NURSE-TABLET AND STANDING COMPUTER WORKSTATION INTERACTION: POSTURE IN THE CONTEXT OF A HEALTHCARE SETTING

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Abstract

Poor workplace ergonomics are responsible for a large percentage of injuries and illnesses that cause lost days of work. Nurses in particular have high risk of musculoskeletal injury due to repeated physical strains and awkward postures during the workday. Nurses also spend a significant amount of time using computers for specific medical assistance software and programs. Standing Computer Workstations (SCWs), which are popular mobile computer housing units often used in medical facilities are often being replaced with mobile tablets. Nursing requires prolonged periods of time documenting patient management upon mobile SCWs, and has the burden of moving these computer-housing units from room to room. However, since tablets lack physical supports upon how a user must physically interact, postural differences should be analyzed to compare device type effects while standing. To better understand the relative merits of SCW's and tablets in healthcare data entry and information retrieval, standing posture was analyzed using motion analysis technology. Sagittal joint angles in the head, neck, and trunk, as well as coronal asymmetries in the upper body were analyzed based on device and interaction types. Subjective workload, technology acceptance, benefit or barrier and perceived exertion were analyzed based on the variables. Postural differences were not significantly different in respect to different device types. Interaction types showed significant head tilt and neck incline differences with respect to SCW interaction types. Subjective questionnaires showed most prevalent difference with higher workload among tablet usage. Posture data from study varied with past studies involving non-contextual methods, and should be studied further.

Introduction

Annually, over 19 million workers in the United States are diagnosed with work-related musculoskeletal disorder (WRMSD) (Frymoyer & Cats-Baril, 1991). In 2009, the U.S. Department of Labor projected that WRMSDs account for 45 to 54 billion dollars annually. Specific occupations are at a greater risk for WRMSDs, based on the tasks they are required to complete. Today, technology determines what the workers of occupations spend their time interacting with. For typical office workers, static and repetitive movement is determined as the largest risk factor for WRMSDs (Ariens et al., 2001). Healthcare workers are commonly affected by WRMSDs. In 2014, the Bureau of Labor Statistics reported that there were 10,900 cases of WRMSDs in the occupation of Registered Nursing (RNs) and 27,020 cases in Nursing Aides (NAs) (AFL-CIO, 2014). Nurses are susceptible to injuries due to regular extreme postures, most notably involving physically handling of patients (Hignett, 1996), and many other nursing duties that involve harmful postures (Nelson, Fragalla & Menzel, 2003). Technology plays a large part in healthcare occupations, and requires nurses to spend up to 19% of an average day documenting patient information on computers (Korst et al., 2005), while most commonly interacting with electronic health records (EHRs) for documentation and information retrieval of patient information. For EHR applications, standing workstations are very common in healthcare facilities, both at patient's bedside and mobile computer units. In a 1997 study, it was estimated that 20%-40% of a nurse's day is spent using a standing computer workstation for various applications (McHugh & Schaller, 1997). Since 1997, technology has drastically changed in healthcare, as Penoyer et al., (2014) found that 73% of bedside nurses in acute hospital settings reported that at least half of a workday is spent using EHR systems. Nurses working in hospital settings have traditionally used standing workstations for documenting patient information, and now tablet devices have increased in popularity among healthcare employees. Tablets are found to be an integration solution between traditional desktop PCs and smart phones for medical information retrieval and documentation (Anderson, 2013). Past research suggests that computer users are at risk of neck, lower back, upper back and shoulder discomfort, however, discomfort in these areas have been found to decrease by allowing adjustment of workstations to specific anthropometries (Lale & Korhan, 2015). Mobile computers cannot be adjusted for user anthropometry, and should be analyzed for postural tendency differences while interaction takes place.

Statement of the Problem

Healthcare professional's posture should be compared during EHR interaction with SCWs and Tablets while undergoing data entry and retrieval.

Purpose of the Study

The purpose of the study is to determine how different EHR device interaction causes unhealthy posture. The outcome of this study will help us better understand potential postural risks associated with EHR interaction on tablets and standing computer workstations. This study may provide recommendations for touch interface redesign, redesign of physical workstations, or ergonomic posture interventions for workstation end users.

Significance of the Study

Past research suggests that standing computer workstations increase the risk to the back, neck and arms due to the high variability between adult anthropometry while standing (McHugh & Schaller, 1997). Standing workstations also force users to work with very flexed, or lordotic positions at the spine. Over long periods with incorrect posture, trunk flexion could promote low back disorders (Adams & Hutton, 1985). Other research suggests that computer screen height is very important to assess, and relates to the posture and health of the neck (Kietrys, McClure & Fitzgerald, 1998). Research involving human-tablet interaction suggests that more neck flexion is observed when using tablets vs. computers when seated (Young et al., 2012), and chronic excess neck flexion is found to be linked to neck pain (Ariens, et al., 2001). Recent research suggests that while standing upright and typing on a tablet, more neck flexion has been found during typing tasks in comparison to information retrieval on a tablet. Additionally, the smaller the device being used, greater the neck flexion was found (Ning et al., 2015). Frontal kinematic imbalances have not been researched when interacting with tablets. Deviations in frontal plane can also cause musculoskeletal stress in the body. Static posture has been studied by analyzing asymmetrical deviations in the head, shoulders, hips and knees. It is suggested that there is more risk of obtaining MSDs when greater asymmetrical deviations in the frontal plane (Pîrvu, Pătraşcu, Pîrvu & Ionescu, 2014).

Postural deviations have been researched in previous studies comparing human-tablet interaction while seated with different usage configuration conditions (Young, Trudeau, Odell, Marinelli & Dennerlein, 2012). A comparison of mobile phone and tablet interaction effects on standing posture has been studied with dependent variables comparable to information retrieval and documentation (Ning et al., 2015), however only neck position has been studied. The present study will analyze specific effects EHR systems have on users while interacting with standing computer workstations and tablets. In addition to analyzing neck flexion as past studies have done, head tilt, trunk angle, head asymmetry, shoulder asymmetry and trunk asymmetry will also be analyzed.

Research Terms

In this study, the following abbreviations will be used as terms:

SCW	Standing Computer Workstation
MSD	Musculoskeletal Disorder
WRMDS	Work Related Musculoskeletal Disorder
EHR	Electronic Health Record
WMW	Wall-Mounted Workstations
COW	Computer on Wheels
VDT	Visual Display Terminal
WRULD	Work-Related Upper Limb Disorder
PDA	Personal Digital Assistant
MVC	Maximum Voluntary Contraction
EMG	Electromyography
RULA	Rapid Upper Limb Assessment
TLX	Task Load Index
TAM	Technology Acceptance Model

Literature Review

Introduction

In 2013, there were 21,900 cases of non-fatal nursing injuries in the United States (AFL-CIO, 2014). MSDs relate to the largest reason for lost days of work (Health and Safety Executive, 2013). Nurses are accustomed to fatigue through extreme postures and intense lifting situations (Hignett, 1996), and are typically mobile throughout a working day (Kuo-Wei & Cheng-Li, 2012) which correlates with increased fatigue. In addition to the main tasks of caring for patients, nurses interact with technology for information retrieval and documentation for long durations throughout an average workday (McHugh and Schaller, 1997). Some of these technologies being used are non-traditional, and should be studied for user's ergonomic risk factors before being widely accepted. If research on tablets finds poor posture while being used in nursing, the at-risk nursing population of developing MSDs should not interact with devices that further increase their risk.

