecting and analyzing human actions from the information acquired from sensors such as RGB cameras, depth cameras, range sensors, wearable inertial sensors, or other modality type sensors (Chen et al., 2015). 3D and 2D pose estimates of the upper body are obtained from inertial data and vision, respectively (Wong et al., 2014). While high frequency inertial sensors enable accurate tracking of fast movements, vision-based tracking enables stable estimation of pose for slower movements.

Previous researches suggests that the whole body posture can be captured in three dimensions using an optoelectronic system (Optotrak). The Markers were then attached to 13 body segments: two feet, two legs, two thighs, two upper arms, two forearms, pelvis, trunk and head/neck and trunk and lumbar angles were calculated from three triaxial accelerometers. Markers were also affixed to the chair in order to track the position of the occupant with respect to the chair, throughout the testing session. For each 5-min sitting trial, the participant's feet were again positioned on the two force plates, and a 1296 channel pressure sensor (XSensor Technology) was placed between the participant and the seat pan (Karakolis et al., 2016; Lebel et al.,2015; Mecheri et al., 2016; Robert-Lachaine et al., 2016).

In addition, Kingston et al. (2016) also evaluated the effect of work surface on upper-limb posture with Optoelectric motion analysis system for computer workers. Three-dimensional upper-limb postures were recorded during three tasks: reading, form filling, and writing e-mails (Kingston et al., 2015).

In another study, the biomechanical measures of computer workers were assessed in five different office-based and computer tasks or determined included a comprehensive postural analysis and physical activity intensity index for each station. The Computer-assisted Recording and Long-term Analysis of Musculoskeletal Load (CUELA system). was used to determine body posture, joint angles and the acceleration of the individual body parts (Botter et al., 2013). The CUELA measurement system was developed in order to allow measurement of stresses upon the musculoskeletal system occurring in a range of occupational tasks under actual working conditions directly at the workplace. CUELA is a personal measurement system employing modern sensor technology. Botter et al. (2013) attached the system to subjects with sensors on the joints to capture data about trunk and upper limb. With the help of sensors, trunk movement can be assessed in 3D. The data was sent back to a computer that can reconstruct the real body motions. The idea behind this ergonomic assessment was to investigate whether the joint positions deviated from neutral position severely.

Ulrike Schmuntzsch et al (2013) explained a hybrid framework for creating an instruction video by means of motion capture technologies. They used Wireless Data Glove with sensors located on finger joints, two sensors being on the thumb and three on each of the rest.

Depending on the sensors being used, the data glove systems available on the market can be grouped into four categories: optical, mechanical, inertial and bend. Each system has its advantages and disadvantages. For instance, optical systems are relatively cheap, but the occlusion problem is inevitable. Mechanical systems are relatively robust, but they are ergonomically hard to use. Inertial systems are precise, yet considerably expensive and very sensitive to magnetic interference. Ulrike Schmuntzsch et al (2013) working environment had high magnetic interference and as the human operator moved around freely, system components were being continuously occluded. Consequently, the cheapest easy-to-use system that fits their working environment was the X-IST Wireless Data Glove that has bend sensors on fingers (Schmuntzsch et al.,2013).

In this context, this literature review aimed to systematize some of the existing knowledge regarding the use of different type of applications for posture analyzing of computer users. For this purpose, the sensor and vision base methods for movement analysis were compared and the results have been analyzed from a methodological and a practical perspective for identifying the best method for computer workers' movement assessment.

2. MATERIALS AND METHODS

Computer work is here defined as a work in front of video display units (VDU) or video display terminals (VDT) that involves the use of a keyboard and/or a mouse. Work that involves the use of a personal digital assistant, handheld computer, personal organizer device or similar forms of small size mobile computers is not considered in this review.

This systematic review was designed in order to non-gait-related and non-invasive body movement analysis tools trying to determine the best of them for movement analysis in computer users. This systematic literature review followed the PRISMA guidelines (www.prisma-statement.org). A systematic review of the literature were performed, searching all papers published until 2017 January 30th, with body movement analysis assessed by sensor based systems, excluding those related to gait, clinical purpose , rehabilitation and sport.

