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Activity Simulation in Radiology: Chest X-Ray in Bed-ridden Patients

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ABSTRACT

Bedside chest radiography is one of the most performed medical imaging examinations requiring repeated movements and awkward postures from Radiographers. During this study the postural strain was evaluated in a simulation set using photogrammetry methods. Results showed demanding postures for X-ray tube manipulation and patient handling, requiring unacceptable arm flexion, and neck extensions, more evident for shorter radiographers. There is a need to improve communication between users, equipment manufacturers and designers to design equipment fitting Radiographers' needs.

Keywords: Ergonomics, Anthropometry, WRMSDs, Design, Usability

INTRODUCTION

Work-related musculoskeletal disorders (WRMSDs) are frequently observed in radiographers (Daniel et al., 2018), however, prevalence, and symptoms are slightly dependent on studies and imaging modalities included (Griffin, 2018; Lorusso et al., 2007; Pompeii et al., 2008; Siewert et al., 2013; Tinetti & Thoirs, 2019). Previous studies dedicated to diagnostic radiographers showed a prevalence of WRMSDs symptoms ranging from 67% (Lorusso et al., 2007) to 93% (Daniel et al., 2018) with back, neck and upper limbs as the most affected anatomical regions (Bright Ofori-Manteaw et al., 2015; Kumar et al., 2004b; Lorusso et al., 2007).

WRMSDs prevalence and symptoms are different in each radiographic modality and there is a need to understand the real work demands that contributes for WRMSDs symptoms. In a Lamar study (2004), low-back pain (LBP) is prevalent in magnetic resonance imaging (MRI) and interventional radiographers, while neck symptoms are more observed in mammography and computed tomography (CT) (Lamar, 2004). Nowadays, radiographers are confronted with high pressure from the organizations to face the patients diagnostic needs, impacting the WRMSDs symptoms, which can vary, according to the physical and psychosocial work demands (Bright Ofori-Manteaw et al., 2015; Kumar et al., 2004b).

Main ergonomic risk factors threaten radiographers health in Conventional Radiology are the adoption of awkward joints angles while positioning the detector under the patient, contributing to upper extremity and low-back pain (Kumar et al., 2004b). This issue was also identified in mammography, where awkward postures are adopted such as twisting the body and using unacceptable joints angles due to technical requirements for breast positioning and equipment handling (Costa, Oliveira, Reis, Viegas, & Serranheira, 2014).

Radiographers frequently manipulate obese and elderly patients, that can promote or aggravated muscular disorders due to the increase low-back load and lack of patient participation (Augner & Kaiser, 2019; European Occupational Safety and Health Administration, 2020; Griffin, 2018). High exposure to physical load was also identified in emergency rooms, having plain and mobile radiography as main responsible for back and upper limbs discomfort (Kumar et al., 2004a). Chest plain radiography performed to the patients in bed, is one of the most demanding X-ray exams.

The study aimed evaluate postural strain in radiographers doing chest plain radiography to bed-ridden in the Radiology department at Centre Hospitalier Universitaire Vaudois (CHUV). The professional activity performance was simulated to identify postural risk factors related to WRMSDs symptoms to take in consideration by stakeholders to promote an improvement in working conditions, and design occupational health and musculoskeletal prevention strategies.

MATERIAL AND METHODS

The targeted population was the diagnostic radiographers currently working in conventional radiology at CHUV and practicing bedside chest examinations for, at least, one year. Radiographers suffering from chronic or acute disease or being pregnant at the time of the study were excluded. For the simulations, two radiographers with extreme heights (shorter and taller) were identified. Another radiographer (weight $\geq$ 80 kg) was invited to simulate a passive patient. All participants gave their agreement to participate in this study.