Occupational MSDs

It is estimated that 11.6 million workdays are lost each year due to Musculoskeletal Disorders (MSDs) (Health and Safety Executive, 2013). In 2007, occupational MSDs accounted for $1.5 billion in illness costs (Bhattacharya, 2014). There are a number of factors that affect the risk of obtaining MSDs, such as job environment and organization, which can affect repetition and lead to MSDs. The environment outside of work, or external responsibilities can create difficulties during the working day, and cause increased risk of work related injury. Psychosocial issues including genetics, gender, social class, personality have also been found to affect WRMSDs (Bernard & Putz-Anderson, 1997). Independent of these issues, the physical stressors that workers are exposed to while doing their job can lead to WRMSDs. Physical aggravations are considered a very prominent WRMSD risk. Heavy physical work, for instance, has been found to compress the spine, and stress other extremities of the body (Marras et al., 1995). Transferring of objects by lifting is a risk factor associated with MSDs, and lifting motions involving twists and rotations of the trunk especially increases the risks of injury (Kelsey et al., 1984). Past research interested in populations who regularly procure biomechanically awkward positions, or non-neutral posture, suggests indications of increased risks of MSD development (Punnett et al., 1991). Areas of the body that are most often affected by WRMSDs include low back, neck, shoulders, and different areas of the upper extremities (Punnett & Wegman, 2004). In order to analyze occupant risk factors, posture deviations are often analyzed with basic assessment tools, such as with the Rapid Upper Limb Assessment (RULA) (McAtmney & Cortlett, 1993). RULA investigates upper limb disorders, which are commonly associated with non-neutral positions and force production from lifting or holding objects. Posture deviations, such as flexed postures, cause compressive forces in joints (Adams & Hutton, 1985) and in effect, induces muscular fatigue (Cortlett et al., 1986). As deviations in posture increase away from neutral, or "recommended" positions, joint loads tend to increase, and muscular efficiency may be compromised (Hrysomallis & Goodman, 2001). Kang et al. (2011) found that the type of work and repetition in which an individual performs duties affects habitual posture. This study tested one group of regular Visual Display Terminal (VDT) users and one group of non-regular VDT users, and found that the group of regular VDT users showed much greater neck flexion deviations than non-users when interacting with computers. In neck flexed positions, it is known that greater muscular loads are placed upon the trapezius muscles to remain upright and static, which over time, can cause common WRMSDs, such as tension neck syndrome (TNS) and VDT syndrome (Aaras, 1994).

The physical composition of a particular computer workstation is believed to be associated with the likelihood of physical discomfort and MSD acquisition (Fogelman & Jeffrey, 2002). Abnormal neck and shoulder deviations, such as common postural deficiencies from inappropriate fitting of VDT equipment can cause frequent pain (Dong-hyun, Hun & Won-gyu, 2013). Risk factors associated with VDT syndrome in seated workstations include improper monitor and keyboard position, which can increase discomfort in the head, neck, shoulders and back (Fogelman & Jeffrey, 2002). Standing desks have become increasingly popular in the recent years, and are used in many office and industrial settings, including healthcare. In the past, no evidence suggested that upright standing workstations cause's reason for concern regarding MSD development (Hoogendoorn et al., 1999). However, in a more recent study by Tissot, Messing and Stock (2009), it was suggested that standing workstations did show associations with low back pain, especially when occupants do not have the option of sitting.

Standing workstations often have the ability of being adjusted to a worker's height. Therefore, this should eliminate considerable biomechanical variability among workers potential postures, and decreases the chance of working at undesirable positions. Mobile device interaction exposes users to more posture variability in comparison to traditional fixed, standing workstations. Ning et al. (2015) suggested that neck flexion deviations among mobile tablet users were linked to at-risk postures. In occupations such as nursing, the musculoskeletal system is strained not only from momentary high force tasks, but also from repetitive movements, such as EHR use. In conclusion, it appears that there is an increased risk of MSDs in susceptible nurses based on nursing VDT tasks. Therefore it is appropriate that a comparison is made between different computer workstations to better understand potential physical hazards.

Nurses and MSDs

In 2014, the U.S. Department of Labor reported jobs with the highest number of occupational MSDs. Of the occupations reported, listed at #1 and #5 were Nursing Assistants and Registered Nurses, respectively (Bureau of Labor Statistics, 2014). In the nursing occupation, physically handling patients for readjustment and transport causes risk factors associated with harmful posture deviations while lifting patient's body weight. Hence, back pain is very prevalent among nurses. Leighton & Reilly (1996) found that 56.4% of nurses admitted to having low back pain. In addition to the low back, neck and shoulder pain is found to be the second most common MSD in the nursing occupation. In a study which evaluated a nursing population of ages 50-54 years (largest age group population of nurses), 51% of the nurses recorded having regular neck and shoulder discomfort, and 57% of nurses had low back pain (Nelson, Fragalla & Menzel, 2003). Similar results were discovered in a study involving 260 nursing students, as 59.2% of students admitted to low back pain, and 34.6% of them had neck and shoulder discomfort (Smith & Leggat, 2004).

Nursing Risk Factors

Predominate physical risk factors in nursing includes regular bouts of heavy lifting, non-neutral and isometric postures, fatigue and cognitive workload.

Heavy Lifting

Loading history has been found to be a major risk factor involving back pain (Adams, 2004). Loading the body of external weight, or lifting history, has been found to be a clear cause of low back pain specifically in the nursing occupation (Videman et al., 1984). Nurses are often responsible for patient handling and transfer situations. The volume of patient handling instances depends on a patient's ability to move, as some nurses are responsible for lifting patients very often depending on the part of the clinical setting in which they work. Smedley, Egger, Cooper & Coggon (1997) suggest that nurses who are responsible for lifting patients more frequently are more at risk of MSDs. High-risk patient handling responsibilities include moving patients to and from wheelchairs, toilets, beds, bathtubs and chairlifts. In a study by Garg, Owen & Carlson (1992), nurses were analyzed for risk assessment during a workday, and it was found that nurse's lower lumbar region experienced compressive forces of 830 pounds to 1,101 pounds during normal patient handling activities. Due to common injuries attributed to patient handling, recommendations have been made to bring changes to the nursing work environment, including the development of organizational tactics, such as patient lifting teams and no lift policies. More importantly, technology for patient lifting is believed to help the nursing occupation (Nelson & Baptiste, 2004). Since 2005, the Safe Patient Handling Policy has provided hospitals with patient lifting technology and safe lifting programs for active nurses (American Nurses Association, 2015), however, nurses are still ranked amongst occupations with the highest rate of work related injury (Bureau of Labor Statistics, 2014).

Non-Neutral Posture

Posture deviations, or extreme postures, occur anytime a segment of the body over extends or remains in a flexed position (Adams & Hutton, 1985). Extreme postures place high torque on joints, creating tension on the muscles and ligaments that surround a joint (McGill, 1991). Patient handling is not the only action that causes nurses to have such high prevalence of MSDs. Feeding, dressing and bathing patients causes harmful posture deviations and awkward positions for lengthy periods of time (Nelson, Fragalla & Menzel, 2003).

Isometric Posture

Nurses are accustomed to high amounts of isometric activity during a workday. Isometric activities could include patient documentation, bedside care and bedside support. During patient documentation, nurses may be sitting or standing at a computer workstation or desk. Nurses provide bedside care when administering medications and services to a patient in bed. While standing or sitting, nurses often bend down towards patients in bed, holding spinal-flexed position while caring for patients. These biomechanically awkward isometric bedside support activities can total up to 38% of a working day (Korst, et al., 2005). In general, isometric posture deviations that are unchanged for more than 3-4 seconds can decrease the oxygenated blood supply to particular areas of the body (Anghel, Argesanu, Talpos-Niculescu & Lungeanu, 2007). Poor posture can lead to a weakening of either the agonist or antagonist muscles responsible for keeping the body still during isometric contraction. Unlike isometric contraction, concentric movement require agonist muscles to move a segment around a joint. During concentric contraction, antagonist muscles are responsible for lengthening, allowing agonist muscles to shorten (Padulo, 2013). If poor posture is chronically activated, co-contraction of antagonists and agonists will eventually be unattainable, as muscles become accommodated to strength imbalances. If similar isometric activities occur over time, a result in necrosis and deterioration can affect muscles, ligaments and tendons. Herniated spinal discs result from recurrent poorly positioned forward flexion at the trunk (Valachi & Valachi, 2003).

Fatigue on Posture

Nurses have a physically demanding job and are responsible for intense physical stress throughout a work shift. In addition to the moments of high intensity during patient handling, nurses walk significant amounts throughout a workday. Welton, Decker, Adams & Zone-Smith (2006) found that nurses walk four to five miles on average per day. One study quantified the fatigue that nurses experience throughout a shift by testing for fatigue before and after a working shift (Ling Hui et al., 2001). Nurses in this study wore surface EMG sensors on the erector spinae muscles of the back during an isometric holding task, and it was found that the nurse's posterior muscles were significantly more fatigued by the end of the shift. Proprioception is related to muscular fatigue, and is defined as the self-perception of body position during and between movements (Johnson, 2010). Past literature shows that fatigue ultimately decreases proprioceptive abilities and movement sensations (Myers, Guskiewicz, Schneider & Prentice, 1999) (Pedersen et al., 1999). Findings such as these suggest that if nurses are fatigued, there will be a lack of awareness of body position when performing work. Fatigue will not be measured in the current study, but it is a relevant risk factor that could promote unnoticed, variable posture deviations.

