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Ergonomic Assessment Tool for Real-Time Risk Assessment of Seated Work Postures

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Abstract. This paper presents a posture assessment tool which utilizes the depth sensing techniques of a 3D imaging sensor for ergonomic risk assessment of seated worker's postures during controlled manual handling tasks. The tool, which has been developed to utilize the manual handling guidelines by the Health and Safety Regulators of some selected countries to measure and assess the postures of the upper bodies of operators, is tested to ascertain its effectiveness in assessing seated postures. The tool offers real-time posture assessment with real-time feedback to inform operators on when to adjust awkward seated postures. An experiment has been performed to record, assess and display the work postures of some seated operators in real-time with 'Good' and 'Awkward' postures identified with real-time feedback provided to the Operators. Results show that the tool can assess seated work postures in real-time which helps to reduce the rate of occurrence of Work-Related Musculoskeletal Disorders.

Keywords: Microsoft Kinect · Awkward Postures · Work-Related Musculoskeletal Disorders · Seated workers

1 Introduction

Manual handling tasks involving reaching, lifting, and assembly tasks sometimes require workers to sit throughout the day. Prolonged sitting as well as poor seated postures has been found to be among the leading causes of low back pain and consequently, Work-Related Musculoskeletal Disorders (WMSDs). [1–4]. The sitting posture has been identified as the worst body posture that exists because it forces the spine to adopt a non-natural posture which negatively affects it [5]. This is further explained by the fact that as the hips turn, greater pressure is applied on the spine when the trunk is bent forward, thereby leading to backaches and injuries [6].
Hence, maintaining good seated posture while working do not only improve efficiency, but also protects the worker's health [7]. Again, providing highly adjustable furniture along with adequate training of the users is a key requirement for ergonomic interventions of seated workers [4, 8]. Various international standards such as the ISO 5970:1979, have established recommended chair and table sizes with respect to the height of the user [9] and chairs with high backrests can reduce the likelihood of low back pains [3, 6]. The ANSI/HFES 100-2007 standard by the Human Factors and

Ergonomics Society recommends adjustable seat pan angles 0° - 4°, seat pan backrest of not less than 90° and seat pan recline not exceeding 25° from the vertical [10]. Good seating involves fitting the chair and desks within the body limits of the user and seats should vary depending on task demands [11].

This paper therefore focuses on the use of a developed Health and Safety (H&S) compliance posture assessment tool which utilizes a 3D imaging sensor for the real-time measurement, analysis and risk assessment of the work postures of seated workers during manual handling activities.

2 Review of Methods for Posture Measurements of Human Body

Work postures, if awkward, can lead to WMSDs among workers on the shop floor [12]; [13]. Measuring posture movements has been found to be very important for determining the risk of WMSDs in the workplace [14] and the methods for assessing these risks depends on the accuracy and precision of the data collection techniques employed [15]. For posture measurements, the reference point is described by the H&S Regulators as the neutral position which occurs when all the joints of the body are naturally aligned, with the trunk and head upright, arms by the side and forearms hanging straight or at a right angle to the upper arm, while the hand is in the handshake position [16–18]. Any deviation from the neutral position beyond the recommended limit often results in awkward postures. This posture can be detrimental to the health when held for prolonged period, hence, the need for a real-time assessment and feedback using appropriate tools with real-time capabilities, so as to inform the operators to adjust any awkward postures they adopt while working.

Research has revealed the existence of several tools developed for measurement of seated work postures. The Computer-assisted recording and long-term analysis of musculoskeletal load (CUELA system), a posture measurement tool developed by the German IFA [19], has been used to measure the body postures of seated Vehicle operators [2]. The system however, does not conduct risk assessment of these postures. Other tools available for measuring human postures include the Ovako Working Posture Assessment. System [20], the force plate [21, 22], photography [15, 22], tape, sensors [23], Microsoft Kinect etc. Photographs and videos often produces inaccurate measurement of joint angles as a result of distortions caused by camera placement issues [15]. Video camera alone cannot be used for posture data measurement, rather, the data obtained needs to be further analyzed using appropriate postural assessment tool [24].