Radiographers' prescribed work regarding equipment manipulation and patient handling for bedside chest X-ray examinations were examined through an internal document of CHUV (DIAG, 2020). The real work was also analyzed through a sequential observation of the radiographers in clinical context. Due to the presence of patients in real practice, simulations were required to record the performance of radiographers during bedside chest X-rays acquisition (Costa et al., 2014). The data collected during observations were used to ensure the similarity between the simulations and clinical activity. The simulations were performed with a radiography device from Philips (Philips Bucky Diagnost TH X-ray, Phillips Healthcare, Guildford, United-Kingdom). Chest X-ray examinations are generally performed by two

Table 1. References for postural assessment (European Standard BS EN 1005-4:2005 + A1:2008).

Body segments	References values		
	Acceptable	Conditionally acceptable	Not acceptable
Head/neck upward/downward bending	0° to 40°		< 0° or > 40°
Trunk forward/ backward bending	0° to 20°	< 0° or 20° to 60°	> 60°
Upper arm flexion/extension	0° to 20°	20° to 60°	< 0° or > 60°

radiographers, one to position the detector and manipulate the X-ray tube (designated as "performing radiographer-P"), and the other to handle the patient (called "helping radiographer-H"). Permutations of heights and radiographers' roles were simulated, resulting in 2 scenarios. The simulations were recorded using photogrammetry methods to assess postural variations of the main body segments (head/neck, upper arm, and trunk) according to Kapitaniak et al. method (2001). Three cameras (one camera Canon EOS 90D and two cameras Canon EOS 1300D, Tokyo, Japan) were placed in order to record simultaneously posterior and lateral views of radiographers. The videos were visualized by the observer and the most demanding and/or persistent postures were selected by two raters. The main body angles of observed body segments were measured with a dedicated software (Kinovea, version 0.8.15).

The joint angles were measured in simulated situations and classified into three categories according to European Standards (EN 1005-4:2005 + A1:2008): "acceptable", "conditionally acceptable", and "not acceptable" (Table 1) (British Standard, 2018).

The research project was submitted and accepted by two Ethics Commissions (EC): SwissEthics of Canton of Vaud (Reference: 2020-011774) and the EC of Centre Hospitalier Universitaire Vaudois (CHUV).

RESULTS

Two radiographers were asked to simulate a bedside chest X-ray performed in a bed in a conventional radiography room. Two scenarios were played according to the radiographers' anthropomorphic characteristics and radiographers' roles (performer-P/helper-H).

Main tasks for chest X-ray in bed-ridden patients were: i) Preparation to position the detector under the patient's back; ii) Patient handling to position the detector under the patient's back; iii) Control of detector's position; iv) X-ray tube positioning; v) Preparation for removing the detector from under the patient's back; vi) Patient handling to remove the detector from under the patient's back.

Scenario 1(Fig. 1) - Taller radiographer (performer-P) & shorter radiographer (helper-H)

i) Preparation to position the detector under the patient's back (A&B). The P and H radiographers prepared to lift the patient by performing a slight

