Development of anthropometric work environment for Taiwanese workers

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Received 15 September 1996; received in revised form 15 April 1997; accepted 1 July 1997

Abstract

This paper presents the first-stage extended results of an anthropometry survey project that has been done recently in Taiwan. The purpose of the anthropometry survey project was to construct a static and dynamic anthropometric database for local workers, for use by designers and engineers involved in designing the work-related facilities. Local human factors researchers and specialists were involved in this large-scale survey. According to the worker population structure in Taiwan’s main industries, 1200 subjects were measured. The database consists of data for 266 static-body dimensions and 42 dynamic ranges of motion. The statistical data are presented in a conventional paper hardcopy handbook and a computerized on-line searching system. It is expected that the data can be used by designers and engineers to create ergonomically designed equipment, devices, and work environment for local workers, thereby ensuring a safe work environment. Based on such data, the primary dimensions for work environment design applications were also proposed. In addition, the stature ratio for males was compared with that of females.

Relevance to industry

The anthropometric data collected in this work provide the designers and engineers the basis for designing safe, healthy, and comfort work environment and facilities for Taiwanese workers. These data can further be analyzed and used for production and inventory planning to meet the market demand and reduce the costs. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Anthropometry; Database; Static-body dimension; Ergonomic design; Workplace; Stature ratio

1. Introduction

Despite efforts in recent decades, the lack of applicable local anthropometric data largely accounts for the inability to promote designing ergonomic products in Taiwan. Two major initial efforts to promote Taiwan’s ergonomic applications were in closely associated areas of industrial design and industrial engineering, which can be traced back to the 1960s (Yu and Wang, 1996).
Anthropometry has been considered as the very basic core of ergonomics in an attempt to resolve the dilemma of ‘fitting people to machines’. However, small- and medium-scale anthropometry surveys were not carried out until nearly two decades later. Those surveys accumulated anthropometric data for both product and workplace designs. Although providing a valuable reference for later anthropometric studies, the data’s applicability from the surveys was limited owing to constraints such as budget, workforce, and time.

Taiwan’s rapid economic growth in recent years has led to a higher quality of life and, subsequently, concerted efforts to ensure a safe, healthy, and comfortable work in an industrial setting. A large-scale anthropometry survey is a means of guaranteeing that such aspirations are fulfilled. This work describes a related survey and some of its results which is part of the long-term ergonomics development strategy at the Institute of Occupational Safety and Health (IOSH) of Taiwan. In particular, the survey aims to construct a static and dynamic anthropometric database for the local worker population. Based on the first-stage extended results of the project, we can recommend that the primary dimensions be applied in work environment design.

2. Anthropometric studies in Taiwan

In general, public health and education departments undertook early anthropometry surveys to plan governmental strategies for public health and nutrition (Li et al., 1990). A majority of the surveys were conducted on an annual or periodical basis, in which only the stature and weight were measured. Starting in the early 1980s, several ergonomics-oriented anthropometry studies were performed, in which a majority used Martin-type direct measuring methods and student subjects for measuring a number of static-body dimensions with both sitting and standing postures (Hsu et al., 1991).

One exception was a static anthropometric data bank for Taiwanese residents primarily using an indirect computerized photographic method (Li et al., 1990). Totally 933 subjects, i.e., students, housekeepers, clerks, and industrial workers, were measured; their ages ranged from 15 to 64 yr old. The photographic (indirect) method was employed for measuring 90 body dimensions by entering the coordination of each surface landmark from photos via a digitizing tablet into a microcomputer for processing. In addition, Martin-type equipment was used for measuring two curvature items and the head circumference. Bimalleolar breadth and foot breadth were redundantly measured with both methods for comparisons. Although containing 93 static measurements, it was far insufficient for designers’ and engineers’ needs. During that period, Ho and Shuan (1987) performed a static anthropometry survey of 16 dimensions for 1186 young pilot trainees in the Air Force Academy.