The research was performed on five databases and scientific journals: Scopus, Medline, Web of science, Springer link and PubMed between 2007 and 2017. The string used for the search was composed according to the following criteria: (1) Appropriate key-words were used in Title, Abstract or Keywords: "human body motion", "movement analysis", "sensor", "tracking", "posture assessment", "occupational biomechanics", "work related musculoskeletal disorders", "pose estimation", and the roots "ergonomic assessment", "computer workers"; (2) Any of the following words should be present neither title nor Keywords: "gait", "clinical", "walk", "elderly", "jump", "rehabilitation", "sport", "questionnaires", "Electromyography EMG". The search was limited to English language items. Only scientific journals were considered.

3. RESULTS AND DISCUSSION

Querying the databases resulted in 3960 papers before exclusion criteria. Additionally 23 records were identified through other sources for instant Google engine, "my library" in Mendeley and some expert suggestions. The total number of papers obtained after elimination of duplicates was 3650 and after application of the exclusion criteria, it ended on 3540. Tacking in to account the selected keywords combinations that allowed greater result were "body motion" and "computer workers" with 159 and "posture assessment" and "tracking" with 70. The search result after application of the exclusion and eligibility criteria is 12 articles, Figure 1. No systematic review on this topic was found during this search. Most of the discarded papers focused on movement analysis in clinical scope or human modeling for other purposes or were conducted manually or self-report methods. Another reason for eliminating some papers was using electromyography (EMG) in their studies. Few comprehensive studies have been conducted in field of posture analysis for computer workers with sensors or videos. The results of these few studies are difficult to summarize, since the differences are so high in terms of methodology and sample studied. The main methodological results are summarized in Table 1.

According to the present research many studies analyzed posture of computer workers with questionnaire-based method or electromyography (EMG). Since computer workers use the chair in their workstation and have various movement on upper limb, articles that were conducted in same workstation or simulated situation have been considered. All studies were quite small, including 1 to 20 participants. Five studies were conducted in laboratory or simulated the work situation in laboratory environment (Seaman et al.,2010; Antonio Diego-Mas et al.,2014; Bataller-Cervero et al., 2016; Hwang et al., 2016; Valero et al., 2016) and just two of them (Botter et al., 2013, 2016; Kingston et al., 2015) specifically were oriented to study computer workers in real time. In order to investigate the posture analysis in different situation and for different goals, various body parts were analyzed, in each study the subjects were asked to perform specific movements: flexion-extension, abduction/adduction and lateral bending.

The most frequent analysis were conducted respectively high to low, involving nine (Botter et al., 2013; C.-H. Chen et al., 2013; Hernoux & Christmann, 2015; Kortier., 2015; Ogris et al., 2012; Seaman et al., 2010; Valero et al., 2016; van den Noort et al., 2014; Vignais et al., 2013) focused on hand and arm, four studies (Kortier et al., 2015; Peppoloni et al., 2016; Vignais et al., 2013; W. Y. Wong & Wong, 2008b) analyzed the trunk , five papers (Kuster et al., 2016; Vignais et al., 2013; Valero et al., 2016; Qin et al., 2014; Peppoloni et al., 2016) analyzed the movement of neck and shoulder, three paper (Holte et al., 2012; Antonio Diego-Mas et al., 2014; Botter et al.,2013),