A 3D marker-based measurement system and electromagnetic tracking system can be used to measure the relative angles of the upper bodies of seated workers [23, 25]. This tool can aid posture data collection and analysis in finer details [21]. Inclinometers based on triaxial accelerometers can be used to measure the flexion, extension and lateral extension angles of the human head and upper arms [26]. A photogrammetric analysis method can aid posture data measurements by measuring the joint angles of the upper extremities of the human body [27]. Models of cards has been used for recording seated dynamic work postures [20]. However, the aforementioned tools are either marker-based and as a result are required to be worn by the operator, or they lack the real-time feedback capabilities which can help to ergonomically improve worker's postures.

Microsoft Kinect has been recommended as an alternative method for posture measurement because of its cost-effectiveness, 3D motion capture and awkward posture classification capabilities [14, 15, 22, 28]. The sensor can measure human joint angles and can compute joint angles for possible posture evaluations and analysis [15, 21, 29, 30]. It has been proved to be a suitable tool for fast and reliable estimation of human morphology [31].

This paper focuses on the use of a Kinect-sensor-based, non-invasive posture assessment tool, developed by the authors, to measure as well as conduct ergonomic assessment of seated work postures of operators with real-time display, in compliance with the H&S Guidelines of different countries.

2.1 Recommended Guidelines while Seating to undertake Manual Handling Tasks

The recommended ergonomic seating practices of the selected Countries are highlighted in this section.

2.2.1. United Kingdom's Health and Safety Executive [4]

The seating recommended guidelines by the UK HSE for safe manual handling activities include:

- Avoid awkward stretching and twisting by placing objects within the recommended reach distance of -0.6m to +0.6m along the horizontal plane
- Ensure the workplace is well lighted to avoid adoption of awkward postures by the workers.
- Adjust the seat to enable you sit comfortably depending on the task.
- Avoid sitting to lift because it strains the back. If not, keep the object to be lifted close to the body.
- Work surface thickness of about 0.03m should not be exceeded.
- Avoid bending and twisting while sitting to handle rather place the load/materials at waist height on a rack.
- Avoid sitting to handle heavy loads.
- Weight of load to be handled while seated should not exceed 3kg for women and 5kg for men.

The following seat dimensions should be ensured;

- Adjustable seat height of 0.38m to 0.56m.
- Well-padded sitting surface of about 0.4m.
- Backrests with adjustable tilt angle of +5° to -5° and 90° to 110° angle with the sitting surface at adjustable height of between 0.17m to 0.3m.
- Adjustable armrests of 0.2m to 0.25m if needed (some jobs may not require armrests).
- Footrests for workers who need them.

- Chairs should pass the test stipulated in BS 5459 to be suitable for use.

2.2.2. United States of America's Occupational Safety and Health Administration [32–36].

- OSHA recommends that Operators should avoid sitting to lift
- Avoid bending while seating in a static position.
- Avoid excessive reaching while seating
- Height adjustable chairs or stools with adjustable lumber supports should be provided
- Footrests should be provided when needed or the feet should rest flat on the floor.
- Backrests, which support the natural curvature of the spine should be provided.
- Armrests must be soft and should enable the elbows to stay close to the body.
- Operators should be trained on the ergonomically correct handling practices, proper use of all equipment, safety precautions and recognition of hazards
- Use ergonomically designed hand tools that enables straight wrists.
- Ensure the elbows are held close to the body while handling or are bent between 90° and 120°.
- Avoid tilting the head rather use tilt work stations
- Do not bend the neck instead use height-adjustable workstations.
- Take frequent breaks
- Ensure the back is always supported
- When seated to handle, the knees must be about the same height as the hips
- The hips and thighs should be supported by a well-padded seat and parallel to the floor.
- Employers should provide highly adjustable chairs for multiple users.
- The chairs must have a five-leg base with casters for adequate support.

2.2.3. Germany's Federal Institute for Occupational Safety and Health (BAuA) [5]

- Chairs should be height and depth-adjustable with minimum depth of 0.38mm as recommended by EN 1335.
- Movable armrests of at least 0.2m length, 0.04m width and 0.2 to 0.25m height should be provided.
- Backrests should have at least 0.36m wide and 15° backward inclination reaching the shoulder.
- Adjustable neck support should be provided.
- Sitting surface should be inclined forward with the front edge radius ≤ 0,06m.
- Adjustable seat heights that makes room for at least 90° angle between the thighs and the calves should be provided.

