Determination of working postures using computational phantoms for dose assessment in radiological accident

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1. Introduction

The widespread use of radioactive materials in various industrial sectors, such as nuclear power plants, non-destructive testing sites, and high-level irradiation facilities, has led to concerns regarding radiological accidents [1]. In these events, accurate and comprehensive methods of assessing individual doses have been emphasized for clinical treatment. Among the techniques, computational simulation using anthropomorphic phantoms has emerged as a powerful tool, allowing for the estimation of individual as well as local doses in different scenarios.

Recent advancements have introduced mesh-type reference computational phantoms (MRCPs), offering enhanced flexibility in posture and deformation compared to the previous voxel phantoms [2]. This development enables a more accurate dose assessment in accident scenarios requiring dedicated working postures.

In previous studies, the influence of body shielding on a dosimeter in various accident scenarios has been explored, showing discrepancies in dose conversion coefficients (DCCs) up to 45% [3]. With these considerations, the present study carried comprehensive approaches to determining working postures using the MRCPs. The approaches encompass representative working postures presented in Ovako Working posture Analysis System (OWAS), the dosimetric influence of body shielding, and recent technologies in posture monitoring using the internet of things (IoT). The findings of this study seek to provide a fast and reliable dose assessment and optimization of radiation protection.

2. Methods and Results

2.1 Classification of body part

OWAS was developed by the Finnish steel company in 1973 and purposed to assess a risk and efficiency of working postures [4]. The system categorized and simplified postures based on major moving parts, such as back, arms, and legs, with considering their working loads. For instance, four different postures are presented regarding a relative movement of a back: straight, bent, twisted, and a combination of bent and twisted. For the movement of arm, three postures are suggested: both arms below shoulder level, one arm above shoulder level, and both arms above shoulder level. In the case of legs, seven postures are considered: sitting, both legs straight, one legs straight, both legs bent, one leg bent, kneeling, and working. The system allows to make various postures through a combination of each body part.

Based on the methodology of OWAS, the classification of body part considering dosimetric effects was presented in Table I.

Table I: Shape and numbering of body parts

Body part	Number	Shapes
Back	1	Straight
	2	Slightly bent upper body
	3	Upper body bent at 90 degrees
Arms	1	Both hands down
	2	Both hands outstretched forward
	3	Both hands raised
Legs	1	Standing
	2	Kneeling with one leg bent
	3	Squatting

In terms of dose assessment for a personal dosimeter located in the chest, the main contributions from body shielding areas are the torso, arms, and legs, which are the same as for OWAS systems. Besides, the degree of shielding is rely on a relative position of each part. To simplify the exposure scenarios and to maximize the degree of shielding, the shape of each body part was determined to be unshielded, partially shielded, and fully shielded case. As a results, three different shapes were selected for each body part.

2.2 Consideration for posture monitoring techniques

The study on the working posture of computational phantoms relies heavily on monitoring systems for workers in the workplace. The present study aims to be universally applicable phantoms to such monitoring systems, but it should also include postures considered in monitoring technologies that are currently undergone.

One monitoring system introduced in the field of dosimetry, utilize IMU sensors, which is integrated with