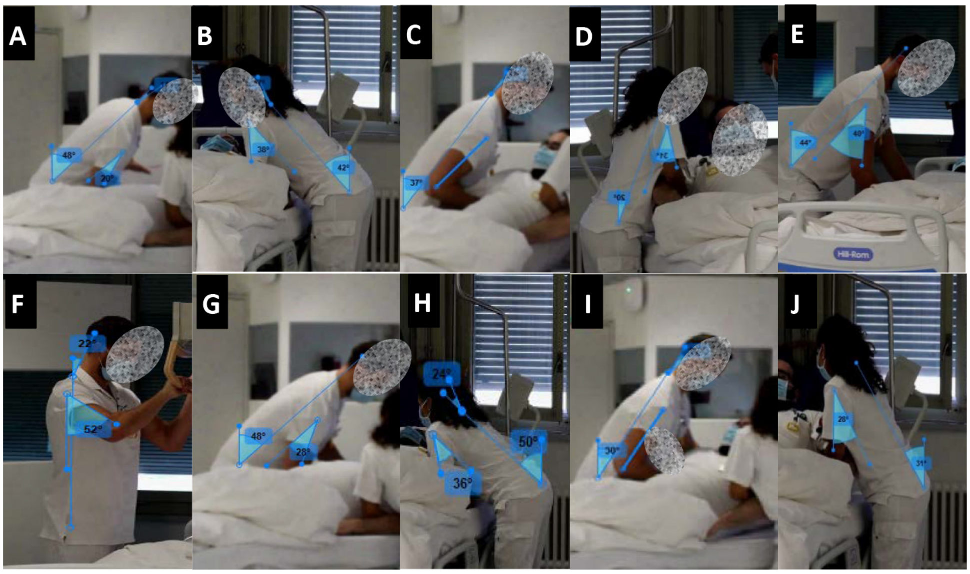

Figure 1: Postures assumed by the taller (performer) and shorter (helper) radiographers during bedside chest X-ray examination in scenario 1 for main tasks (A-J).

trunk flexion. The performer slightly bent downward the head/neck, while the helper tended to extend it. Both radiographers' visible arms assumed a slight flexion by placing the forearm under patient's back. The trunks ($P = 48°$; $H = 42°$) and arms angles ($P = 20°$; $H = 38°$) were classified "conditionally acceptable". The flexion of the head/neck of the performer was classified as "acceptable" (11°), and the neck extension of the helping radiographer was "not acceptable" (−7°).

ii) Patient handling to position the detector under the patient's back (C&D). Trunk flexion of the performer was more critical than those of the helper during patient's lift. The arms supporting the patient's back remained in a neutral position for the performer and flexed for the helper. Performer slid the detector under the patient keeping the same posture as before. The trunk angle (37°) position of the performer was classified as "conditionally acceptable", while the upper arm (0°) and head/neck position (10°) were rated as "acceptable". The helper trunk angle (20°) was considered as "acceptable", but the arm's flexion was classified as "conditionally acceptable" (31°). The head/neck for the helper was not measurable due to a slight rotation.

iii) Control of detector position (E). During this task the performer bent the trunk to overview the detector position. Both arms were flexed to verify and reposition when necessary. The trunk (44°) and arm flexion (40°) were rated as "conditionally acceptable" while the head/neck was classified as "acceptable" (0°).

iv) X-ray tube positioning (F) required the adopting an orthostatic posture from the performer with the trunk aligned with the mid-sagittal plane of the body. The posture of the trunk was "acceptable", the head/neck (22°) and arms angles (52°) were classified as "conditionally acceptable".

