Vitamin D concentration is known to correlate with various parameters, including local latitudes. According to a previous study, individuals who live at higher latitudes are likely to have lower concentrations of vitamin D due to reduced vitamin D$_3$-effective UV radiation. In another study, UVB radiation was sufficient for vitamin D$_3$ synthesis year-round below a latitude of approximately 35° North; however, at higher latitudes, vitamin D$_3$ was not produced during the winter season. In addition, the duration of sun exposure and occupation correlates with vitamin D concentrations. In a previous study that investigated the difference in 25-hydroxyvitamin D (25(OH)D) concentrations by occupation, outdoor workers had relatively lower rates of vitamin D insufficiency than indoor workers. Foods also affect vitamin D concentration. Foods such as salmon, sardines, mackerel, tuna, cod liver oil, and vitamin D-fortified foods that have sufficient vitamin D. In a study in Norway with a latitude of 70° North, only 15% of subjects who consumed cod liver oil demonstrated vitamin D deficiency.

Measuring serum 25(OH)D is the most widely used method for determining vitamin D status. Although there is no consensus on the criteria for assessing optimal concentrations of 25(OH)D, the generally used criteria for vitamin D status are as follows: less than 20 ng/mL (50 nmol/L) is considered vitamin D deficient and 20 to 30 ng/mL (50–75 nmol/L) is considered vitamin D insufficient. In a previous study that applied these criteria to Korean children, 18.4% of the Korean pediatric population qualified as vitamin D deficient and 64.0% qualified as insufficient. In another study, the rates of deficiency and insufficiency in Korean adults were reported to be 56.9% and 33.5%, respectively. Although there have been many studies on vitamin D, most have been related to disease; there are only a few epidemiologic studies of vitamin D concentrations in adults.
previous study has investigated the difference in vitamin D concentrations between the most sun-exposed occupation group and a relatively less sun-exposed occupation group living in the same local region. In fact, there has never been a study measuring serum vitamin D concentrations in people who are exposed to sunlight during most of the daytime.

In this study, we evaluated the effects of occupational sun exposure on vitamin D status. We compared the serum concentrations of 25(OH)D in 2 occupational groups: the fisherman group, who were the most sun-exposed, and the general occupation group, who were relatively less sun-exposed. Subjects from both occupation groups resided in 2 cities located in the southernmost region of Korea. We also analyzed vitamin D concentrations according to gender and age and have calculated a vitamin D reference interval for the region.

2. Methods and materials

2.1. Study subjects

This study was conducted on 140 healthy fishermen, who lived in the city of Tongyeong, and 140 healthy residents with various occupations, who lived in the city of Jinju. Tongyeong and Jinju are close, about 40 km away, and belong to Gyeongsang nam-do province. All fishermen were registered with the national fisherman health checkup program, a free health government-funded program. The same number of subjects from both groups visited Gyeongsang National University Hospital for a health checkup from June to August 2016. The study was approved by the Gyeongsang National University Hospital Institutional Review Board (2016-12-016).

2.2. Measurement of serum 25(OH)D concentration

Vitamin D concentrations were measured in all subjects using serum samples taken 8 hours after fasting, and the results were confirmed on the day of the test. Measurements of serum 25(OH)D concentrations were performed using the Elecsys Vitamin D Total Kit with the Cobas e602 module (Roche Diagnostics, Mannheim, Germany); this is an electrochemiluminescent assay that is based on the day of the test. Measurements of serum 25(OH)D concentrations in the general occupation group were 13.60 ± 6.43 and 23.74 ± 8.88 ng/mL, respectively. The mean serum 25(OH)D concentrations in the general occupation and fisherman group were 12.8 and 22.8 ng/mL, respectively. The median serum concentration of 25(OH)D was 1.8 times higher in the fisherman group compared with the general occupation group, which was statistically significant (P < .001). In the general occupation group, 12 subjects were self-employed, 31 were administrators, 51 were clerks, 45 were homemakers, and 1 was unemployed (Table 1).