Since the establishment of IOSH in 1992, the government on Taiwan has realized the relevance of a large-scale anthropometry survey. IOSH and National Tsing Hua University (NTHU) collaborated on a preparatory project to investigate the anthropometric needs of workers as well as to evaluate anthropometry techniques in 1993. The project subsequently led to this anthropometry survey for local workers, as initiated in 1994 and completed in two years. In addition, Taiwan’s National Science Council (NSC) has also granted a three-year project for measuring the dimensions of other adult populations in Taiwan, which has recently been completed. Successive efforts will be extended to the applications of these data and the measurement of the body dimensions for the young, elderly, and handicapped populations.

3. Methods used in the anthropometry survey

In the anthropometry survey, 266 static and 42 dynamic items were measured from 1200 local workers. The static items include both standing and sitting postures. A direct measuring method was employed and advanced equipment was used to ensure the data accuracy. Initially, each item to be measured was precisely defined to guide the training and measurements. The research team members involved in this project were trained by osteological physicians prior to the survey to familiarize them with the items and accurately identify the surface landmarks on the human body. In addition, the team members were given intensive practices; and
their performances were also evaluated to ensure that consistent measuring techniques would be applied. Such measures minimized the intra- and inter-personal errors as well as the operational variations. The data were compiled into two forms: a hardcopy and a computer database.

3.1. Subjects

Totally, 1200 subjects, including 735 males and 465 females (ages ranging from 18 to 65 yr old), were measured. Subjects of older than 20 yr old were categorized into groups with an age interval of five years. The number of subjects in each group were calculated according to Taiwan’s worker population structure of the same ages. Thus, in terms of the age, the subjects’ distribution corresponded to that of the target population. All subjects were volunteers from local industries and were compensated for their absence at work. Personal information was also collected for further data analysis.

3.2. Measurement procedures

During each session, a pair of subjects was parallelly measured with one for static items and another for dynamic items. They were then shifted after the items were measured to maximize the utilization of the equipment. The male subjects were asked to wear only shorts and the females wore comfortable leotards or underwear during measurement. The measurement sequences were carefully planned and standardized. Although the survey assistants could perform the measurement with a high degree of accuracy and efficiency, a measuring software was used to offer graphic measuring hints and recording the data. The graphic hints that were displayed on the computer monitor illustrated the measuring items and the associated surface landmarks in the pre-determined sequences to ensure that no items would be missed and the high efficiency of the work could be achieved. Roughly, 60–75 min were necessary for the pair of subjects to complete the measurement session.

3.3. Equipment and its use

All the measurement equipment was mounted in a mobile laboratory to provide easy access to the subjects. The fact that the equipment contained high precision electronic parts accounts for why protection materials and customized accessories were installed to protect the equipment from vibration and shocks while moving. Safety and comfort facilities were also added to the laboratory to ensure an enjoyable environment and pleasant experience for the subjects as well as for the research team members who stayed for several hours each day in the confined laboratory space.

3.3.1. Measurement equipment for static anthropometry

Three kinds of digital equipment were used for static measurements: a three-dimensional (3-D) coordination measuring probe, two electronic calipers of different measuring ranges, and an electronic tape measure. The calipers and the tape measure were modified to fit the needs of the project. The digital encoding feature allowed the data to be entered into computers and processed in real time with the software developed by the research team. The 3-D coordination measuring probe was used to measure the coordinations of surface landmarks in space on each subject. The calipers were used for measuring straight lengths of small and medium size body segments whenever deemed appropriate. The tape measure was for measuring either body contours or the lengths of body curvatures. All equipment was calibrated prior to measurement. To prevent entering invalid data or causing operational errors, an error-proofing feature was added to the software which, in a real-time basis, checked a new datum with the updated statistics of the specific measuring item. Auditory warnings were given when a suspicious datum was measured and the research team had to double check the datum and make corrections immediately by re-measuring the item if deemed necessary. This feature significantly reduced the errors of the data.

3.3.2. Measurement equipment for dynamic anthropometry

A three-lensed, infrared motion analyzer was used for measuring the ranges of motion of the body segments. To ensure the validity of the
angular values, a number of infrared LEDs (IREDs) were fixed on several rigid bodies, as worn by the subjects on the head and limbs when measuring. The positions (coordinations) of IREDs were sensed by the motion analyzer, digitally encoded and entered on a computer. With the assistance of a software developed by the team, the center lines of the body segments in question could be real-time calculated and determined. These processes were also graphically displayed on the computer monitor and supervised by the research team to ensure the validity of the measurements. The angles of the ranges of motion in degrees were further calculated by comparing the displacement of the center lines of the measured body segments before and after the movements.

