



A study on the thermal comfort and clothing insulation characteristics of preschool children in Korea



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ABSTRACT

The present study was intended to examine thermal comfort in kindergartens for children aged 4–6 years (preschool children). Centering on Seoul, Korea, thermal comfort characteristics of kindergartens in four seasons (spring, summer, autumn, winter) from June 2013 to May 2014 were evaluated. Indoor/outdoor dry-bulb temperatures, relative humidity, air-flow speed, and globe temperatures. The number of kindergartens included in the study were 19, 29, 21 and 16 during spring, summer, autumn and winter, respectively. The study results were derived through a questionnaire survey on TSV (thermal sensation votes) and metabolism conducted with 994 respondents. The relationships between children's clothing insulation and 4-day weighted mean ambient temperatures, operative temperatures, and outdoor temperatures were evaluated and the results indicated that the amount of clothing was changed the most by operative temperatures. The seasonal mean amounts of clothing were 0.29 clo in summer and 0.81 clo in winter, which were smaller than the amount of clothing of adults presented by ASHRAE. The seasonal amounts of clothing for male and female children differed from each other. In addition, children's comfortable temperatures were identified as being lower than those of adults by approximately 0.5 °C in the summer and by approximately 3.3 °C in the winter, indicating that children have different thermal awareness from adults.

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1. Introduction

Modern people live at least 90% of their lives in indoor environments [1,2], and the comfort of indoor working environments and residential environments is an important element that can enhance efficiency and improve the quality of life. The comfort of indoor environments is directly evaluated based on physical elements such as temperature, humidity, air currents, and radiation, and such comfort is related to the thermal environment [3]. Furthermore, thermal environments indoors can affect the health and comfort of the occupants [4]. In particular, children are known to have lower levels of immunity [5], and if ventilation rates are maintained low to maintain indoor temperatures or thermal environments are inappropriate, respiratory diseases may be triggered or the efficiency of academic performance may be adversely affected [6].

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Information on thermal comfort has been provided mainly by international organizations, such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) [3] and the International Standard Organization (ISO) [7]. It is characterized by the presentation of subjective evaluations, which are affected not only by personal factors but also by psychological factors, the time of day, or by physical conditions [8]. In a study conducted by Sassa et al., when individuals were allowed to adjust indoor temperatures to the temperatures felt comfortable by them in an artificial climate room where temperatures were not indicated, a large temperature difference of 7.2 °C was seen among 29 test subjects [9,10]. Thus, the definition of “thermal comfort” differs depending on behavior patterns, psychological conditions, climate, race, age, gender, and the degree of fatigue that subjects experience [8,11]. It also varies in relation to the thermal environment preference of people who live in warm climates or cold climates [12]. Outdoor temperatures in Korea can be classified into the climatic characteristics of the four seasons. By The Korea Meteorological Administration, Korea is middle latitude temperate climate region, with four distinct seasons include spring, summer, autumn and

winter. In winter, it is cold and dry due to the impact of continental high pressure. In contrast, it has high temperature and humidity under the influence of a North Pacific anticyclone in summer. Spring and autumn, meanwhile, there are many clear and dry days influenced by migratory anticyclone.

ISO 7730 [7] and EN15251 [13] determined the design values of the standard of comfort using operative temperatures at schools, which are based on heat balance and applicable thermal comfort models. Thus, children's thermal comfort may be shown to be different from that of adults because their biological characteristics differ from those of adults and the characteristics of their activity spaces such as the numbers of occupants in school classrooms (kindergarten, elementary/middle/high school) are diverse [14,15].

Because standards for children's thermal comfort have not been set, several studies such as those conducted by Yun et al., and Teli D et al., used *adult* PMV models to compare children's thermal comfort with adults' thermal comfort [15,16]. According to the results, children's thermal comfort showed different characteristics from those of adults' thermal comfort and because major factors of PMV models, such as metabolic rates, skin temperatures, and thermal sensation, were different from those of children's thermal comfort, there are limitations in applying the PMV models to children's thermal comfort [8]. Thus, a previous study indicated that children were more sensitive to high temperatures than adults [14,17], and a study conducted with classrooms in different climates indicated that children felt comfort at lower temperatures than adults [16,18–20]. In particular, in a similar study conducted with children and elementary school students (not older than 11 years), the ranges of children's thermal comfort were different from those of adults depending on differences in physical conditions, clothing insulation, and metabolic rates [16,21]. Through studies on the difference between the thermal comfort of children and adults, researchers have therefore modified the PMV model, based on differences in metabolism [8,22,23].