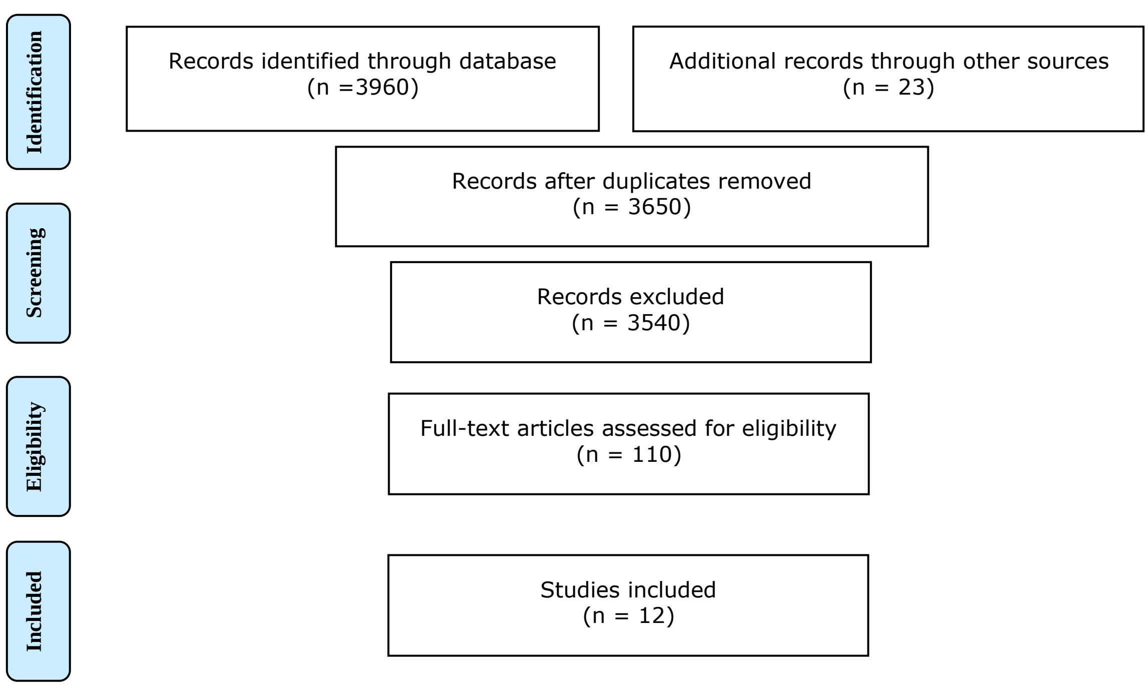

Figure 1. Flow diagram of included studies

analyzed posture. Other organs were analyzed in these studies: back (Valero et al., 2016), finger wrist (Botter et al., 2016; Choi, Yoo, Kang, Seo, & Kim, 2016; Schmuntzsch et al., 2013), head (Morency, Whitehill, & Movellan, 2010), seated posture (Albert et al., 2014; Karakolis et al., 2016), hip and knee and ankle (Menguec et al., 2013) were analyzed.

According to these studies it is possible to divide all analyzed papers in three categories, according to the method used: 1) video 2) video and sensors 3) sensors (Table 1). Sensors: This systems permit a real-time ergonomic assessment of manual tasks in various environments: hand pose estimating (Kortier et al., 2015), evaluation of human body motion (Valero et al., 2016), risk assessment for biomechanical load in repetitive efforts (Peppoloni et al., 2016). In this systematic review, three types of sensors were analyzed: ultrasonic positioning system (UPS), inertial measurement units (IMU) and inertial and magnetic measurement system (IMMS).

In relation to video or image analysis: The use of marker-less video is simple and does not require attaching sensors to the body which often interferes with the job and restrain movement patterns and exertions. This could lower the instrumentation barrier and make routine analysis of upper limb work-related occupational hazards more accessible to general industry (C.-H. Chen et al., 2013). In this systematic review three type of devices for video based methods were analyzed: kinect range sensor, simple monocular camera, Vicon motion capture, Panasonic digital video camera, XSensor. These devices record body positions at high sampling frequency, thus providing accurate and reliable estimates of frequency and duration of risk exposure.

Video and sensor combination: According to table 1 in some studies video and sensors are used simultaneously. In some studies, they were used for one object and in other studies different segments were monitored separately. For example Albert et al. (2014) pressure on the seat and back rest were analyzed by sensors and seat pressure mapping and video analysis was used to monitor changes in driving posture such as cycles relating to right turn, left turn, passenger stops and driving straight were clipped using video capture software.

According to the applied methods, different results can be obtained. However, the application of video recordings requires overcoming problems such as: lack of accuracy when the tracked subject is not visible to the camera, is sensitive to lighting, illumination changes, background clutter and camera calibration. However video base analysis is cost effective and widely available and it is easy to operate and provide rich texture information of the scene (C. Chen et al., 2015).