Cognitive Workload on Posture

Cognitive workload has the potential to directly affect postural ability. Specifically, high mental demand is found to limit proprioceptive abilities in the body (Andersson, Yardley, & Luxon, 1998), which has been measured by studying variability in Center of Gravity (CoG) and Center of Pressure (CoP). Cognitive workload should be analyzed and compared to posture variability within nursing tasks.

Background of Nursing Information Systems

Aside from direct patient contact, nurses are responsible for completing documentation of patient information. It's estimated that nurses spend up to 19% of an average working day documenting patient information (Korst et al., 2005) and depend on information retrieval during treatment. Mobile technology solutions are an important factor for nursing informatics support, and the software involved in this technology has been extensively evaluated for efficiency of use. Electronic health records (EHRs) have been distinguished as valuable systems that decrease complications and cost in the medical industry (Amarasingham, 2009) by consolidating patient documentation and medical information retrieval on one platform.

Documentation

The most important aspect of medical documentation includes the quality in which a patient is cared for (Tufo & Speidel, 1971). Researchers have found traditional methods of paper documentation in healthcare to be inefficiently organized and a detriment to patient care. In 2002, IDX Corporation, an EHR developing company, estimated that nurses who are obligated to use paper-based systems spend 30% of a normal day documenting information. The goal for improved patient documentation is to decrease the time nurses spend documenting information and focus more on the patients themselves. Over time, computer based documentation increased in popularity and bedside computer terminals were added to few facilities for integration. In the early years of computer documentation, research studies compared handwritten documentation to computer-based documentation and found that 25% of handwritten documents contained error that could be eliminated with computer information system use (Hammond, Johnson, Varas & Ward (1991). Overall, bedside terminals increased efficiency and were accurately estimated to gain popularity. Medical providers also considered EHRs successful tools at this time, and became a common source for healthcare documentation and information retrieval. Most importantly, EHRs were ultimately found to decrease wasted effort and errors, as well as increase overall productivity due to easy access of information, and improvements in the quality of documentation. (Schmitt & Wofford, 2002). Thus, the affiliation between bedside computers and EHRs has shaped into a healthcare facility standard, with options including wall-mounted workstations (WMWs) and computer on wheels (COWs), which are more generally known as standing computer workstations (SCWs). In 2012, The Health Information and Management Society (HIMSS) reported that 87% of healthcare facilities in the United States provide clinicians with COWs to integrate with computer information systems, which were the first modes of 'mobile' healthcare documentation technology. Mobile solutions are suggested to decrease the cost of furnishing a facility of bedside computers by 36% (Cuda, 2013), as every room in a facility doesn't need to be outfitted with a static computer terminal. Due to bedside computer and EHR accessibility of information retrieval, standards for patient care quality have been improved to balance technological improvements in documentation and information retrieval.

Information Retrieval

Diagnosis, medication reconciliation and treatment methods are examples of common information retrieval needs in the nursing occupation (Cogdill, 2003). In the past, nurses used textbooks and journals to independently find clinical answers. As technology has embedded itself in the medical field, solutions for mobile information retrieval have become a typical purpose for Personal Digital Assistants (PDAs). In 1996, the Palm Pilot 1000 was introduced as the first PDA in which simple medical information applications were used (Johnson & Broida, 2003). Later, patient tracking applications allowed clinicians to share information about patient history to other PDA devices (Manning & DeBakey, 2004). Researchers have studied the effects that PDAs have on healthcare practices, including a project which observed a health system that did not have previous experience with PDAs, then implemented PDAs for comparison of 'before and after' (Grasso, Genest, Yung & Arnold, 2014). As a result, medication discharge lists were specifically determined to show error decrease from 22% (before PDAs) to 8% after. By the year 2005, 40% of healthcare providers in the United States and Canada had adopted the use of a PDA during work (Yen-Chiao, Xiao, Sears & Jacko, 2005). Mobile smartphones have exceeded the technological capacity that traditional PDA devices once provided, thus, 'smartphones' are now used as exclusive medical informatics devices, which can operate custom medical applications (Phillippi & Wyatt, 2011). In a study involving questionnaires given to nurses (Berglund el al., 2007), 86% of nurses determined that the most important function PDAs provided was pharmaceutical information retrieval, followed by patient medical information. Other than patient documentation, EHRs contain informational objectives including provider-to-provider communication, decision support, registration applications and information access (Schiff & Bates, 2010). Medical information retrieval through EHRs is accessible using bedside computer workstations, as well as with the latest mobile advancement, tablets.

Tablet EHR Advantages

In a study involving 2,000 healthcare providers, it was found that nearly 50% of the providers used tablets for occupational use (Mace, 2013). Anderson (2013) tested the effects tablets had in healthcare environments by providing four physicians with iPads that contained specific useful medical applications, and reported that tablets provided efficient advantages. In one study, it was reported that 54% of nurses used duplicate methods to document patient information (Moody, Slocumb, Berg & Jackson, 2004) due to spatial concerns within an exam room. Duplicate documentation methods such as transferring notes from pen/paper records to computer-based records may decrease the accuracy of a documenter's notes, which makes for a greater chance of human error by inaccurate record keeping. Tablets are also a much more economic option as an EHR device, as Cuda (2013) reports that SCWs cost almost $7,000 per nurse (assuming 50 nurses in a facility at once). Furthermore, companies involving the development of modern EHRs understand the value of touch device compatibility. In 2012, 20 EHR software systems were ranked by popularity of use, and each of the top three companies (eClinicalWorks, McKesson, Cerner) at that time provided an interface for touch friendly devices, supporting the important role of tablets in healthcare.

Workstation Biomechanics

Past research has shown prevalent results linking computer use to upper extremity risk factors, however, results associating posture and workstation biomechanics are not as consistent (Gerr, Marcus & Monteilh, 2004). Normal risk factors associated with MSDs include both repetitive movements and static postures (Ariens et al., 2001). While at computer workstations, users must remain static to balance posture and vision for efficient performance (Ankrum & Nemeth, 1995). Static postures require isometric contraction for stability (Caron, 2003), which can lead to the modification of posture positioning, thus, creating repetitive unhealthy joint loads (Leighton & Reilly, 1995). Nurses currently use different forms of workstations to connect to EHR applications. Standing computer workstations are currently the most common bedside technology solution amongst nurses. In 1997, McHugh and Schaller estimated nurses were obligated to work 1.6 to 4.8 hours at a standing workstation each day. Currently, tablets are popular in the medical field due to economic factors and the portability that they provide, however, human-tablet interaction has been shown to cause repercussions such as significant neck flexion during use (Ning et al., 2015). In order to accept tablets for regular use in an already at-risk population of attaining neck, shoulder and back disorders, biomechanics of tablet use should be researched before replacing traditional SCWs.

Computer Workstations

Standing workstations allow users, such as nurses, to communicate easily and share visual display units (Vink, Konijn, Jongejan & Berger, 2009). Considering the functionality of standing workstations, they are the most common workstations used for EHR applications. Visual Display Terminal (VDT) Syndrome is a common muscular disorder among seated computer workers who have misaligned cervical posture within the sagittal plane (Hickey et al., 2000), as the head deviates too far forward about the trunk. Szeto & Raymond (2002) compared posture of symptomatic and asymptomatic individuals of work-related neck and upper limb disorders (WRNULDs) and found that symptomatic workers showed to have significantly higher degrees of head tilt, neck flexion and acromion protraction. Another study showed similar findings, as a neck flexion of greater than 20 degrees was linked to neck pain (Ariens et al., 2001). Aaras et al. (1997) compared how sitting vs. standing workstations without forearm support loaded the trapezius muscles of the back, which is a relevant topic regarding SCWs used by nurses. It was found that the strain on trapezius muscles directly related to MSD incidents in the neck and shoulders (Aaras, 1994), as workers interacting with standing workstations were shown to apply significantly less strain (compared to sitting) upon on the trapezius muscles. Much less is known about how seated vs. standing workstations affect users in the low spine. Seated positions are believed to produce higher compression upon the lower back due to increased trunk angle flexion, however, there's often more posture variability in seated positions, which allows more oxygen to access muscles, relating to less fatigue induced (Callaghan & McGill, 2001). Due to medical facility layouts, nurses typically don't have the opportunity to both sit and stand at bedside workstations, so standing workstations should be researched for ergonomic concerns.