To date, studies on thermal environments have been conducted mostly with adults although recently, some studies have been conducted with elementary school students, middle/high school students, and university students. In contrast, few studies on the amounts of clothing and thermal environments have ever been conducted with kindergarten children (4–6 years old) who have relatively weak self-decision making abilities. Thus, in the present study, the characteristics of changes in the amount of the clothing of children (4–6 years old), according to 4-day weighted mean ambient temperatures, operative temperatures, and outdoor temperatures, were examined. The characteristics of children's thermal comfort for which there has been no PMV model until now, seasonal ranges of temperatures for children's thermal comfort and major influencing factors were grasped and these characteristics were compared with those of adults and evaluated. The derived range of temperatures for children's thermal comfort was applied to ASHRAE 55 [3] and EN15251 [13]. Thus, the objective of the present study was to provide basic data for setting appropriate thermal environments for children's thermal comfort and activity spaces based on the results of examination of the characteristics of thermal comfort temperatures and changes in the amount of clothing of children (4–6 years old) for which existing studies are insufficient.

2. Method

In this study, we conducted two types of research to examine environmental factors: surveys of thermal environments and on-site measurements of kindergarten classrooms. Both types of investigation were performed within kindergartens, which were the target facilities of this study, throughout four seasons from June

2013 to May 2014. The target kindergarten facilities, survey items, and thermal environment measurements are described below. In obtaining the result values using the environmental measurement data, the thermal sensation vote (TSV) and metabolism were calculated based on ISO 7730 [7]. With regard to clothing insulation, the clothing amount was calculated on the basis of ASHRAE Standard 55: 2004 [3]. The variation characteristics of clothing insulation by outdoor temperature were examined by measuring the outdoor temperatures for 4 days before the thermal environment measurements in kindergartens, to obtain and apply a 4-day weighted mean, which was calculated using the formula presented in EN15251 [13].

2.1. Kindergarten case studies

Subject kindergartens were selected by collecting the present situation of registration with local autonomous entities in Seoul and getting approval from the directors of the relevant kindergartens through phone calls. The survey and measurements were performed at 19 kindergartens in the spring, 29 in the summer, 21 in the autumn, and 16 in the winter, and the numbers of children who participated were 213, 334, 238, and 209, respectively. In total, 994 children between the ages of 4 and 6 participated (493 boys, 501 girls), and their average age was 5.5 years. The children were surveyed in relation to the amount of clothing worn, their metabolism, and their thermal comfort. Metabolic rate was based on the ISO 7730 [7]. The metabolic rate was based on the adult rate; hence, it was corrected to the metabolic rate in children based on the budding metabolism. Complimentary calculation was applied to the resting metabolic rate (RMR) in children [24]. The RMR value was 1147.9 Kcal/day in the 7–11 age group. In addition, our calculation showed that the resting metabolism rate was $1 \text{ met} = 48.8 \text{ W/m}^2$ based on the average child volume of 1.14 m^3 . Therefore, we corrected the met unit according to the children's activity based on the Kindergarten activity. The general conditions of the children were surveyed once a day (14:00) in all seasons. Through the cooperation of the directors of the kindergartens, the generally present situations of the kindergartens such as building types on the certificates of license and registration of kindergartens were investigated and children's ages and physical information were investigated through student management charts.

Table 1 presents the general conditions, and the number of survey respondents by season with their ages, for each of the 32 kindergartens where on-site measurements and surveys were performed. A typical classroom was selected at each measurement site to undertake the measurements and survey. Almost all the kindergartens were equipped with air conditioners but the air conditioners were not operated during the measurement and most of the kindergartens were equipped with floor heating systems (*ondol*). The traditional Korean type system (*ondol* system) was used to control the indoor temperature to the normal Korean range. Thus, the operation of mechanical ventilators was not required but the kindergartens were naturally ventilated through window opening as necessary.

2.2. Survey questionnaire

The survey was performed using the ISO 7-level scale (−3 to +3) (Cold, Cool, Slightly cool, Neutral, Slightly warm, Warm, Hot) [3]. As the respondents were between 4 and 6 years old, the survey was performed in a way where we first explained thermal sensation to the pre-school teachers, who then asked the children the survey questions, and the researchers completed the survey forms. Because the children have relatively poorer understanding and cognitive abilities than adults, when the questionnaire survey was

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