3. Results

3.1. General characteristics of study subjects

Among the 280 healthy subjects included in our study, 140 belonged to the general occupation group and 140 belonged to the fisherman group. The male-to-female ratio was 1.06:1 in each group. The median age was 50.5 years (range, 31–76 years) in the general occupation group and 58.5 years, (range, 40–80 years) in the fisherman group. The fisherman group had no subjects in their 20s and 30s; therefore, the difference in age between the 2 occupation groups was statistically significant (P < .001). In the general occupation group, 12 subjects were self-employed, 31 were administrators, 51 were clerks, 45 were homemakers, and 1 was unemployed (Table 1).

3.2. Comparison of serum 25(OH)D concentrations between the 2 occupation groups

The mean serum 25(OH)D concentrations in the general occupation and fisherman group were 13.60 ± 6.43 and 23.74 ± 8.88 ng/mL, respectively. The median serum 25(OH)D concentrations in the general occupation and fisherman group were 12.8 and 22.8 ng/mL, respectively. The median serum concentration of 25(OH)D was 1.8 times higher in the fisherman group compared with the general occupation group, which was statistically significant (P < .001). Serum 25(OH)D concentrations in both genders were significantly higher in the fisherman group compared with the general occupation group (Table 2).

In the general occupation group, subjects in their 20s showed the lowest serum 25(OH)D concentrations, whereas those older than 70 showed the highest concentrations. The serum 25(OH)D concentration tended to increase with age in the general occupation group, which was statistically significant (P = .022). In the fisherman group, subjects in their 50s showed the highest serum 25(OH)D concentrations, whereas those older than 70 years showed the lowest concentrations. Comparing the different age groups, subjects in their 40s, 50s, and 60s had significantly higher serum 25(OH)D concentrations in the fisherman group compared with the general occupation group; however, this trend did not evidence in subjects older than 70 (Table 3).

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### Table 1

| Demographic characteristics of study subjects. | General occupation group | Fisherman group | P |
|-----------------------------------------------|--------------------------|-----------------|---|
| N                                             | 140                      | 140             |   |
| Sex, male:female                              | 1.06:1                   | 1.06:1          |   |
| Age (median), y                               | 50.5                     | 58.5            | <.001 |
| Age group, y                                  |                          |                 |   |
| 20–29                                        | 17                       | 0               |   |
| 30–39                                        | 29                       | 0               |   |
| 40–49                                        | 21                       | 10              |   |
| 50–59                                        | 40                       | 66              |   |
| 60–69                                        | 25                       | 56              |   |
| >70                                          | 8                        | 8               |   |
| Occupation                                    |                          |                 |   |
| Fisherman                                    | 0                        | 140             |   |
| Self-employed                                 | 12                       | 0               |   |
| Administrator                                 | 31                       | 0               |   |
| Clerk                                        | 51                       | 0               |   |
| Homemaker                                    | 45                       | 0               |   |
| Unemployed                                    | 1                        | 0               |   |
3.3. Distribution of serum 25(OH)D status in both occupation groups

The distribution of serum 25(OH)D status in both occupation groups according to the criteria provided by Roche, the manufacturer of the assay kit, are summarized in Fig. 1. The number of subjects with serum 25(OH)D deficiency was 115 (82.2%) in the general occupation group and 52 (37.2%) in the fisherman group. The number of subjects with serum 25(OH)D insufficiency was 22 (15.7%) in the general occupation group and 56 (40%) in the fisherman group. The number of subjects with sufficient serum 25(OH)D status was 32 (22.8%) in the fisherman group but only 3 (2.1%) in the general occupation group. The difference in the distribution of serum 25(OH)D status between the 2 occupation groups was statistically significant ($P < .001$).