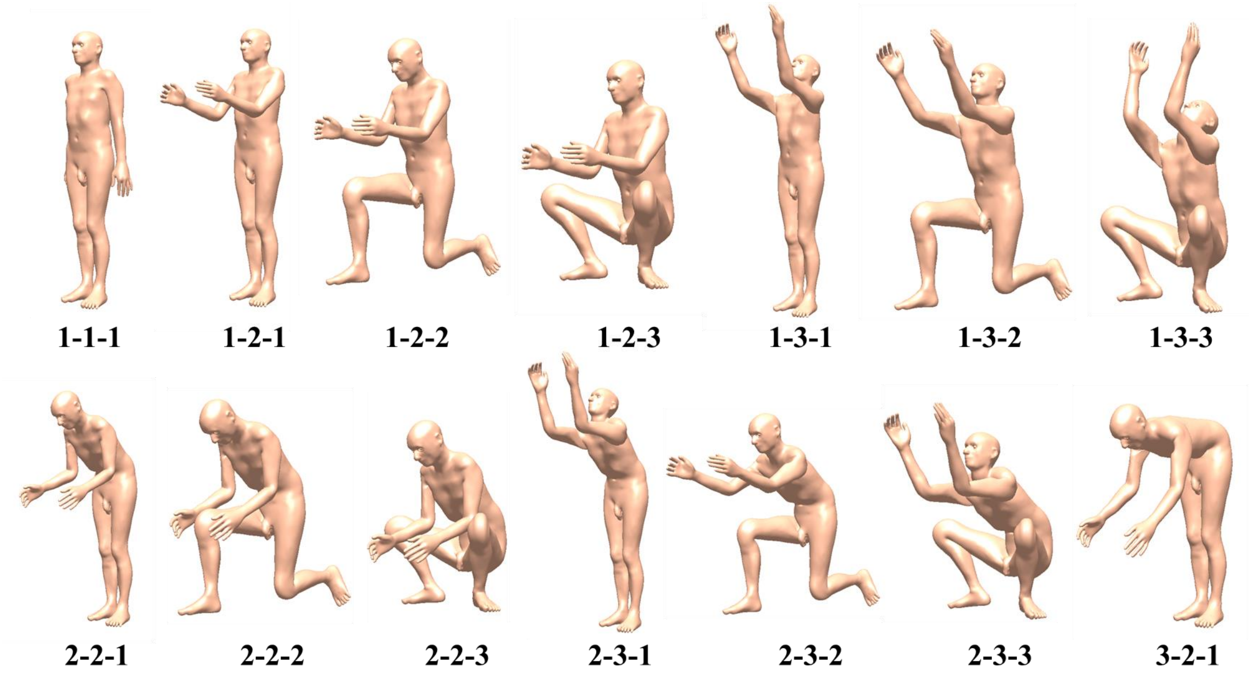

Fig. 1. A total of 14 working postures finally selected for dose evaluation.

an accelerometer, magnetometer, and gyroscope, to estimate the posture and position of a worker on a personal dosimeter [5]. The working postures targeted by this technology is as follows: 1. standing with the sensor fixed to the chest, 2. hands up while standing, 3. waist bent at 45 degrees, 4. waist bent at 90 degrees, 5. fully seated, and 6. hands up while fully seated.

2.3 Determination of working postures

In Table I, a total of 27 postures can be created. The postures were labeled from 1-1-1 to 3-3-3 as 'Back-Arms-Legs' in order. For instance, a posture in which the upper body is standing straight (1), both arms outstretched forward (2), and squatting (3) is marked as 1-2-3. However, some of these postures are not realistically sustainable or acceptable, and some are repetitive in terms of body shielding. Excluding the above, the final selection is the 14 postures in Figure 1.

2.4 Results of dose assessment

Table II: Comparison for absorbed dose per fluence (pGy cm^2) of effective dose (ED) and dosimeter dose (DD) with 1-1-1 and 2-2-1 postures

Geometry	1-1-1		2-2-1		Ratio	
	ED [pGy cm^2]	DD [pGy cm^2]	ED [pGy cm^2]	DD [pGy cm^2]	ED [%]	DD [%]
AP	2.97	3.12	2.85	3.05	0.96	0.98
PA	2.46	1.38	2.25	1.05	0.92	0.76
LLAT	2.15	2.41	2.19	1.82	1.02	0.75
RLAT	1.81	2.35	1.83	1.84	1.01	0.78
ISO	2.12	2.32	2.12	2.02	1.00	0.87
ROT	2.35	2.32	2.28	1.94	0.97	0.84

Table II shows the calculated effective dose (ED) and dosimeter dose (DD) between 1-1-1 and 2-2-1 postures. The calculation was done by Geant4 code with a deformed MRCP provided by Hanyang University. The ED difference between two postures were less than 4%. Whereas, that of DD difference were ranged from 2% to 25%, indicating a shielding from a body part.

3. Conclusions

In the present study, working postures for dosimetric simulation were determined. The major considerations were a methodology of body part categorization, dosimetric impact, and currently available monitoring techniques. The selected postures will be used to build a database for a calculation of dose conversion coefficients which will be implanted into a personal dosimeter having a posture monitoring module.

REFERENCES

[1] 김형택, 방사선 피폭 사고 시 인체선량평가를 위한 전산모사기술 현황. The Korean Association for Radiation Protection Workshop, 24th. Feb. 2023.

[2] C.H. Kim, et al., New mesh-type phantoms and their dosimetric applications, including emergencies, Ann. ICRP 47, 45–62, 2018.

[3] M.C. Kim, et. al., Evaluation of shielding effect of personal dosimeter according to working postures, The 11th International Symposium on. Radiation Safety and Detection Technology, P2-15 , 2023.

[4] R. Eom, et. al., Analysis of working posture for construction workers using OWAS method, Fashion & Textile Research Journal, Vol. 20, No. 6, pp. 704-712, 2018.

[5] 김용권, 핵종/위치 분석 기반 개인전자선량계 개발 현황, The Korean Association for Radiation Protection Workshop, 24th. Feb. 2023.

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