Does Common Standard Brain Template Standardize for All Brains Regardless the Different of Age, Gender and Culture?

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***Abstract*—In functional brain imaging studies, especially when adjusting the functional image to define a standard brain, it is essential to describe the brain images obtained from different subjects using the same coordinate system. Across the years, studies have been conducted to develop a standard brain template that is compatible to different population although the human brain is highly different in shape and size between individuals and basic demographic factors. The Korean standard brain template was the early Eastern template developed and shows the difference between Eastern and Western brains. Compared to MNI and Talairach atlas, Korean brain template was shorter in anterior-posterior length. In Singapore, neonates' brain template for multiple races was developed, where brain of the Indian neonates more elongated than Malay neonates. The latest study on 1,000 Chinese subjects has developed 10 new Chinese brain atlases comprising different ages and gender. Via these researches, it is proved that standard brain template could be different across age, culture and gender. In this review paper, the scenario of the standard brain templates development is briefly discussed, followed by the comparison of results obtained from previous study.**

***Index Terms*—functional magnetic resonance imaging (FMRI), standard brain template, neuroimaging, western people, eastern people.**

I. Introduction

In recent years, the development of imaging modalities has contributed to the understanding of human brain structure and function in neuroscience research. The use of non-invasive functional Magnetic Resonance Imaging (fMRI) which involves the adjusting of the functional images to a defined standard brain has become prevalence since decades ago[1]–[4]. This adjusting process is essential to briefly describe the brain of different subjects using the same coordinate system. The importance of brain coordinate systems of the standard brains is to express the location of the brain structure among individuals without being affected by differences in brain size or shape. Thus, to provide a standard reference coordinate system of the brain especially for neuroscience research, brain atlases were the most commonly used as human brain template in various types of image analysis [5]–[7]. However, since Talairach atlas represents only the shape of Western people's brain, several limitations of the atlas have been pointed out, which is the use of uneven slice thickness (3 to 4 mm) in the development of the system and deviation exist from the orthogonal planes [6], [7]. To overcome such limitation, Montreal Neurological Institute (MNI) atlas was developed using MR images of 305 healthy young people, unfortunately, this new standard brain template was still focusing on Western people's brain [8], [9]. Currently, MNI templates are the most widely used for human brain mapping studies since it was adopted and uses as a new international standard by the Statistical Parametric Mapping(SPM) Program.

Psychologically, it is known that the human brain is highly different in shape and size between individuals and basic demographic factors (group of ages, gender and races). Therefore, the normalization process using these standard brain templates may be directly affected when performed on subjects other than Western people or pediatric subject with racial differences or different age groups. Since majority of the existing brain atlases are constructed from the Western population, some confound exist in the scientific studies on the Eastern subjects. In conclusion, it is necessary to develop and construct an appropriate standard brain template which is more compatible for Eastern subjects in neuroscience research.

Recently, the development of human brain atlases has furnished a standard platform for precise appraisal of brain function. By comparing the average brains of Korean, Japanese and Chinese to the Common standard brain template, it clearly shows the difference of the brain shape and size. Generally, the average brain of the Eastern subjects is shorter in anterior-posterior length and rounder in shape compared to the Western subjects of the

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Montreal Neurological Institute 305 (MNI305) template, Talairach template and the International Consortium for Brain Mapping 152 (ICBM152) atlases which were developed based on Caucasian's adult brain. The focus of this paper is to review the current scenario of the development of human brain atlases between Western and Eastern population, to briefly describe the definition of common terminology used in constructing the standard brain template and the summary of previous study that have been conducted through the years. Do findings of new standard brain template from the three different populations of Eastern countries (Japanese, Korean and Chinese) be really compatible and suited for all brain images of other Eastern countries especially for Malay, Indian and Chinese population in Malaysia?

II. Literature Review

Due to some limitations that exist in the standard brain models that have been used prevalently, a group of researchers had conducted a study to demonstrate the significant differences in brain structure between Chinese and Caucasian populations [10]. They discovered that the Caucasian brains were generally longer while the Chinese brains were generally rounder in shape. Besides that, by comparing both the Chinese brain template with the ICBM152 brain template, it is shown that the Chinese brains are relatively shorter but wider and its height notably smaller as shown in Fig. 1(a).Earlier, a Koreans' research group had developed a specific (age, gender and ethnic) brain templates based on MR and Positron-Emission Tomography (PET) images of Korean normal volunteers[11]. It is crucial to know that the sulcal patterns of brains relative to age, gender, race and disease cannot be fully overcome by the non-linear spatial normalization technique. From the result obtained in Table I, it is shown that anterior-posterior length of the Korean standard man and women templates are shorter than the MNI templates and Talairach atlas.

TABLE I. The Comparison of the Global Hemispheric Features of Korean Standard Man and Woman Templates to the MNI and the Talairach Templates. All Measurement are in cm [11]

	Length	Height	Width
Korean standard man	16.5	12.1	14.3
Korean standard woman	15.6	11.4	13.5
MNI template	18.3	13.3	14.2
Talairach Atlas	17.4	11.9	13.5

Recently, a study of the standard brain among Japanese children had been conducted [9]. The results obtained were compared with the MNI template, which is one of the common brain templates that had been adopted into SPM toolbox analysis. The comparison shows that the brain of Japanese children is 10% smaller in both anterior-posterior diameter and height and 3-5% shorter for the width regardless of age. The differences of the brain size between Japanese children and MNI template can be clearly seen by the naked eyes. Figure shows the differences between the two images, which are visually apparent. The anterior-posterior diameter and height are relatively shorter in the Japanese children template compared to the MNI template, but there are little differences in width between the two templates.