3.4. Reference intervals for the general occupation and fisherman groups

We attempted to provide a reference interval for the population in our local region. The calculated serum 25(OH)D reference interval for all subjects in our study was 3.8 to 44.4ng/mL. Reference intervals for the general occupation and fisherman groups were 3.0 to 31.6 and 7.7 to 45.8ng/mL, respectively. The percentile values (2.5th and 97.5th percentiles with median) of serum 25(OH)D concentrations in both groups are shown in Fig. 2.

4. Discussion

Vitamin D deficiency is a major health issues around the world and is the main causes of hypovitaminosis, which is thought to be due to less sun exposure and lifestyle modifications.[11,12] A major source of vitamin D is synthesis in the skin. It can be postulated that people with longer periods of outdoor activity due to their occupation or other reasons will have higher serum vitamin D concentrations than people with relatively shorter outdoor activity periods. To the best of our knowledge, there has never been an epidemiologic study directly measuring and

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### Table 2

| Serum 25(OH)D concentration (median, range), ng/mL | General occupation (N=140) | Fisherman (N=140) | $P$ |
|-------------------------------------------------|--------------------------|------------------|-----|
| Overall                                         | 12.8 (3.0–34.5)          | 22.8 (6.7–46.0)  | <.001 |
| Male                                            | 14.6 (5.3–34.5)          | 25.7 (10.1–46.0) | <.001 |
| Female                                          | 10.9 (3.0–31.8)          | 19.5 (6.7–44.2)  | <.001 |

25(OH)D = 25-hydroxyvitamin D.

### Table 3

| Serum 25(OH)D concentration (median, range), ng/mL | General occupation (N=140) | Fisherman (N=140) | $P$ |
|-------------------------------------------------|--------------------------|------------------|-----|
| Age, y                                          |                          |                  |     |
| 20–29                                           | 12.2 (4.1–19.1)          | –                | NA  |
| 30–39                                           | 10.8 (3.0–26.2)          | –                | NA  |
| 40–49                                           | 11.4 (3.8–31.0)          | 19.9 (9.6–27.5)  | .004 |
| 50–59                                           | 12.4 (3.9–31.8)          | 23.4 (6.7–45.8)  | <.001 |
| 60–69                                           | 16.0 (6.3–24.5)          | 22.8 (8.8–46.0)  | <.001 |
| >70                                             | 17.8 (3.0–34.5)          | 18.0 (12.1–23.5) | .942 |

25(OH)D = 25-hydroxyvitamin D, NA = not applicable.
comparing serum vitamin D levels in people with longer versus shorter periods of outdoor activity. In this study, we investigated the actual serum vitamin D level and vitamin D status in 2 occupation groups in the same local region in Korea: the fisherman group, who were the most sun-exposed, and the general occupation group, who were relatively less sun-exposed. In addition, we calculated a suggested reference interval for serum 25(OH)D concentrations in both groups.

As expected, compared with the general occupation group, serum 25(OH)D concentrations were significantly higher in the fisherman group compared with the general occupation group. The mean concentration of serum 25(OH)D in the fisherman group was 23.74 ± 8.88 ng/mL. We can assume that this group represents Koreans with the most occupational sunlight exposure because fishermen spend most of the daytime outdoors. Since this study was conducted during the summer season (June–August), the serum vitamin D levels measured in our study likely represent the highest levels based on seasonal variation. Yearly sun graphs for Tongyeong and Jinju were shown in Fig. 3. In addition, because the cities that typically recruit fishermen and general workers (Tongyeong and Jinju, respectively) are the southernmost cities in Korea, the serum levels measured in this study could represent the highest levels based on latitude effect. Taken together, serum 25(OH)D concentrations in the fisherman group showed the highest level in the Korean population taking into account sun exposure time, seasonal variation, and latitude effect. Therefore, the serum 25(OH)D data in this study could be very useful for epidemiologic studies.

