Introduction

Aging of an individual can vary depending of various internal and external factors. Despite the rapid growth in field of science and technology, the exact mechanism of aging is still in the mist. More than 300 theories exist that explain the aging phenomenon with different perspectives [1,2]. Grossly viewed, there may be an infinite number of perspectives on aging since different species have different aging rates and patterns. For example, some specifies such as tortoise and many other reptiles decrease or remain the same as they age [2]. With humans, the mortality rate increases exponentially with increasing age. It has been a fundamental quest for many scientists to deter or reverse the aging process for better longevity and extended life for centuries. However, despite the efforts invested in the quest for everlasting youth, aging still is a natural
phenomenon that cannot be influenced by external manipulation. Although external manipulation may not alter the genetic composition and extend expected lifespan, influencing exogenous and endogenous factors to some extent may deter the expedited aging process up to a certain level. For example, free radical and reactive oxygen species (ROS) have been known to increase the damage biologically significant targets with oxidative stress for accelerated aging [3]. In addition, numerous tests are available to predict clinically problematic conditions to deter or eliminate further progression of the adverse conditions. Predicting the possibility of disease onset and progression has helped humans to live their expected lifespan to the fullest.

With different internal and external influencing factors for aging, a different concept of aging has been suggested to differentiate between the age calculated by the passing time and the age calculated by the deterioration rate of different sectors of human physiology. The age calculated by the elapsed time since the birth is called the Chronological age (CA). CA merely informs the health status of the majority of population at certain stage in elapsed time. It does not inform specific state of an individual. Although the normal developmental phases and rates can be calculated by simple mathematics, the rate of physiological decline cannot be clearly estimated by CA [4,5]. The physiological aging process is an individually uniquely process where multivariate factors influence the outcome. The concept of biological age (BA) was proposed to estimate the gradual functional and structural deterioration of an individual [5-7].

Numerous scientists have focused their research goal on estimating accurate BA for decades [6,8]. Several BA estimating models have been reported to estimate BA of individuals with various biomarkers. Since multivariate factors such as genetic, physiological, and psychological factors may be involved in the aging process, different sets of biomarkers have been used to estimate BA [9-13]. A few groups of biomarkers with specific characteristics have been contemplated to represent the progressive state of individuals in comparison to their CA. The groups of biomarkers have been composed of either physical, biochemical, hormonal, or physiological parameters [4,14,15].

The biomarkers of BA have been selected based on the correlation with CA. Since the concept of BA was proposed to provide reliable estimation of deterioration in a general population, a set of biomarkers should change in function of CA. Although previous BA estimation models with specific groups of biomarkers showed correlation with CA, they could not present all corners of the deterioration state. Therefore, different sets of biomarkers seem necessary to represent the deterioration rate or BA of specific health state. As there is increasing evidence of bone health and aging, BA model should be based on osseous parameters. Bone loss with advancing age has been known to threaten loss of independence and health [16,17].

The BA prediction models have been used in the clinical environment as a health promotional tool to provide clinical information by comparing the health status of an individual with CA and the general population. Therefore, commonly assessed bone health related parameters were used to select biomarkers and develop a BA prediction model. In addition, tedious inclusion and elimination steps provided by previous studies were applied to obtain accuracy in assessment and diagnosis [4,12,18,19]. In addition, the BA prediction model developed with osseous parameters were tested for its applicability by comparing two parameters, the regularly performed walking duration and fall experience. First, three groups of participants were selected based on their walking duration (less than 1 hour, between 1 and 2 hours, and more than 2 hours) to calculate and compare BAs between the groups. Second, two groups of participants were selected based on their fall experience to calculate and compare BAs between the groups. These groups were further subdivided by three age groups to thoroughly observe the deteriorating effects of aging.

Since a working prediction model needs to representative of a general population, this epidemiological research was conducted in a large-scale cross-sectional study at a population level using the fourth and fifth Korean National Health and Nutrition Examination Survey (KNHANES) data, adjusting for relevant covariates in selecting osseous aging biomarkers and associated BA prediction model. The goals of this study were to (a) obtain a set of osseous biomarkers from a group of participants that represents the Korean population, (b) develop an osseous BA prediction model through thoroughly selected biomarkers, (c) apply the BA prediction model to a group of individuals with previous history of fall and walking habit to predict and compare BAs.

Materials and Methods

Participants

Data of a total of 4,644 eligible male participants (age ≥ 30 years) from the fourth and fifth KNHANES which included the health behavior questionnaires, anthropometric, and osseous health measurements were utilized for the study. The fifth and fourth KNHANES assessment data of 2010 and 2008 were approved by the ethics committee of the Korea