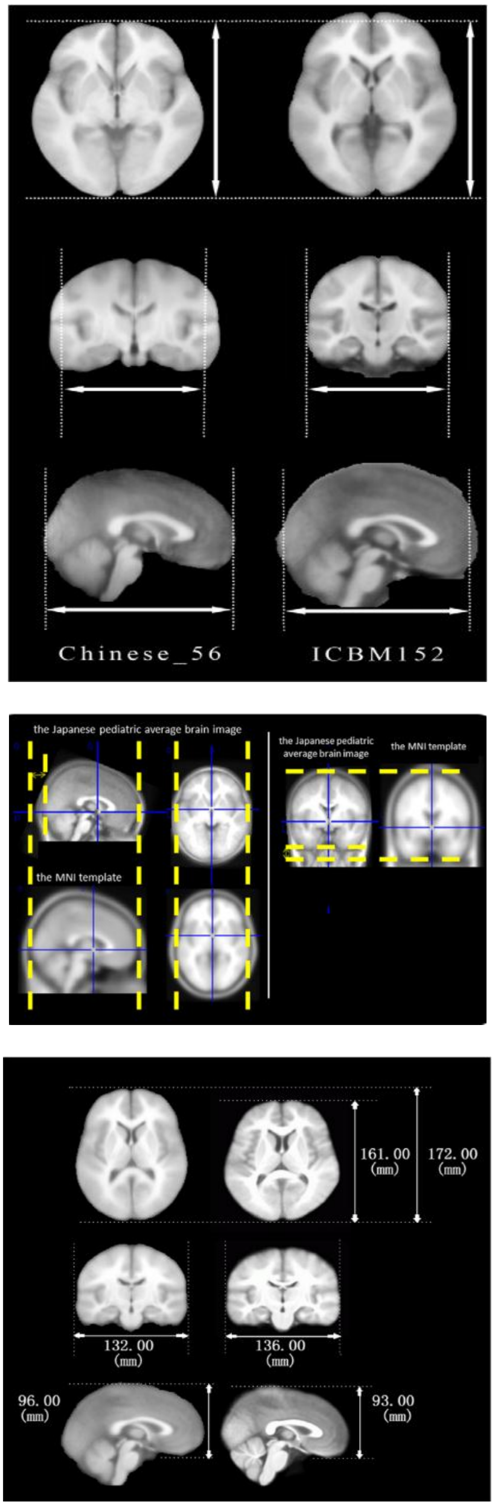

Figure 1. (a) Differences in shape between Chinese Brain Template and ICBM152 atlas. (b) The differences between the Japanese children average image and the MNI template. (c) Comparison between the Chinese Atlas (Group 1: Average age between 18-30 years old) and the MNI atlas. Both MNI and the Chinese atlas are shown on the left and the right respectively.

A few months before, there was a study on neonatal brain morphology and microstructure differences in the Asian community on three distinct populations of Chinese, Malay and Indian[12]. This research focused on approximately 34 weeks neonates with birth weights larger than 2000g. Through this study, they discovered that there are no differences in global brain size among the three Asian Populations at birth but there is a distinct pattern of brain global shape. The results shows that in the anterior-posterior axis relative to the superior-inferior axis, the brain of Indian neonates tend to be more elongated than Malay neonates.

TABLE II. THE COMPARISON OF THE BRAIN GLOBAL SIZE WHICH OBTAINED FROM PREVIOUS STUDY. ALL MEASUREMENT IN CM

Brain Global Morphology	Length (L)	Height (H)	Width (W)
MNI Template	18.3	13.3	14.2
Talairach Template	17.4	11.9	13.5
Korean			
• Women	15.6	11.4	13.5
• Man	16.5	12.1	14.3
Chinese	16.9	11.1	14.4
Neonates			
• Chinese	11.5	9.55	8.91
• Malay	11.4	9.53	8.93
• Indian	11.6	9.45	8.78

Table II shows the comparison of the brain global size for Korean Volunteers, young male Chinese volunteer and Neonates of three Asian populations to the existing standard brain model, which is MNI and Talairach atlases[1]-[4]. From this table, we can conclude that the average brain of both Chinese and Korean adults is generally shorter than the Montreal Neurological Institute (MNI) and the Talairach atlases.

The most updated standard brain template was constructed based on 1,000 Chinese subjects, which supported the earlier findings of Chinese brain atlas (Chinese_56) [13]. From this research, the group has discovered that the Chinese Brain Template is smaller in length and height compared to the MNI template. However, the width/length ratio for the average Chinese brain shows a larger value than the MNI template. Figure shows the comparison in images between the Chinese and the MNI atlases. Besides that, researchers have successfully identified that the brain volumes of males are significantly larger than the brain volumes of females.

III. CONCLUSION

Starting with the development of the Korean standard brain template in 2005, followed by the Chinese and Japanese population in the recent years, it shows that significant differences do exist between the Eastern population and common standard brain template, which is based on the Western population. These findings support the facts that the human brain is highly different between individuals and basic demographic factors (e.g., age, gender, race and background of culture). Therefore, with the rising study in neuroimaging field over the years, several questions have arise and worth to be pondered at. Among others, are common brain templates (both Talairach and MNI templates) still compatible to be adjusted with other than the Western population? In Asia, among three existing standard brain templates (Korean, Chinese and Japanese) developed, which one of them can be adjusted compatibly with the Malaysian population especially Malay population without affected by differences in brain size or shape, since differences in brain structures between these populations may underlie different brain functions? It is possible to develop one standard brain template to represent the Eastern population without being affected or is it necessary for each main population to develop its own standard brain template that fulfills the basic demographic factors?

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