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A New Approach to Developing Digital 3-D Headforms

Ziqing Zhuang and Dennis Viscusi

National Institute for Occupational Safety and Health

National Personal Protective Technology Laboratory

Pittsburgh, PA 15236 USA

ABSTRACT

Facial measurements were collected during the 2003 National Institute for Occupational Safety and Health (NIOSH) survey of 3,997 respirator users. In addition to traditional measuring techniques, 1013 subjects were scanned with a Cyberware 3-D Rapid Digitizer. Ten facial dimensions relevant to respirator fit were chosen for defining a principal component analysis (PCA) model which divides the user population into five face-size categories. Mean facial dimensions were then computed as a goal for a representative headform for each size category and used to identify 5 scans in each category. An average of the five scanned subjects was used to develop a single standard headform for each face-size category. Four digital 3-D models were developed: small, medium, large, and long. The new headforms include facial features not found on current standard headforms. However, reducing differences between the headform dimensions and the computed mean facial dimensions will require additional future work.

INTRODUCTION

Anthropometric measurements of human heads are used to create headforms to test the efficacy of personal protective equipment (PPE). Headform requirements vary depending on the equipment being certified. Certification tests are performed on respirators, eye and face protective equipment and helmets to ensure minimal risk of exposure to employees working in hazardous environments. Using human subjects for respirator certification tests is costly. In addition, a high degree of variability is observed when taking repeated measurements with the same human subject and between human subjects. Using headforms limits the variability between measurements and allows certification testing to occur on PPE created for users of all shapes and sizes. The use of human subjects in performance evaluations of the human interface issues (e.g. communications, visual acuity, effects on mobility, etc.) will always be required. However, the development of headforms more representative of the worker population will enable better assessment of performance where the use of headforms is appropriate.

PPE standards that use headforms for performance testing exist globally. For example, in the U.S., NIOSH has numerous respirator certification tests which require the use of headforms: resistance, air flow, O_2 and CO_2 levels, and field of view [1]. Internationally, 18 headform tests are required in eye and face protection standards being developed by International Standards Organization (ISO) TC94/SC6, and future SC15 standards may require the use of a number of headforms for evaluating the performance of Respiratory Protective Devices.

Although certification of respirators and other PPE occurs world-wide, there is no international standard headform. "The first international draft standard for headforms was ISO/R1511:1970, followed many years later by ISO/DIS 6220:1983. Both of these documents were based upon the British Standard, BS 1869:1960, which itself was developed from the first set of test headforms produced by the UK Transport Road Research Laboratory in the 1950s" [2]. The ISO/DIS 6220:1983 draft was never implemented as an international standard, but many countries and organizations base their standards on this document. Depending on the country of origin and the product being certified, different standard testing procedures and headforms are used.

In Great Britain, BS EN 960:2006, specifies headform sizes for testing protective helmets. When testing optical equipment, the standard headform has facial features and is based on the 50^{th} percentile male headform developed by the UK Health and Safety Executive [3], which is the same standard headform used when testing equipment for eye and face protection for use during welding [4]. Most European countries use standard headforms specified in EN 960:2006, a standard developed by correcting errors associated with ISO/DIS 6220:1983. Canada also follows the guidelines provided