On the other hand the result of sensor base device is sensitive to sensor location on the body and sensor drift and intrusiveness of wearing single or multiple sensors (C. Chen et al., 2015). Although they are cost effective, widely available, have a high sampling rate, can work in total darkness and can work in unconfined environment.

Table1: Methodological summary of methods

References	Type	Equipment	Body part	Task
(Seaman et al., 2010)	video	Two Panasonic video cameras and 3DMatch software	hand	push, pull or lift
(C.-H. Chen et al., 2013)	video	A JVC video camera	Hand(HAL)	Repetitive task(reaching and grasping)
(Morency et al., 2010)	video	Simple monocular camera	head	free head motion
(Antonio Diego-Mas & Alcaide-Marzal, 2014)	video	Kinect range sensor and Microsoft Kinect Software And OWAS	postural loads	Lab
(Kuster et al., 2016)	Video and sensor	camera Vicon System compare with KinectOne	shoulder	Shoulder abduction in sitting and standing
(Hernoux & Christmann, 2015)	Video and sensor	Microsoft's Kinect 3D camera Compare with 3d Gloves	hand	Complex manipulative tasks
(W. Y. Wong & Wong, 2008b)	Video and sensor	3D video-base motion analysis system, Vicon camera compare with three sensor modules and a portable posture monitoring system	trunk	daily activity
(W. Y. Wong & Wong, 2008a)	Video and sensor	smart garment and video-base motion analysis system	Trunk	Daily activities.
(Albert et al., 2014)	Video and sensor	3DMatch software+ Panasonic video camera and XSENSOR series + sensor series pressure+ X3 MEDICAL software	Trunk , neck, shoulder, elbow, pressure on the seat	Bus driver
(Menguec et al., 2013)	sensor	A Vicon motion analysis system + eight infrared cameras and soft motion sensing suit with hyper elastic strain sensors	hip, knee, and ankle	Flex/extend leg's ankle, knee, and hip joint individually (sagittal plane motions)
(Ogris et al., 2012)	sensor	IMU and UPS	hand	manipulative gestures
(Vignais et al., 2013)	sensor	wireless Colibri IMUs compare with RULA	Upper limbs	Industrial manufacturing
(Kortier et al., 2015)	sensor	IMMS	hand and trunk	various hand and trunk tasks
(Valero et al., 2016)	sensor	IMUs, accelerometers, AT-BAN system	full body	complex task in nonstationary work construction:
(Qin, Lin, Faber, Buchholz, & Xu, 2014)	sensor	IMU + active-marker infrared motion analysis	shoulder	Repetitive Assembly work
(van den Noort et al., 2014)	sensor	wireless IMMS sensors and xsens software	thorax, scapula and arm	arms ad/abduction
(Peppoloni et al., 2016)	sensor	IMU Compare with RULA	neck, trunk and upper limb and Strain Index	Cashier (reaching and grasping)
(Choi et al., 2016)	s ensor	IMUs	Hand, fingers and wrist	hand flexion/extension
(UPS: ultrasonic positioning system, IMU: inertial measurement units, (HAL): The hand activity level, IMMS: inertial and magnetic measurement system)				

4. CONCLUSIONS

In recent decades the motion analysis with sensor, video and other equipment has become a common tool for researchers in assessment of the human posture and movement, thanks to the technical and procedural improvements that have made it possible to reduce manual ergonomic assessment errors and to the development of appropriate biomechanical models.

A review of different approaches for human movement was done and it was noted that the simultaneous utilization of the different methods allows achieving better human movement analysis for computer users, compared to situations when each one of them was used individually. Far as much as computer workers have various tasks like keyboard activities, mouse activities and idle activities over time, so that it is truly the variation in patterns of computer activities driving the variations in physical exposures. We recommend in future study researchers can use our result and select appropriate method according to purpose of study, type of worker's tasks, body part that will be measured, their budget and limitations. In future systematic review, they can clarify the criteria that each equipment can measure.

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