In our study, serum 25(OH)D concentration was higher in the older subjects in general occupation group. In fisherman group, serum 25(OH)D concentration in 50s and 60s was higher than in 40s. Usually vitamin D production in the skin is known to be decreased with aging. However, the findings in our study were different but also similar with the findings of other previous studies. According to the study by the United States, serum 25(OH)D is the highest level at birth, the lowest level at 20 to 49, and increases again after age of 50. In addition, the previous Korean study reported that the serum 25(OH)D level in Korean adults aged ≥50 years was found to be higher than that of adults aged <50 years. Similar findings were observed in Thailand National Health Examination Survey (2008–2009). In addition, there was a large-scaled nationwide study of 2515 Korean adolescents (age: 10–18 years). In this study, the mean serum concentration of vitamin D was 16.68 ± 0.17 ng/mL, which was higher than that (13.60 ± 6.43 ng/mL) of the general occupation group in this study. In addition, the proportions of deficiency, insufficiency, and sufficiency were 73.3%, 24.4%, and 2.3%, respectively, in which the proportion of deficiency was lower and the proportion of insufficiency was higher than those (82.2%, 15.7%) of the general occupation group in our study. This probably means that serum vitamin D level might be determined by a wide variety of factors, including sun exposure time, genetic predisposition, age, and dietary intake. In order to elucidate the effects of factors contributing serum vitamin D level, further sophisticated and large-scaled researches might be required.

Approximately 98% of the general occupation group and 78% of the fisherman group demonstrated vitamin D insufficiency or deficiency. Subjects in the general occupation group, in particular, demonstrated very low serum 25(OH)D concentrations and high rates of vitamin D deficiency (82.2%) and insufficiency (15.7%). The prevalence of vitamin D insufficiency in this study was consistent with previous studies; however, the prevalence of vitamin D deficiency was higher than previous studies that reported rates of deficiency and insufficiency in Korean adults as 52.5% and 32.8%, respectively. In a study conducted in China, the prevalence of vitamin D deficiency, insufficiency, and sufficiency was found to be 55.9%, 38.7%, and 5.4%, respectively. The relatively small number (N = 140) of subjects and the fact that many indoor occupations were included in the general occupation group might explain the higher prevalence of vitamin D deficiency in our study.

In addition, subjects in the general occupation group had significantly lower serum 25(OH)D concentrations than subjects in the fisherman group. Because our study was performed in the summer, this result ruled out seasonal variation and reflected the maximal 25(OH)D status during the year. In a previous study looking at occupational exposure to solar UVB, outdoor workers showed a 4-to-8-fold greater 25(OH)D concentration compared with their indoor counterparts. In a recent study looking at...
Korean wage workers, those who worked outdoors showed higher serum 25(OH)D concentrations than indoor workers. While fishermen work mostly outdoors, subjects in the general occupation group work mostly inside buildings. This suggests that serum 25(OH)D concentration is directly related to the amount of sunlight exposure.

Whereas the fisherman group showed a relatively lower proportion of vitamin D deficiency than the general occupation group, we found that only 22.8% of subjects in the fisherman group had sufficient 25(OH)D levels. As mentioned earlier, the fisherman group represents the highest level of sun exposure in the Korean population; nevertheless, the prevalence of vitamin D deficiency or insufficiency in the fisherman group was 78% when using general reference values. Because there are no definite reference values or criteria for serum vitamin D levels in the Korean population, our result showed that new reference value or criteria might need to be set up for Korean population.

Vitamin D deficiency in young adults has recently become a significant issue in other regions of the world. Similarly, we found that people in their 20s, 30s, and 40s in the general occupation group demonstrated lower serum 25(OH)D concentrations than other age groups in this study. Other national surveillance studies have demonstrated that people aged 20 to 49 years showed lower serum 25(OH)D concentrations than other age groups. In Korea, the main industry has changed from agriculture and fishery to manufacturing and commerce. Furthermore, younger generations prefer indoor jobs, whereas older generations still commonly work in outdoor industries such as agriculture, forestry, and fishery. A previous epidemiologic study using the fifth Korean National Health and Nutrition Examination Survey reported serum 25(OH)D concentrations across the national population. In this study, increasing age was significantly correlated with serum 25(OH)D concentration. Our results from the general occupation group showed serum 25(OH)D concentrations were lowest in people in their 20s and highest in those older than 70 years. However, in the fisherman group, serum 25(OH)D concentrations were highest in subjects in their 50s and gradually decreased with age. Unlike the general occupation group, subjects in the fisherman group were exposed to a substantial amount of sunlight during their lifetimes. Thus, these results suggest that the fisherman group subjects might reach a maximum serum 25(OH)D concentration at an earlier age than subjects in the general occupational group.

