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The development of sizing systems for Taiwanese elementary- and high-school students

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Abstract

This study aims to develop sizing systems for Taiwanese elementary- and high-school students. A total of 7800 students' anthropometric data covering their ages from 6 to 18 years for both genders were used in this study. A two-stage cluster analysis was performed for the classification of figure types. The size charts were developed based on the morphological characteristics of each figure type. Twelve sizing systems were established systematically by age group (elementary-, junior high-school and senior high-school students), gender (male and female) and garment type (upper and lower garments). The coverage rate of the developed sizing systems was over 85%, and the number of sizing groups of each system was less than 36. In addition, an index of aggregate loss of fit was used to validate the size charts, and the results showed that all the developed size charts had a good fit. Moreover, the developed sizing systems were compared with the Korean Standards, and a similar trend was found.

Relevance to industry

The developed sizing systems were based on the most recent and complete anthropometric database in Taiwan. The proposed method can be used to develop sizing systems for different populations. The results obtained provide important references for the design and production of different clothing.

Keywords: Anthropometric data; Sizing system; Cluster analysis; Figure type; Student clothing

1. Introduction

A garment sizing system is essential for effective clothing design and production. A sizing system classifies a specific population into homogeneous subgroups based on some key body dimensions. Persons of the same subgroup have the same body shape characteristics, and share the same garment size.

With the difference in body dimensions and morphological characteristics, different body shapes can be generalized to a few figure types (Ray et al., 1995). Figure type plays a decisive role in a sizing system and contributes to the issue of fit. Emanuel et al. (1959) recommended the use of the difference in figure types as the classification of ready-to-wears, and developed a set of procedures to formulate standard sizes for all figure types. In early times, the classification of figure types was based on body weight and stature. Later on, anthropometric dimensions were applied for classification. Based on this method, a linear structure was found in many of the commonly used sizing systems, such as KS K 0050 and JIS L 4002. This type of sizing system has the advantages of easy grading and size labelling. But, the disadvantage is that the structural constraints in the linear system may result in a loose fit. Thus, some optimization methods have been proposed to generate a better fit sizing system, such as an integer programming approach (Tryfos, 1986) and a nonlinear programming approach (McCulloch et al., 1998).

For the development of sizing systems using optimization methods, the structure of the sizing systems tends to affect the predefined constraints and objectives. Tryfos

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(1986) indicated that the probability of purchase depended on the distance between the sizing system of a garment and the real size of an individual. In order to optimize the number of sizes so as to minimize the distance, an integer programming approach was applied to choose the optimal sizes. Later on, McCulloch et al. (1998) constructed a sizing system by using a nonlinear optimization approach to maximize the quality of fit. Recently, Gupta et al. (2006) used a linear programming approach to classify the size groups. Using the optimization method has the advantages of generating a sizing system with an optimal fit, but the irregular distribution of the optimal sizes may increase the complexity in grading and the cost of production.

Furthermore, data mining techniques such as cluster analysis (Moon and Nam, 2003), neural networks (She et al., 2002) and the decision tree approach (Hsu and Wang, 2005) have been applied to develop garment sizing systems. Cluster analysis was used as an exploratory data analysis tool for classification. A cluster which is typically grouped by the similarity of its members' body shape can be considered as a size category or a figure type. Moon and Nam (2003) used the *K*-means cluster analysis method to classify the lower body shapes of elderly women into fewer figure types, and then used the control dimension and size interval to establish a lower garment sizing system. The pitfall of the method is that it requires one to pre-assign the number of clusters to initialize the algorithm, and it is usually subjectively determined by experts. To overcome this disadvantage, a two-stage cluster analysis is proposed here to eliminate the requirement of subjective judgment and to improve the effectiveness of size classification.

About 29% of the world populations are children (under the age of 15 years) (Population Reference Bureau, 2006). For children's sizing systems, the related studies are rare because of its complexity and lack of up-to-date anthropometric data. Age and gender are the two important factors affecting children's body shape characteristics. Girls start to grow between the ages of 8 and 12 years and reach puberty about 2 years earlier than boys. During the growth period, there is a rapid change in body proportion, and the segmental relations of children have more variations than adults. This issue can be addressed if we include more body dimensions to describe figure types.

Among all the sizing systems for children, only a few were developed by classifying figure types. Many sizing systems for children were developed by referring to the adult's sizing systems. If we neglect the fact that children's figure types have much more variations than adults, there will be a fit problem. For example, using the drop value (the difference between chest girth and hip girth) is a popular method to classify figure types for adults, but it is not suitable for classifying figure types for children during the growing period, because the girth difference for children is not so obvious. Thus, it is necessary to consider the body's dimensional characteristics in each growing period to establish the corresponding sizing system. The objective of this study is to develop sizing systems for elementary- and high-school students by using a two-stage cluster analysis approach.

2. Method

2.1. Data preparation

Anthropometric data of 7800 Taiwanese elementary and high-school students (3960 males and 3840 females) from an anthropometric database were obtained (Wang et al., 2002). It is the most recent and complete anthropometric database in Taiwan. The age of the students ranged from 6 to 18 years. For the elementary-school (6–12 years), junior high-school (13–15 years) and senior high-school students (16–18 years), the samples in each of the three groups were 3958, 2594 and 1248, respectively.

Thirty-six anthropometric dimensions that are commonly used in clothing design were selected to establish the sizing systems. The definitions of the anthropometric dimension are the same as ISO 8559, except for waist girth. Waist girth was defined as the girth of the natural waistline between the top of the hip bones and the lower ribs in ISO 8559. But the location of the natural waistline may vary from person to person. Using the navel as the reference point can be an easy landmark to identify the waistline while taking the measurement. Thus, the waist girth was measured by taking the horizontal girth around the navel.

During anthropometric data measurements, three kinds of equipment were used, i.e. a 3D coordinate measurement probe, a digital caliper and a digital tape measure. The 3D coordinate measurement probe and the digital caliper were used to measure the linear dimensions, and the tape measure was used to measure the contour length and circumference. All equipments were calibrated with an accuracy level of up to 0.1 mm (Wang et al., 2002). The male subjects were asked to wear shorts and the female subjects were asked to wear leotards during measurement.

2.2. Factor analysis

Factor analysis is a multivariate statistical analysis method that examines the inter-relationships among a large number of variables and extracts the underlying factors. Here, factor analysis with varimax rotation was applied to obtain important factors for body shape representation. Using the factor scores extracted by factor analysis, cluster analysis was performed for the classification of body shape.

2.3. Cluster analysis

A two-stage cluster analysis which combines hierarchical and non-hierarchical methods was proposed to classify figure types. For the hierarchical approach, the Ward's minimum variance method was applied to identify the number of clusters. Subsequently, the non-hierarchical