- Footrests of at least 0.45m wide and 0.35m depth is required for short workers.

2.2.4. Singapore's Workplace Safety and Health Council [37, 38]

- When seated to work, the feet should be flat on the floor or supported by a footrest to reduce pressure on the thighs.
- The chair should be adjustable, stable and fitted with removable armrests and footrests.
- Backrests of 100 to 120° height/tilt should be provided.
- Adjustable work surface should be provided in such a way as to suit the needs of every worker.
- The recommended height of the chair should be between 0.35m to 0.5m while the width should be the dimension of the worker's hip + 0.5m which is approximately 4.6m in women. The depth should be between 0.38m to 0.43m.
- Hand tools should be ergonomically designed to minimize workers adopting awkward hand and arm postures.
- The physical environment, which include temperature, lighting and noise, should be conducive.
- To avoid excessive reaching and overstretching, more frequently used objects should be placed within the primary reach zone while less frequently used items are placed within the secondary reach zone.
- Sufficient room should be provided under the worktable for easy movement of the knees and legs.
- Do not handle heavy loads while seated.
- Group all the items that are frequently used together on the workplace.
- Avoid prolonged sitting. Always change postures.

3 Methodology

In this section, we discuss how the developed H&S compliance posture assessment tool was utilized to assess the postures of the upper bodies of seated operators. A total of ten (10) seated operators were tested while carrying out different manual handling activities. There were 7 males and 3 females whose age range from 25 to 35 years. None of the participants was unhealthy or had a case of back pain or injuries at the time of the experiment.

3.1 Overview of the developed Posture Assessment Tool

The developed tool consists of Microsoft Kinect sensor and a developed software application which enables the sensor to capture, analyze and assess the postures of workers during any manual handling operation. It can carry out ergonomic assessment in real-time and in compliance to the H&S guidelines.

The assessment tool was developed through appropriate codes written in C# Programming Language and which uses the APIs provided by the Kinect for Windows SDK and the WPF Application of the .NET Framework 4.5 in Visual Studio [39]. The algorithm enables the Microsoft Kinect to record the joint angles of seated Operators and display same in real-time.

The first step in the development of the tool was the computation of the vectors for each joint which triggered the joint angle measurement, using equation (1). The reference point which is the neutral position was then established such that any deviation from the neutral position results in awkward postures according to the recommendations of the H&S professionals.

$$\theta = {}^{A\,.B\ COS^{-1}}\!/_{|A||B|\,.} \tag{1}$$

The flow chart below shows how the developed tool assesses seated work postures in compliance with the H&S guidelines.

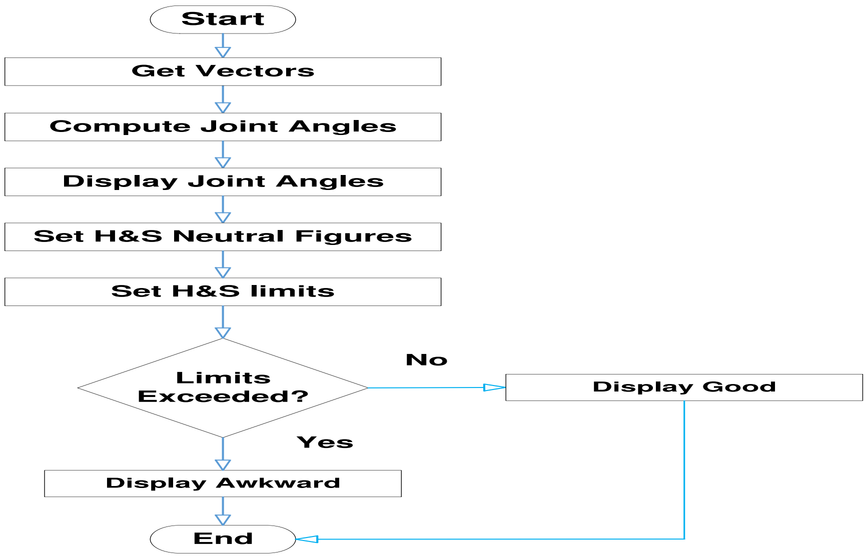


Fig. 1. Developed tool's flow chart

3.2 Procedure for Testing the Developed Tool

Participants were asked to handle a 1kg load under different ergonomic conditions while seated. These include far and normal reaching, bending to lift, bending and twisting, turning etc. Before starting the experiment, the participants were first familiarized with the manual handling regulations on safe handling techniques to avoid the risk of sudden injuries.