Mobile Workstations

Nurses are regarded as very mobile occupation (Kuo-Wei & Cheng-Li, 2012), as they are constantly moving between wards, rooms and offices. For this reason, PDAs and other mobile devices are considered valuable assets. Mobile device use is not traditionally regarded as physically taxing on the musculoskeletal system, but research suggests that MSDs may be connected to repeated exertions of mobile device use, which causes users to manipulate posture in unnatural ways (Chany, Marras & Burr, 2007). VDT syndrome is not just linked to traditional computer use, but any type of musculoskeletal issue associated with cervical flexion of the upper spine during excessive device interaction (Gong, 2015) (Berolo et al, 2011). Szeto & Raymond (2002) compared the posture of users while interacting with three different sized devices: Desktop PCs, Notebooks and Subnotebooks. As the device screen size decreased during experimentation, cervical and thoracic deviations became more flexed, with cervical deviations being the most pronounced in each anatomical plane. It was hypothesized that thoracic flexion was lesser in comparison to cervical deviations due to the responsibility of the thoracic region to stabilized the rest of the body during typing performance. Additionally, typing performance was much better on a desktop than on smaller devices. One research study specifically tested how tablets and mobile phones cause functional performance differences, as well as posture and muscle activity changes as a result of typing vs. reading (Ning et al., 2015). Neck flexion angles, similar to other studies, were greater as result of mobile phone and typing (vs. reading) use. Significant differences were found between EMG data in the left and right extensor muscles in the neck, which suggest that frontal plane postural imbalances were apparent, which could cause compressive forces to damage the spinal column in the sagittal plane with repeated use. However, only neck deviation in the sagittal plane was analyzed, limiting the study's findings relating to common MSDs associated with the nursing occupation. Researchers also only studied very basic functions on computer devices and not specific applications that are used in contextual environments.

Damecour et al. (2010) measured standing muscle activity of the trunk with different desk support systems, including leaning on a desk with physical support and with no support. This study was meant to replicate how user typically interact with standing desks, and can be compared to that of standing workstations and tablets, as standing tablet interaction allows for no standing support. The study concluded that leaning on a desk did not produce evidence to suggest less muscle activation in large stabilizer muscles of the core or legs, but did suggest that users were closer to the workstation when supported by the desk, potentially decreasing the workload of the low back.

Workload, Technology Acceptance, Exertion and Barrier

The Technology Acceptance Model (TAM)(Davis, 1989) has been used in the past to determine experiential acceptance, specifically in regards to technological tools and applications. The TAM was built upon the Theory of Reasoned Action (TRA) (Ajgen & Fishbein, 1975), which is a theory developed to analyze intended behavior, and meant to target how to change the analyzed behavior. The TAM is directed towards analyzing the perceived ease of use (PEU), perceived usefulness (PU) and Usage (U) of technological interactions, and is regarded as a rigorous form of subjective analysis (King & He, 2006) that can be applied to comparing device types for technology acceptance.

In addition to technology acceptance, the workload of individuals while interacting with EHR devices should also be considered. Common practice in human factors research is to subjectively test workload with the NASA-TLX (Hart & Staveland, 1988). Workload is termed as a representation of the costs that users have while accomplishing goals or undergoing requirements (Hart, 2006), which can be measured through subjective experience and physiological consequence. Workload is important to measure in populations at risk of obtaining MSDs due to past research findings suggesting interactions between mental workload and physical posture stability (DiDomenico & Nussbaum, 2005). Variable mental demands have been controlled while undergoing different levels of cognitive tasks and measuring Center of Gravity (CoG) and Center of Pressure (CoP) displacements (Anderson, Yardley & Luxon, 1998)(Caron, Faure & Breniere, 1997). CoG and CoP indirectly determines postural sway as deviations away from neutral positions are collected. Postural control weakness is suggested while participants withstand high levels of mental demand, leading to inconsistent posture. Nurse's cognitive workload has been quantified in contextual studies by analyzing interruptions, and suggests that nurses are at risk of dealing with very high amounts of disturbances, ultimately leading to high levels of dual-task complexity (Redding & Robinson, 2009), increasing mental workload and potentially causing workload-posture interaction effects. Additionally, rating of perceived exertion (RPE) may identify potential differences in psychophysical strain between interaction types, as well as estimated exertions for longer periods of time (Borg, 1982). Recently, Anderson, Henner & Burkey (2013) designed a questionnaire with the goal of measuring user's judgement on whether a device was a benefit or barrier. The Benefit or Barrier questionnaire could be utilized to compare specific device types used by nurses for EHR interaction.

Method

Purpose

The purpose of this study was to identify postural differences of nurses while interacting with Electronic Health Records (EHRs) on tablet computers versus standing computer workstations (SCWs). This study also analyzed different interaction types, including patient documentation and information retrieval. Posture kinematic differences between variables will be tested to suggest which common device interaction is better suited for clinical EHR use. Subjective measurements were analyzed to compare differences between technological devices, including workload, technology acceptance, benefit or barrier and rate of perceived exertion.

Participants

The participants recruited for this project included nursing students from a nursing program at a state university in the United States. 27 (23 female, 4 male) participants were recruited, all of them were undergraduate students ages 20-50 (Mean= 24, SD=6.35) years. The participants were current students in the nursing program and were either first, second or third year program students, similar to the nursing student sample used by Smith & Leggat (2004). The nursing program administration deemed this research project acceptable, and allowed participants to be recruited within the program during normal academic sessions. To recruit participants, researchers attended scheduled nursing simulation sessions, and asked students if they would be willing to participate. If the students showed interest in participation, a screening protocol and consent process was used for the potential participants.

Consent

All nursing students who showed interest in participating in the study were provided an informed consent. The consent explained the procedure of the project, along with the potential risks and benefits of the experience, which involved the experience of using EHRs in a real-world clinical simulation. Upon being informed of the process, the participants were screened regarding physical anthropometry, vision and discomforts. The participants were not allowed to participate if they had any current physical disability or discomfort that would affect physical posture. The participants were also required to be of anthropometric standing height between the 5^{th} and 95^{th} percentile, had to be older than 18 years old, and if they had visual impairment of any kind they were required to be wearing their prescribed lenses or contacts at the time of testing.

Experimental Design and Implementation

Normal nursing simulations were used to gather experimental data. During typical simulations, two nursing students at a time were assigned to participate in clinical processes as a group. The researchers added one role to the experiment, which designated one student responsible for interacting with an EHR device during the experiment. If the nursing students consented to participate and met the requirements of the screening process, four Inertial Motion Sensors (IMUs) (STT, San Sebastian, Spain) were placed on specific landmarks of the body (Figure 1): Head (top), Cervical-7, Thoracic-10 and Sacrum.

Figure 1: Diagram of IMU sensor placements.