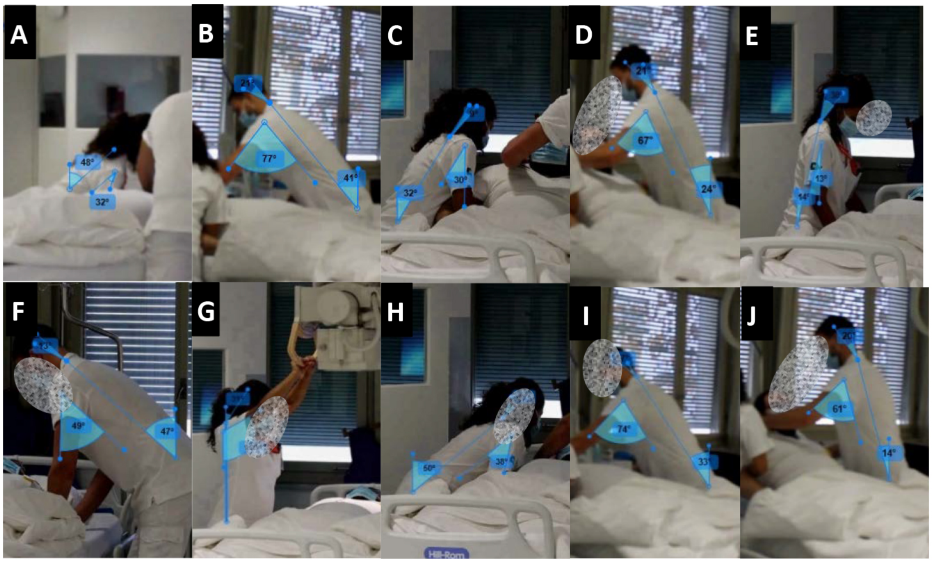

Figure 2: Postures assumed by the shorter (performer) and taller (helper) radiographers during bedside chest X-ray examination in scenario 2 for main tasks (A-J).

v) Preparation to remove the detector from under the patient's back (G&H) obliged both radiographers to bend the trunk and flex the arms to place their hands under the patient's back and prepare to exert force to lift the patient. The head/neck of performer stayed aligned with the rest of the vertebral spine in contrast to helper, who extended her head/neck during this procedure. The angles of the trunk (P = 48°; H= 50°) and arms (P = 28°; H= 36°) were considered as "conditionally acceptable" for both radiographers. The segment of head/neck for performer was "acceptable" (0°), while the helper adopted a head/neck extension (−24°) considered as "not acceptable".

vi) Patient handling to remove the detector from under the patient's back (I&J) required a slightly flexion of the trunk from both radiographers. The arm pulling the patient was in a neutral position (0°) for the performer and in flexion for the helper arm. The performer slightly bent downward the head/neck segment, while the helper has extended. The angles formed by trunk (30°), arms (0°) and the head/neck (16°) segments for the performer were considered "acceptable". The helper adopted postures classified as "conditionally acceptable" for trunk (31°) and arms (28°), while head/neck was not measurable.

Scenario 2 (Fig. 2) - Shorter radiographer (performer-P) & taller radiographer (helper-H)

i) During the *preparation to position the detector under the patient's back (A&B)*, the radiographers bended over to place their hands to lift the patient. The performer put the right arm under the scapula passing by under the axilla, which required the upper arm's flexion. The helper also flexed the upper arms to put the hands on the patient's shoulders. Besides, the head/neck of the taller radiographer was bending downward to observe the patient. The trunk angles (P = 48°; H = 41°) were determined as "conditionally acceptable" in both radiographers. The upper arm flexion for performer (32°) was considered "conditionally acceptable", while the arm flexion in helper (77°) was considered as "not acceptable". The head/neck angle of the helping radiographer (21°) was classified as "acceptable".

ii) Patient handling and detector position under the patient's back (C&D) required from the helper to apply force to pull the patient back to allow the performer to slide the detector under the patient. Their trunks were less flexed when compared to the previous situation. The visible arms were flexed to support the pulled patient. Both radiographers flexed the head/neck to observe the position of the detector. The performer slid the detector under the patient. This action did not induce a change in the posture. Radiographers' trunks (P = 32°; H = 24°) were in a flexion considered as "acceptable". The performer arm's angle was considered as "conditionally acceptable" (30°) while the helper (67°) was considered as "not acceptable". The angles of the head/neck were both classified as "acceptable" (P = 9°; H = 21°).

iii) Control of detector position (E&F). In this scenario, both radiographers controlled and adapted the position of the detector under the patient. The head/neck, trunk and upper arm segments were in flexion. These segments' angles were more critical in the taller radiographer due to the difference between his height and the patient height. The body segments measured in performer radiographer were all rated as "acceptable" (trunk = 14°; arm = 13°; head/neck = 30°). The posture adopted by the helper required to assume a "conditionally acceptable" angle in the trunk (47°) and arms (49°), only the flexion of the neck (13°) was "acceptable".