There is currently no definite reference interval for serum 25(OH)D concentrations in Koreans. There are many factors such as gender, age, ethnicity, and latitude that can affect vitamin D levels, making it very difficult to establish an international standardized reference interval. In our study, we calculated a suggested regional reference interval for both occupation groups. These data will be useful for establishing a national vitamin D reference interval in Korea.

In this study, although dietary vitamin D intake was not investigated, elevation of serum vitamin D level by food might be minimal comparing to that by sun exposure. Also, it is relatively unlikely that fishermen group have higher in serum 25(OH)D level than in the general occupation group because of the higher consumption of fish. First, in this study, the city of Tongyeong, where fishermen group are from, and the city of Jinju, where the general occupation group live, is only 50km away, and because both cities are close to the seashore, local people possibly tend to have common eating habit regardless of their occupation. Therefore, the dietary habits of fishermen and general occupations are not significantly different. Second, according to previous studies, the amount of vitamin D3 from dietary intake is much less than the amount of vitamin D3 from the exposure to sunlight. It is known that there is a relatively large amount of vitamin D in fish comparing with other food. While the amount of vitamin D3 contained in the fish is about 200 to 300IU/100g (3.5oz), the amount of vitamin D3 from the exposure to sunlight is reported as 3000IU for 5 to 10 minutes. Therefore, it can be calculated that 1 kg of fish should be consumed daily to reach the equal amount of vitamin D from the exposure to the sunlight for 5 to 10 minutes. In addition, vitamin D-enriched foods contain vitamin D3 at levels from 50 to 400IU, suggesting that the effect of vitamin D concentration from the dietary intake might be minimal when compared to the sunlight. It is worth noting, however, that people taking vitamin D supplements may show a vitamin D3 difference of about 2000IU when compared to those who do not. Third, our research was performed during the summer season from June to August. A previous study regarding the relative importance of vitamin D synthesis in sun exposure and dietary intake showed that serum 25(OH)D elevation by dietary intake was about 3.1 nmol/L during periods of low sunlight exposure, such as spring/ winter, and to the contrary, serum 25(OH)D increase by dietary intake was only 1.0nmol/L in the case of the abundance of sunlight, such as summer/autumn. In summary, in this study, the concentration of serum vitamin D level could be mainly determined by sunlight exposure, and the effect of dietary intake is minimal during the summer when sunshine is high.

Our study has several limitations. First, this study is cross-sectional design. Second, dietary vitamin D intake including the vitamin D supplements in both groups was not surveyed. Third, there are no data on serum 25(OH)D concentrations from people in their 20s and 30s in the fisherman group. Finally, physical activity levels were not assessed, and some studies have found a positive correlation between physical activity and 25(OH)D concentrations. In conclusion, we investigated the actual serum vitamin D level and vitamin D status in 2 occupation groups in the same local region in Korea: the fisherman group, who were the most sun-exposed, and the general occupation group, who were relatively less sun-exposed. We found that serum 25(OH)D concentrations in the fisherman group were significantly higher compared with the general occupation group. Despite exposure to a large amount of sunlight, 78% of subjects in the fisherman group presented with either vitamin D deficiency or insufficiency. The laboratory measurements of serum 25(OH)D concentrations in fisherman, who were expected to have the highest vitamin D concentrations in Korea, could be epidemiologically useful. However, future regional, national, and worldwide studies looking at serum vitamin D concentrations are needed.

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