IMUs are wearable devices that are used to calculate 3D kinematic data. Each IMU sensor contains an accelerometer, gyroscope and magnetometer. Specific to the dependent variables in this study, the sensors were positioned on the participants to calculate upper body flexion/extension in the sagittal plane (trunk, neck and head) and asymmetry in the frontal plane (trunk, shoulder, head) (description of kinematic analysis: see Table 1)(diagram of kinematic angles: see Figure 4). The Sacrum sensor was dedicated as the reference sensor due to the lack of movement at this location, which was assigned for best accuracy of kinematic data. All incline data were projected on the sagittal plane, and asymmetries were projected on the coronal (frontal) plane. The sensors were attached to participants with Velcro straps on the Sacrum and the Throacic-10 landmarks. The head sensor was attached to a knitted hat, which was pulled snug on the participant's head to avoid shift from movement, and double-sided tape was used to fix the Cervical-7 sensor in place (for example of sensor orientations: see Figure 2). The IMU sensors were programmed to record at a frequency of 60 Hz. Before the data collection began, the participants had to stand upright and remain still in order to calibrate reference frame positions of the IMU sensors. Upon calibration, the normal nursing simulation began and deviations based on the calibrated IMU positions of the sensors provided angular kinematics over time of the participant's upper body biomechanics. The participants were provided with an EHR (SimChart, Elsevier, Amsterdam, Netherlands), which the students were already familiar with before the start of this project. Before the EHR was used during the experiment, researchers preloaded the EHR application with relevant material for the specific simulations, such as patient medical history and information provided by nursing professors. Although the participants were familiar with the specific EHR used during testing, the researchers provided a demonstration of the EHR application before starting the experiment. The EHR interface was designed for touch screen as well as desktop computers, as the screen zoom did not change between the tablet and laptop, however, when participants documented information a virtual keyboard would partially cover the main interface. Due to the different screen sizes (Tablet=9.7", SCW=14.0"), the stroke height and stroke width differed between the two device types (Tablet = 3.175 mm, 4.762 mm SCW= 4.762 mm, 6.350 mm).

Figure 2. IMU sensor orientation on nurse during experiment

One sample group of participants used a tablet (iPad 2, Apple, Cupertino, CA) with a 9.7” display to interact with the EHR while standing with no desk. The second sample group of participants interacted with the EHR on a laptop computer (Vostro 2420, Dell, Round Rock, TX) with a 14” display and was placed on a Standing Computer Workstation (SCW) (Neo-Flex Laptop Cart, Ergotron, St. Paul, MN) (examples of device interactions: See Figure 3), which was the normal laptop and SCW used in the simulation lab. Before the SCW group started testing, the work surface height of the SCW was measured and positioned at the standing elbow height for each participant, which is a recommended ergonomic height for standing computer users (Sauter, Schleifer & Knutson, 1991). The simulation laboratory used in this study had normal interior lighting with additional natural daytime light. The participants were asked to remain engaged with the EHR throughout the experiment, but were also told to communicate with other individuals in the simulation as normal. The researchers did not control whether a participant typed, and a variety of postures were observed. The length of the experiment varied depending on the needs of the educators running the simulation session. After completing the experiment, the participants in the study were asked to complete a series of post-experiment questionnaires.

Figure 3. Example of nurse interacting with SCW (left) and tablet (right).

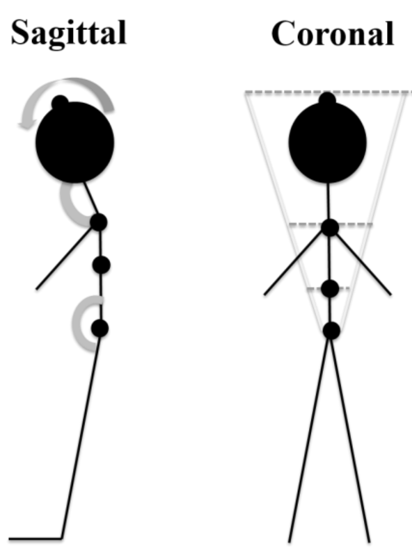

Figure 4. Diagrams of biomechanical angles measured on the sagittal (left) and coronal (right) planes.

Table 1. Biomechanical angles and the description regarding how the angle was standardized.

Dependent Variable	Sensor Data Description
Head Incline	Angle of head sensor rotation about the sagittal axis respect the calibrated sacrum position.
Neck Incline	Angle of head sensor respect cervical-7 sensor projected on sagittal plane.
Trunk Incline	Angle of the cervical-7 sensor respect the thoracic-10 sensor projected on sagittal plane.
Head Tilt	Angle of head sensor respect the sacrum sensor projected on coronal plane.
Shoulder Tilt	Angle of the cervical-7 sensor respect the sacrum sensor projected on coronal plane.
Trunk Tilt	Angle of the cervical sensor respect the thoracic-10 sensor projected on coronal plane.

Data Analysis

The experiment consisted of two levels of independent variables that were tested with different sample groups. The first independent variable consisted of device type, as participants either used a Tablet or SCW during the experiment. The second independent variable consisted of two levels of interaction types, which were Documentation (DOC) and Information Retrieval (IR). A webcam (Microsoft LifeCam Studio, Seattle, WA) recorded video of and remained focused on the participants being analyzed throughout the experiment, and was used to define the specific interaction types during data analysis. The interaction types were defined after the trial took place from the webcam footage. Documentation (DOC) was defined as participants typed on a device, and information retrieval (IR) was defined when participants viewed the device display without manipulating a keyboard with their hands. Each type of interaction was recorded by the time displayed from the webcam footage. Different segments of interaction types were defined as the participants changed between IR and DOC depending on the nursing demands during the experiment. The segments began when a participant started IR or DOC, and ended when that segment was completed. If the users changed their posture and continued with consistent IR or DOC, the segment was extended. The segment lengths and amounts varied between the individual participants, as the mean length of time for IR segments was 14.37 seconds (SD = 8.92), and the mean DOC segment time was 12.45 seconds (SD = 7.85). Segments shorter than 2.0 seconds were not considered as a consistent interaction, and the data from these segments were not analyzed. The average number of IR segments were 2.90 (SD = 1.09) and DOC segments were 2.80 (SD = 0.92). The interaction type video footage was independent from the IMU kinematic data, as the video footage was synchronized with the data from the IMU recordings to identify interaction events within the kinematic data. The synchronized IMU data were then exported to Microsoft Excel to organize and identify total means between IR and DOC with regard to the device type used. The kinematic from IMU sensors collected six dependent variables in angular degrees: Head incline, neck incline, trunk incline, head asymmetry, shoulder asymmetry and trunk asymmetry. The measurements for asymmetry were rectified to measure a total angular deviation, and inclination data were analyzed as positive and negative values regarding joint flexion and extension in degrees. Each dependent variable was analyzed with respect to the independent variables of device type (Tablet vs SCW) and interaction type (IR vs DOC). Two sample T-tests were used to analyze a between-subject sample (α 0.05) to test for significance between Tablets and SCWs. Equal or unequal variance was assumed based on the outcome of a Levene's F-test for each comparison. A separate series of Paired T-tests were used to compare differences between IR and DOC, depending on device types. The P Values from the T-tests were corrected using a Bonferonni correction. Minitab statistical software (State College, PA, United States) applied all statistical significance testing.

Results

A total of 27 nursing students participated in the study. Three of the participant's data showed to have sensor connectivity issues and were excluded from kinematic data analysis. One of the 27 participants failed to complete the post-test survey for subjective data analysis.

Kinematic Data

The dependent variables did not show any significant differences in kinematic measurements when comparing Tablets and SCWs (T-test significance outcomes: see Table 3)(for device type comparisons: see Figure 5). Significant findings were only found amongst SCW data, including significantly more head incline during IR (p = 0.004) (for interaction type comparison: see Figure 6). Neck flexion was also significantly more deviated during DOC as opposed to IR when using SCWs (p = 0.006). There were non-significant differences in SCW asymmetries between IR and DOC.

Table 2. Mean kinematic angles in degrees (°) (*Indicates significant difference, p<0.05) (N=23)

	Head Incline		Neck Incline		Trunk Incline	
	Tablet	SCW	Tablet	SCW	Tablet	SCW
IR	24.175	*29.574	9.827	*14.160	9.827	14.160
DOC	23.425	*25.449	13.502	*10.391	9.207	15.161
	Head Asymmetry		Shoulder Asymmetry		Trunk Asymmetry	
	Tablet	SCW	Tablet	SCW	Tablet	SCW
IR	7.911	5.874	3.088	2.601	2.857	2.411
DOC	8.587	6.211	2.508	2.959	4.252	2.215

Table 3. T-test outcomes for comparing significant differences (Device types and Interaction types) (*Indicates significant difference as shown in Table 1) (N=23)