4. Results and the proposed work environment dimensions

The subsequent data were compiled into a worker’s anthropometric database with a total of 266 static dimensions for both standing and sitting postures and 42 dynamic ranges of motion. A searching interface was also developed to easily search the data of the specified groups of subjects.

For promoting ergonomics, establishing an anthropometric database is a milestone; however, applying the data in our daily life is even more relevant. The real value of the database lies in its applications. According to previous experiences and a survey among the professional designers and engineers, not many of those professionals exactly knew how the anthropometric data can be used. To demonstrate the use of the collected data, this work presents 18 major dimensions that must be considered in work environment design for sitting and standing postures (Figs. 1–3, and Table 1). These data were transferred from the raw data, the mean and standard deviation values of the dimensions for male and female workers were displayed as well. The data can be further processed to find out the data of major percentiles, thereby providing more flexibility for designers and engineers in designing ergonomic products and facilities. This continuous effort will be underway until all raw data are transferred into the applicable data that are ready for use.
5. Mysterious male/female stature ratio

In addition to the anthropometric database and the proposed dimensions, the stature data were compared with those of a decade earlier. The average statures of the 465 females and the 735 males in the recent survey were calculated. Although not surprising, the data revealed an interesting phenomenon in which people are taller than a decade ago. The average statures are 0.09% and 1.24% taller than those of 1986 for the female and the male workers, respectively. Restated, male workers were 1.067 times taller than females in 1986; this figure has grown to 1.079 today, i.e., a 1.15% growth. Although the reason for faster growth rate with male workers remains unclear, one possibility might be the different methods used in the surveys. In terms of the anthropometric prediction, more closely examining this issue would be a worthwhile task.

Furthermore, assuming that the growth rates are valid, will the stature difference between male and female workers continue increasing in the future? Although this is unlikely to occur, the male/female stature ratio could likely approach a constant in the future. It was found, according to Kroemer’s data (Kroemer, 1989), that such stature ratios of the 5th, the 50th, and the 95th percentiles of the US adult civilians were 1.082, 1.082, and 1.076, respectively. Does this finding suggest that the constant male/female stature ratio is around 1.082? The fact that these figures are extremely close to what the authors found in this study, e.g. 1.079, implies that the male/female stature ratio of Taiwan workers will approach the constant of 1.082 at the beginning of the 21 century. If so, such an event might imply that the constant of 1.082 is a possible upper limit.
of male/female stature ratio across the borders. Above issues require further studied and other interesting results are expected as the data are further analyzed and compared with the longitudinal as well as the latitudinal data.

6. Conclusions: Further developments

An anthropometric database is a prerequisite for designers and engineers if they want to design ergonomic products and facilities. This database is important for users as well if they desire to use ergonomically designed products and facilities. However, a quality anthropometry survey is an extremely demanding task for researchers, both physically and mentally. For many academic researchers, it is considered a trivial and tedious work. The authors have done the most demanding part of the work which provides a key to a safer, more healthy, and more comfortable work environment for Taiwan workers. With this project, a valuable anthropometric database for Taiwan workers is available. Further work and efforts are underway, among which include the following: (1) to transfer the data into practical dimensions that designers and engineers may use conveniently for various products and facilities, (2) to setup the dissemination channels to promote the applications, (3) to establish a database maintenance system for maintaining the updated data, and (4) to collect anthropometric data for other populations, i.e. the young, the elderly, and the handicapped groups.

Quality of life can be improved by applying anthropometric data, which can be regarded as an indicator of life quality for a nation. This study has laid groundwork for improving the workers’ safety, health, and life quality in Taiwan.

Acknowledgements

The authors would like to thank the IOSH (Project Nos. IOSH83-H121, IOSH84-H121) and the NSC of the Republic of China (Project Nos. NSC84-2221-E-007-016, NSC84-2215-E-007-055 and NSC85-2221-E-007-062) for financially supporting this research. The subjects are appreciated for their participation, as well as the research team members for their diligent efforts.

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