During the experiment, the neutral position of each participant was tracked using the sensor after which the rate of deviation of each joint from the neutral position is assessed with the result displayed in real-time to the participants. The chair used for the experiment was carefully selected to meet the H&S recommended standards for chairs, as described in section 1.

4 Results

4.1 Tracking the Neutral Position

H&S Professionals have established that awkward posture occurs when a part of the body deviates from its neutral position or its natural alignment and a neutral position is when the joints are naturally aligned with the trunk and head upright, the arms by the side, and forearms hanging straight or at a right angle to the upper arm, while the hand is in the handshake position with the wrists not bent or deviated and the buttocks and back are supported [16, 18, 34, 41–17]

The figure below shows the result obtained from tracking the neutral position of a seated participant. Notice that all the joints are specified as "Good" and displaced to a worker in real-time.

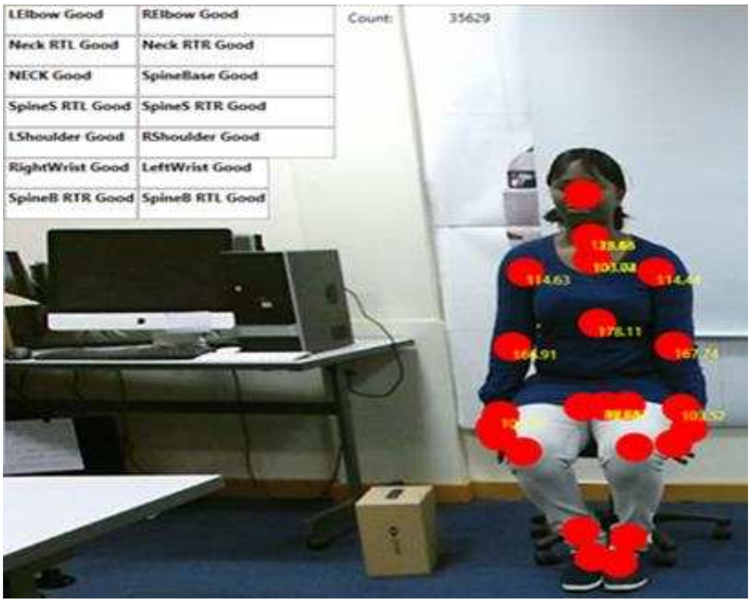
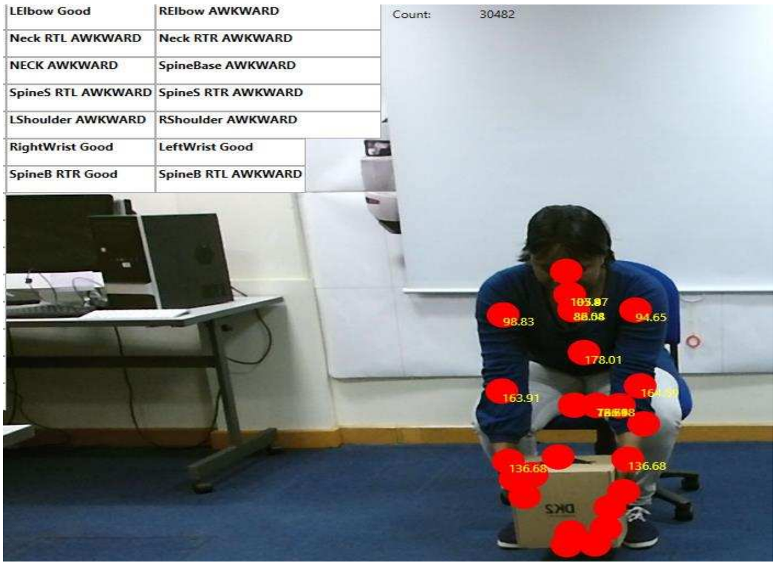