Tablet vs. SCW				Tablet vs. SCW			
Information Retrieval	*df*	T	*p*	Documentation	*df*	T	*p*
Head Incline	21	0.87	0.396	Head Incline	14	0.33	0.748
Neck Incline	21	0.04	0.967	Neck Incline	21	-0.68	0.506
Trunk Incline	20	1.52	0.145	Trunk Incline	21	0.32	0.751
Head Asymmetry	21	0.88	0.388	Head Asymmetry	13	1.22	0.245
Shoulder Asymmetry	21	0.45	0.659	Shoulder Asymmetry	21	-0.41	0.684
Trunk Asymmetry	21	0.44	0.662	Trunk Asymmetry	21	-2	0.058
IR vs DOC				IR vs DOC			
Tablets	*df*	T	*p*	SCWs	*df*	T	*p*
Head Incline	20	-0.4	0.7	Head Incline	22	-3.64	*0.004
Neck Incline	20	-0.36	0.723	Neck Incline	22	-3.4	*0.006
Trunk Incline	20	-0.62	0.551	Trunk Incline	22	0.97	0.354
Head Asymmetry	20	-0.96	0.361	Head Asymmetry	22	-0.68	0.509
Shoulder Asymmetry	20	0.04	0.97	Shoulder Asymmetry	20	1.73	0.114
Trunk Asymmetry	20	2.06	0.066	Trunk Asymmetry	22	-2.06	0.064

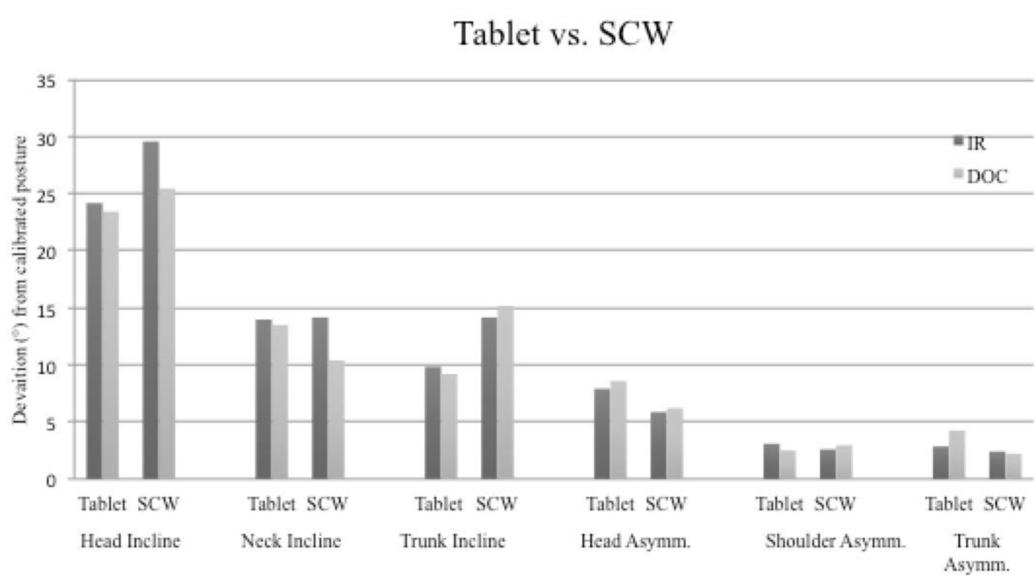

Figure 5. Mean kinematic data in degrees comparing device types (Tablet vs. SCW) (N=23)

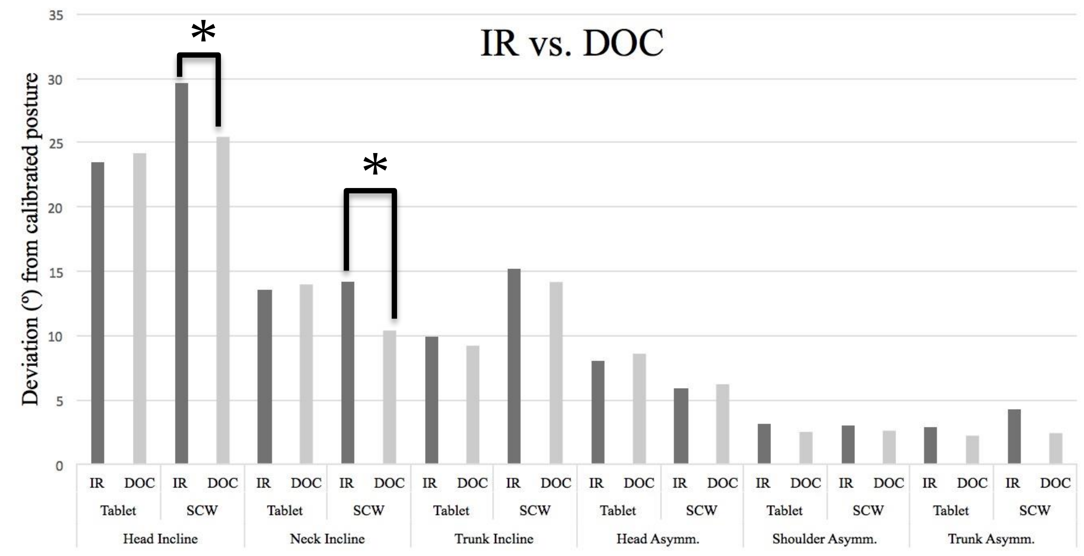

Figure 6. Mean kinematic data in degrees comparing interaction types (IR vs. DOC). (* indicates significant difference, p<0.05) (N=23)

Subjective Data

Subjective data were organized and compared between device types (Tablet vs SCW) (for TAM, Benefit or Barrier and RPE results: see Table 3). The Technology Acceptance Model (TAM) was found to be slightly lower for Tablets in comparison to SCWs in regards to both Perceived Usefulness (PU) and Perceived Ease of Use (PEU). A Two sample T-test was used to compare weighted NASA-TLX workload averages due to the difference observed (for NASA-TLX results: see Table 4). The higher Tablet scores compared to SCW scores did not show significant differences between average workload device scores (p = 0.269). The Benefit or Barrier questionnaire suggests that SCWs had slightly higher scores pertaining to "benefit". Rate of Perceived Exertion (RPE) compared IR and DOC and estimated exertion for an 8-12 hour shift. Slightly higher exertion scores were found amongst Tablet users for each of the three categories of exertion.

Table 3. TAM, Benefit or Barrier and RPE results showing mean (and SD).

Questionnaire		**Tablet**	**SCW**
TAM	PU	3.61 (0.68)	3.87 (0.74)
	PEU	3.94 (0.89)	4.00 (0.70)
NASA-TLX	Mean	50.72 (15.95)	44.02 (14.34)
Benefit or Barrier	Mean	3.77 (0.56)	3.88 (0.49)
RPE	DOC	10.38 (2.10)	9.15 (2.37)
	IR	10.15 (2.44)	9.23 (2.31)
	SHIFT	12.23 (2.68)	11.15 (2.85)

Table 4. NASA-TLX results showing overall mean and mean categorical weights (and SD).

NASA-TLX	**Tablet**	**SCW**
Overall	**50.72 (15.95)**	**44.02 (14.32)**
Mental	2.84 (1.02)	3.35 (1.75)
Physical	2.15 (1.02)	1.71 (1.22)
Temporal	2.53 (1.39)	2.35 (1.34)
Effort	3.07 (1.07)	3.00 (1.07)
Frustration	0.77 (1.42)	1.28 (1.62)
Performance	3.53 (1.69)	3.28 (1.27)

Discussion

Device Types

The lack of significant differences in kinematic data between device types is dissimilar from past research that has compared user posture while operating smaller vs. larger devices (Ning et al., 2015)(Szeto & Raymond, 2002). More neck deviation has been associated with users that interact with smaller devices, such as mobile phones (Ning et al., 2015). However, mobile phones and tablets are considerably different in regards to display sizes, which suggests reason for large posture differences between device types. It is suggested that the lack of kinematic difference between Tablet and SCW users in the current study may be due to the less substantial difference in screen display sizes between the tablet and laptop. In a separate study, users interacted with different size devices and were seated at a workstation (Szeto & Raymond, 2002). The users were only allowed to adjust seat height and screen tilt, and significantly more neck flexion was found while using the smaller devices. The lack of difference between postures in the current study may be related to the easier posture adjustments in the head, neck and trunk when standing. This is consistent with research that suggests individuals will initially alter their posture to avoid future discomfort (Gregory & Callaghan, 2008). Thus, standing computer and tablet interaction may afford users functional biomechanical adjustments to avoid posture deviations that cause discomfort.