iv) X-ray tube positioning (G) required from the performing radiographer to raise the arms above the head, in hyperflexion, due to a need for sufficient distance between the source (tube) and the detector. The head/neck was flexed, allowing observation of patient position, the centering and diaphragms verification. The trunk was in an orthostatic posture aligned with the body's mid-sagittal plane. The radiographer's posture was considered as "acceptable" regarding measured angles of trunk (0°) and head/neck (31°), while arms flexion (119°) was classified as "not acceptable".

v) During the *preparation to remove the detector from under the patient's back (H&I)*, the performer flexed the trunk to reach the patient's back passing under the axilla and extended the head/neck. By taking the patient by the shoulders, the helper was less bent downward than the performer. The visible arms of both radiographers were flexed to support the patient's back. The postural assessment of the performer revealed that angles of the trunk (50°) and right arm (38°) were "conditionally acceptable", but "not acceptable" for head/neck (-27°). The helper's head/neck (17°) and trunk (33°) positions were "acceptable" but the arm (74°) was in a "not acceptable" position.

vi) Patient handling to remove the detector from under the patient's back (J) required force from both radiographers while maintaining a flexion of the trunk. The arms and head/neck were also in flexion to support the patient's back and keep the patient lifted to remove the detector, observing the patient at the same time. Helper's trunk (24°) was considered as "conditionally acceptable". The patient handling required to the helper adopting an arm flexion

(61°) considered as "not acceptable". The flexion of the head/neck (P = 20°; H = 20°) was "acceptable" for both radiographers.

DISCUSSION

Postural strain in radiographers' occupational activity, such as reported during patient and equipment handling (Kumar et al., 2003; Pompeii et al., 2009), were also observed in this study during bedside chest plain X-ray simulations. The most demanding postures assumed by radiographers as "performers-P" mainly occurred during the X-ray tube manipulation requiring arm flexion, being more evident for shorter radiographers. Smaller is the radiographer, more flexion of the arm is required due to the need to respect a certain distance between the source (tube) and the detector. There is a lack of literature on the impact of anthropometric characteristics of radiographers performing X-rays, but mammography related studies showed that when the medical imaging equipment is not adaptable to the anthropometrics characteristics, there exists a physical risk factor, requiring radiographers to assume awkward postures leading possibly to WRMSDs symptoms (Cernean et al., 2017; Costa et al., 2014a). It seems critical to improve communication between users, equipment manufacturers and designers to fit the needs of a wider range of anthropometrics characteristics.

From "helping radiographer" viewpoint, patient handling required upper arm flexion that was "not acceptable" when holding and pushing the patient by the shoulders. This arm posture may increase the risk of injuries especially since it is associated with high exertion of force and it is repeated during the examination. In contrast, by supporting patients by scapula passing under the axilla, the constraint in the upper arm was reduced and the trunk flexion, even being slightly more important, remained "acceptable". Unacceptable neck extensions could be also observed for the medium and shortest radiographers while handling the patient to have probably a full overview (Cernean et al., 2017; Giger et al., 2008) and/or maintain a certain physical distance from the patient.

Most of the radiographers self-associated conventional radiography practice with low back complaints, which is in line with previous studies considering X-ray radiographers (Lorusso et al., 2007). This result was not surprising, even though the trunk posture was just once classified as "not acceptable", because the repetitive truck flexion with exertion of force to lift the patient may increase the risk of WRMSDs symptoms. Preventive action for this specific imaging modality needs to be considered for low back complaints as a priority. This action could improve physical well-being, but further research is needed to identify the tasks/causes responsible for the symptoms, even it can be hypothesized that they are related to patient handling.

CONCLUSION

Observation of clinical activity permitted to characterize the real work performed during bedside chest plain radiography, and simulations allowed the identification of "not acceptable" postures for upper arms and/or necks, especially during patient handling and the X-ray tube manipulation. During patient handling, the collaboration of radiographers with anthropometric differences did not significantly affect the postures classification, but it affected manual handling techniques and radiographers' practice. However, anthropometric characteristics directly impacted the constrained postures of the arm during X-ray tube positioning.

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