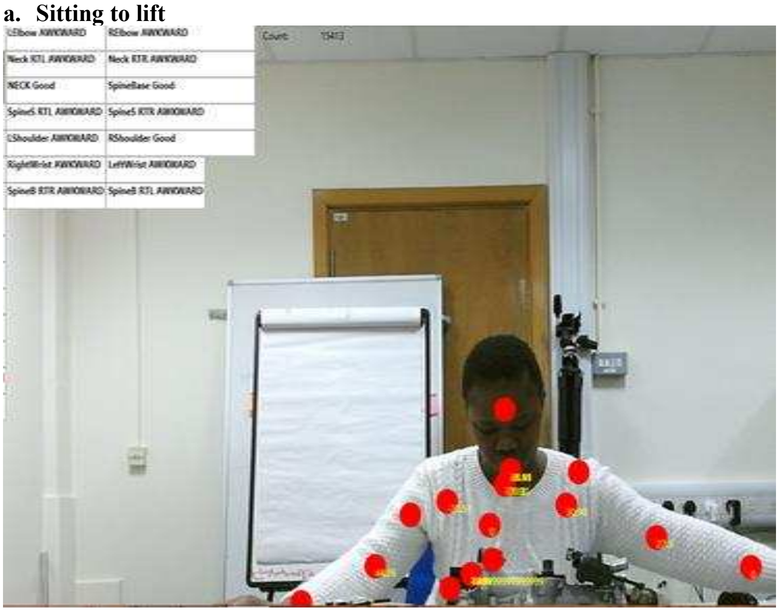
Fig. 2. Neutral position for seated human as specified by the tool

4.2 Tracking deviations from the Neutral position

In order to assess the tool further, deviations from the neutral position were simulated as shown in figure 3. The results show that the tool can detect awkward positions and can provide a real-time display of the assessed posture towards enabling a worker to adjust possible awkward postures.



a. Sitting to lift



b. Reaching to Pick while seated

Fig. 3. Sitting to handle

5 Discussion

The study is limited to posture assessment of the upper body of seated Operators. Having studied the manual handling guidelines as recommended by various H&S professionals, the relevant definitions are used to develop a posture assessment tool using 3D imaging sensors. The first step in the experiment was to ensure that the chair provided meets the standards as specified by the H&S professionals and highlighted in section 1. Next, the neutral posture of each participant was tracked as in figure 2. Finally, the deviations from the neutral position of each of the joints are assessed by the tool and displayed to the participants in real-time.

In figure 3a in which the Operator is bending to lift while seated, the left elbow, right and left wrists, and right hips (SpineB RTR), are displayed as 'Good'. This means that the specified joints have not exceeded the recommended limits as at the time of the capture. Every other joint, including the back posture (SpineBase), are displayed as 'Awkward'. This agrees with the UK HSE regulation that operators should avoid sitting to lift as it strains the back.

Figure 3b shows an Operator sitting to pick. The location of the items on the work table forced her to extend her left arm. Therefore, even though she did not flex/bend her back and neck beyond its neutral position (SpineBase and Neck = 'Good'), her elbows, wrists and left shoulder were stretched further away from their neutral positions resulting in 'Awkward' posture display for these joints. This real-time display can enable the Operator to adjust awkward postures so to minimize the likelihood of WMSDs.

6 Conclusion

This paper presents an ergonomic posture assessment tool which utilizes the depth sensing techniques of a 3D imaging sensor to conduct an ergonomic risk assessment of seated worker's postures during controlled manual handling tasks. The tool consists of the Microsoft Kinect sensor and its data-retrieval software application on which the H&S recommendations for manual handling activities were incorporated.

When tested on some selected seated Operators, the tool was found to measure and assess the postures of the upper bodies of the Operators with real-time feedback to the seated workers to alert them on when to adjust awkward postures which may be detrimental to their health when held for prolonged period.

Finally, the developed tool is beneficial to every workplace that seek to improve worker's productivity and plant efficiency as it can help to reduce the rate of occurrence of awkward postures among its seated workforce.

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