The biomechanics of users in this study have been compared to ergonomic guidelines for estimated posture risk. Ariens et al. (2001) associated high rates of discomfort occurrence with frequent neck flexion angles of 20° or more. Neither tablets nor SCWs promoted average neck flexion higher than 15.1°, which may suggest a relatively low chance of neck discomfort to occur with repeated and frequent use. This implication does not completely correspond to the Rapid Upper Limb Assessment (RULA) guidelines, as neck flexion angles associated in this study are categorized as a level "2" of 4, which is estimated pertaining to posture risk (McAtmney & Cortlett, 1993). Non-significant trunk angle differences between Tablet and SCW users show RULA classification differences, as tablet interactions were presented with a higher RULA score ("2" of 4 vs. "1" of 4), which suggests more risk of lower back discomfort when interacting with tablets.

Interaction Types

Significant differences were found in interaction types (Tablet vs. SCW). Information retrieval interactions on SCWs promoted users to lean more forward at the neck and with less forward head tilt when documenting information. This is suggested to be due to nurses observing the environment while recording patient information and remaining in a "head up" position when typing. This may be influenced by the QWERTY haptic keyboard on the SCW laptop used in this study. Every participant was a ‘touch typist’, and it was not vital for them to look at the haptic keyboard when typing. This trend was not observed during Tablet use, as IR vs. DOC was very similar by comparison. Future research should analyze how younger populations adapt to using touch screen devices, as haptic keyboards may show less of an advantage in performance over time.

These findings are notable because of the differences found in past research when comparing IR and DOC on different types of devices, as significant differences were found between interaction types (Ning et al., 2015). The contextual methods used here may be the reason for a lack of interaction type differences. Tablet users in past studies have been instructed to simply document information without being concerned about acting on external factors, which is dissimilar from current study, as Tablets showed consistency in posture. In past research, tablet users have been prompted to undergo specific interaction tasks at a time. The current study did not define these tasks for users, as the interaction types were defined after the user completed the study. Thus, users may have adjusted their posture ‘more neutrally’ in order to effectively be able to react to the needs of transitioning between information retrieval and documentation, depending on the contextual events during the simulations. These differences highlight the importance of contextual study for high-risk environments.

Subjective Measurements

Subjective measurements were utilized to compare differences between device types and interaction types. Similar to the quantitative kinematic measurements, the subjective measurements showed consistencies between device types and interaction types. The results of the NASA-TLX, however, indicated higher workload with Tablet devices in comparison to SCWs. Carayon & Gurses (2004) stresses that high workload in clinical settings increase the rate of error, and ultimately add risk to patients. Categories of the NASA-TLX indicated that ‘Performance’ (success in accomplishing a task) was an influence between device types as higher demand was recorded when using Tablets. The kinematic data from the current study suggests differences in posture due to the lack of haptic feedback when typing on tablets, and may be related to increased performance demand needed when typing on tablet keyboards. The kinematic data also show that there was more consistency between interaction types when using a tablet, which may suggest higher workload was needed to remain stable in order to operate tablet devices. Isometric posture deviations that last for three to four seconds can reduce normal blood-oxygen supply to affected regions of the body (Anghel, Argesanu, Talpos-Niculescu & Lungeanu, 2007). It is possible that if tablet use increases needed isometric contractile force to remain still, perceived workload may be higher.

Contextual Effects

The current study greatly differed from prior similar research due to the contextual environment of the nurse simulation setting. Past research using non-contextual settings may significantly differ the overall posture of users while interacting with computers. For instance, the non-contextual methods of Ning et al. (2015) found that users interacted with tablets while holding the device with notably greater neck flexion (M=43.00°) in comparison to the current study (M=11.66°). This suggests that the contextual setting of nursing students greatly affected posture while having the responsibility to remain engaged with external demands, such as communicating with other individuals, aside from computer interaction. This suggests that users may interact with computers with less deviation in the neck to promote more communication with other individuals in the shared setting. The results of the current study can be closer compared to that of a study concerned with seated posture differences between desktop, notebook and subnotebook computers. Cervical flexion of users in seated positions and typing on a subnotebook computer (M=10.6°) (Szeto & Raymond, 2002) more closely related to results of the current study (M=13.50°), but was not researched in contextual settings. Some real-world environments do not differ wildly from laboratory environments (such as the office ergonomics study outlined in Nathan-Roberts, Chen, Gscheidle & Rempel (2008) which was not dissimilar to office workers' experience), however the current study more closely replicated a high-stress, multi-person, interruption-rich environment that is more similar to what nurses experience than previous laboratory studies. There are no past studies to compare head tilt data in regards to tablet use, however, the current study showed more head incline deviations in comparison to neck incline, which may suggest a more relevant posture repercussion during human-computer interaction more social environments. Past research suggests that increased head tilt is associated with computer users that experience neck and shoulder discomfort (Szeto, Straker & Raine, 2001) and may cause increased neck and shoulder discomfort in at-risk nursing populations. The largest deviation in head incline in the current study is associated with SCWs during information retrieval (M=29.57°), which was found to be significantly more deviated than when documenting on the same device type (M=25.44°). The results indicate that head tilt and neck flexion trends complimented each other during SCW use, and may be a variable of social factors associated with the contextual intercommunication between healthcare professionals and patients. Patient-centered care (PCC) is a model that medical systems have adopted to focus on communication between patients and caretakers (Stewart, 2003), and participants in this study may have adjusted their posture promote PCC during experimentation.

Limitations

In regards to limitations among participants, the mean age of nurses in this study was 24 years, however, the largest age group of in the nursing occupation is between 50-54 years. It is possible that the kinematic posture data from this study limits the representation of an older nursing population. Additionally, only one EHR was used in this study (SimChart, Elsevier, Amsterdam, Netherlands), and it was strictly designed to be used in academic simulation settings, which may not represent the most relevant EHR interfaces that are used in industry. Similarly, this study was limited to using only one type of SCW, as it would have been ideal to test multiple types of relevant SCWs to compare posture differences. Computer screen size has the potential to affect the posture of users (Szeto & Raymond, 2002). The different computer devices used in this study had different size screens (9.7" tablet, 14" laptop), which may have affected how individuals orient themselves, regardless of the type of interaction taking place. This study could have controlled for a consistent screen size between device types to reduce the chance of screen size alone, affecting posture. A similar control for keyboard size could have been implemented, as the keyboard on a laptop was larger than the virtual keyboard on the tablet.

Conclusion

This study suggests limited differences when comparing posture deviation among relevant EHR computer devices currently used in healthcare. Significant kinematic inclination differences in the head and neck were found between information retrieval and documentation when using standing computer workstations. Overall, asymmetry was not shown to be a relevant risk factor when comparing device types or interaction types. Workload differences were not shown to be significant between device types, however 'Performance' is suggested to be a potential indicator of increased workload associated with tablet use. Subjective information related no major differences between Tablets and SCWs in regards to technology acceptance, 'benefits or barriers', or perceived exertion. Arguably the most important outcome from the current study suggests that more research should be undergone to analyze how contextual environments, such as in healthcare, may influence posture during human-computer interaction, as this study showed sizable differences between prior human-computer interaction posture studies involving non-contextual protocols. In the present time, technology allows people to constantly work using mobile devices, which suggests the importance of researching how mobile technology affects posture in contextual environments.

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Appendix

Appendix A Informed Consent

INFORMED CONSENT OF PARTICIPATION

TITLE OF STUDY
Human-tablet and SCW interaction: Posture in health care occupations

NAME OF RESEARCHERS
Dan Nathan-Roberts, Ph.D, Tim Visich, Graduate Student, Deirman Kamaruddin, Undergrad Student
Department of Industrial and Systems Engineering, San Jose State University

PURPOSE
To better understand the relative merits of Standing Computer Workstations (SCWs) and tablets in healthcare data entry and data consumption, standing posture should be analyzed using motion analysis technology. User joint angles during tablet and SCW usage should be compared to ergonomic standards. Qualitative information regarding technology acceptance and workload will be analyzed alongside biomechanical data. The result of this study should help indicate physical ergonomic concerns comparing the advantages and disadvantages of common types of devices used for EHR interaction.

DESCRIPTION OF PROCEDURES
You will have 4 Inertial Motion Unit (IMU) sensors placed on your upper body and proceed to participate in the schedule simulation session (See Figure 1). The IMU sensors are smaller and lighter than a pager and it will not limit the movement ability. Within the simulation, you will be retrieving information or document information on an EHR by the use of the Computer on Wheels (COW) or the tablet. Once you have completed the simulation, you will be given a questionnaire for experiential feedback.

Figure 1: IMU Sensor Placement

RISKS
There are no external risks in addition to the normal liability involved with regular student simulation sessions used in nursing program courses.

BENEFITS
You will gain a better understanding on using EHR and be able to apply it in the real world setting.

COMPENSATION
Upon the completion of the experimental trial, you will receive a gift card for a free large coffee at Philz Coffee.

PARTICIPANT RIGHTS
Your participation in this study is completely voluntary and you may refuse to participate. If you agree to participate, you have the right to stop at any time without penalty and receive full compensation. You also have the right to skip any survey question that you do not wish to answer.

CONFIDENTIALITY
The results of the study will not be associated with you in any way. We are required to keep a copy of this informed consent document, but it will be kept separate from the study results. No records are kept that allow your name to be associated with your responses in the study or on the survey. Your responses will be anonymous.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study.

- For further information about the study, please contact Tim Visich, Graduate Student.: timothy.visich@sjsu.edu or at (989) 289-4115.

- Complaints about the research may be presented to Dan Nathan-Roberts, Ph.D.: dan.nathan-roberts@sjsu.edu or at 408-924-7501.

- For questions about your rights or to report research-related injuries, please contact Dan Nathan-Roberts, Ph.D.,: dan.nathan-roberts@sjsu.edu .

PARTICIPANT SIGNATURE
Your signature indicates that you voluntarily agree to participate in the study, that the details of the study have been explained to you, that you have been given ample time to read this document, and that your questions have been satisfactorily answered. You may request a copy of this consent form for your records.

Participant's Name (printed) *SJSU ID*

Participant's Signature Date

INVESTIGATOR STATEMENT
I certify that the participant has been given adequate time to read and learn about the study and all of his/her questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits, and the procedures that will be followed in this study and has voluntarily agreed to participate.

Signature of Person Obtaining Informed Consent Date

Appendix B Pre-Trial Questionnaire

Pre-Trial Questionnaire Device Used: Tablet / SCW
Date: _________ Researcher: TV / DK Participant ID:

PRE-TRIAL QUESTIONNAIRE

1. Are you over 18 years old? *(Please circle Yes/No)*

Yes No

2. For **Females -** is your height over 4'11" and under 5'9"? *(Please circle Yes/No)*
Yes No

For **Males -** is your height over 5'4" and under 6'4"? *(Please circle Yes/No)*
Yes No

3. Do you have any musculoskeletal disorders or discomforts that currently affect your posture? *(Please circle Yes/No)*
Yes No

4. Do you have normal visual acuity, or are you wearing corrective lenses at this time? *(Please circle Yes/No)* (glasses/contacts are okay)
Yes No

5. Do you have, or have you used a mobile tablet? *(Please circle Yes/No)*
Yes No

6. What is your age? __________ years

7. What is your sex? __________

=== For researcher use ==

___ Subject not eligible ___ Subject eligible

Researcher: _________

Appendix C Post-Trial Questionnaire

Post Trial Questionnaire #1 Device Used: Tablet / SCW
Researcher: TV / DK Participant ID:

Please rate on a scale of 1-5 (1 totally disagree – 5 totally agree) regarding each statement below.

Totally Disagree *Totally Agree*

Item to answer	**1**	**2**	**3**	**4**	**5**
Using the *device* in my job helps me to accomplish tasks more quickly					
Using the *device* improves my work performance					
Using the *device* increases my work productivity					
Using the *device* enhances my effectiveness at work					
Using the *device* makes it easier to do my work					
I find the *device* useful in my work					
Learning to operate the *device* has been easy for me					
I find it easy to get the *device* to do what I want it to do					
My interaction with the *device* is clear and understandable					
I find the *device* to be flexible to interact with					
It is easy for me to become skillful at using the *device*					
I find the *device* easy to use					

Post-trial Questionnaire #2A Device Used: Tablet / SCW
Researcher: TV / DK Participant ID:

Circle the Scale Title that represents the more important contributor to workload for the specific task(s) you performed in this experiment. Each box will have a single title circled. See example below:

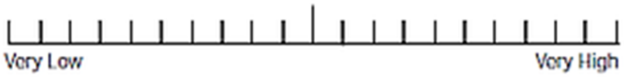
Effort or Performance	Temporal Demand or Frustration
Temporal Demand or Effort	Physical Demand or Frustration
Performance or Frustration	Physical Demand or Temporal Demand
Physical Demand or Performance	Temporal Demand or Mental Demand
Frustration or Effort	Performance or Mental Demand
Performance or Temporal Demand	Mental Demand or Effort
Mental Demand or Physical Demand	Effort or Physical Demand
Frustration or Mental Demand	

Post-trial Questionnaire #2B Device Used: Tablet / SCW

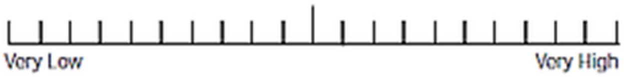
Researcher: TV / DK Participant ID:

When interacting with the EHR…

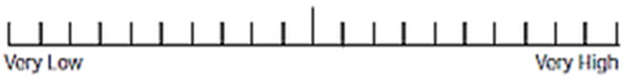
1. **Mental Demand:** How mentally demanding was the task?



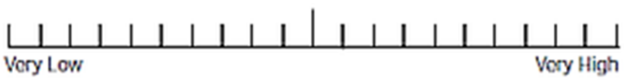
2. **Physical Demand:** How physically demanding was the task?



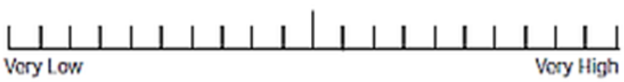
3. **Temporal Demand:** How hurried or rushed was the pace of the task?



4. **Effort:** How hard did you have to work to accomplish your level of performance?

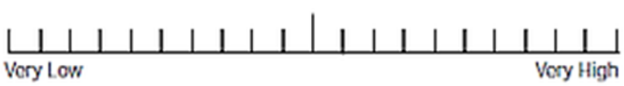


5. **Frustration:** How insecure, discouraged, irritate, stressed, or annoyed were you?



Performance: Please note that the following scale is a measure of how well you think you did the task.

6. **Performance:** How successful were you in accomplishing the task?



Post-trial Questionnaire #3 Device Used: Tablet / SCW

Researcher: TV / DK Participant ID:

Please rate on a scale of 1-5 (1 total barrier – 5 total benefit) on the aspects of the EHR <u>device</u> listed below.

Total Barrier *Total Benefit*

Item to answer	**1**	**2**	**3**	**4**	**5**
Weight					
Shape – carry					
Surface - disinfect					
Combo - handling					
Ruggedness					
Text and Graphics					
Keyboard					
Text entry errors					
Workplace training					
Workplace culture					

Exertion and Demographic Questionnaire Device Used: Tablet / SCW

Researcher: TV / DK Participant ID:

Perceived Exertion and Demographics

1. Rate your perceived exertion while documenting patient information on the device. *(Please circle number)*

6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Very, very light		Very light		Fairly light		Somewhat hard		Hard		Very hard		Very, very hard	Maximum

2. Rate your perceived exertion while retrieving information on the device. *(Please circle number)*

6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Very, very light		Very light		Fairly light		Somewhat hard		Hard		Very hard		Very, very hard	Maximum

3. Rate your estimated perceived exertion if you were to use this device for an 8 or 12 hour shift. *(Please circle number)*

6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Very, very light		Very light		Fairly light		Somewhat hard		Hard		Very hard		Very, very hard	Maximum

4. Did you notice any posture changes through the experiment? What do you think caused these?

5. Did you have any discomfort or concerns that we should be aware of?

6. Do you have any other feedback for us?

7. What is your age? _________

8. What is your sex? _________

9. What is your height? _________

Thank you for your participation in this experiment. We value your time and help. Please feel free to contact Dr. Nathan-Roberts (dan.nathan-roberts@sjsu.edu) with any questions or concerns.

=== For researcher use ==

Researcher: _________ Researcher Signature: _________ Date: _________