Assessment of ambulatory activity in the Republic of Korea Navy submarine crew

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ABSTRACT
A submarine crew in the Republic of the Korea Navy experienced significant physical inactivity during undersea deployment because of the narrow and confined space. Physical inactivity is known to be associated with a number of adverse health conditions in the long-term perspective. This study aimed to assess the ambulatory activity of submarine crew using pedometers. Study subjects (n=109) were the submarine crew from two diesel submarines and personnel from the Submarine Command. The subjects wore pedometers at their waistline and recorded their walking steps daily for a month. The submarine crew walked more than 7,000 steps/day on average during the stationed period. However, the ambulatory activity of the submarine crew greatly declined to a level of around 2,000 steps/day during deployment, which corresponded to the sedentary status category. Active exercise is recommended for the submarine crew to prevent potential adverse health outcomes related to the physical inactivity.

INTRODUCTION
The living and working conditions of submarines are uncomfortable due to its small size. The size guarantees operational concealment. In the case of the 209-class diesel submarine that is operated by the Republic of Korea (ROK) Navy, the situation is even more pronounced. Space is very crowded on-board, and there is no proper area for exercise, not even for walking. As a result, the physical activity of submarine crew is quite limited during deployment.

The physical inactivity is a great concern to the submarine crew, considering their long-term service in the submarine forces. The physically inactive status in the workplace, combined with modern sedentary lifestyle, may cause a number of adverse health outcomes, including obesity, hypertension, cardiovascular disease and diabetes mellitus; all of these conditions can result in mortality [1].

However, the extent of physical inactivity in submarine crew has not yet been properly evaluated in the ROK Navy. Various tools have been attempted to assess individual physical activity for research, surveillance, intervention and evaluation purposes [2]. Although each tool has both advantages and shortcomings, no single method has been accepted as a gold standard for assessing physical activity [3]. Among different types of physical activity, walking is the most representative form of daily activity. In terms of measuring walking, pedometer has been recognized recently as a relatively objective and simple tool [2-11].

This study aimed to assess ambulatory activity of a submarine crew in a stationed and deployed period. Further, we assessed which factors affected the ambulatory activity in the submarine crew.

METHODS
Study subjects were submarine crew members from the two 209-class submarines (n=76) and personnel from the ROK Navy Submarine Command (n=33). All subjects were male because submarine positions are currently available only to males in the ROK Navy. Each crew member voluntarily participated in the study and signed informed consent forms.

Subjects wore pedometers (product name: DMC-03, manufactured by the Shinwoo Electronics Co., LTD in the Republic of Korea) at their waistline and recorded ambulatory activity (steps/day) on a daily basis.
basis for a month; this included both deployment and stationed period. The accuracy of the pedometer was tested in 17 young enlisted men before use. The pedometer recorded 98.5-102.0 percent of actually walked steps under controlled conditions (using a running machine).

Medics who were assigned to each submarine and the Command medical unit frequently checked the compliance of subjects to the study. Basic sociodemographic information and height/weight measurements to calculate body mass index (BMI) were obtained from the periodic health exam data.

The ambulatory activity of the subjects was analyzed in the submarine crew and the Command personnel. Among the submarine crew, the ambulatory activity was compared in between deployment and stationed period (paired T-test). Age was categorized into 20-29, 30-39, and 40-upwards; then, the ambulatory activity in these categories was analyzed (via one-way analysis of variance [ANOVA] test).

Ambulatory activity was compared between officer and the other ranks (T-test). The BMI of the subjects was classified into normal (18.5-23), overweight (23-25) and obesity (25-) according to the Asia-Pacific region BMI classification system [12]. The ambulatory activity according to the BMI categories was analyzed (one-way ANOVA).

**Table 1 – General sociodemographic characteristics of study subjects (n=109)**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Submarine (n=76)</th>
<th>Submarine Command (n=33)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AGE (years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>31 (40.8)</td>
<td>9 (27.3)</td>
</tr>
<tr>
<td>30-39</td>
<td>38 (50.0)</td>
<td>13 (39.4)</td>
</tr>
<tr>
<td>40 –</td>
<td>7 (9.2)</td>
<td>11 (33.3)</td>
</tr>
<tr>
<td><strong>RANK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Officer</td>
<td>16 (21.1)</td>
<td>4 (12.1)</td>
</tr>
<tr>
<td>Petty Officer</td>
<td>60 (79.0)</td>
<td>27 (81.8)</td>
</tr>
<tr>
<td>Warrant Officer</td>
<td>–</td>
<td>1 (3.0)</td>
</tr>
<tr>
<td>Civilian</td>
<td>–</td>
<td>1 (3.0)</td>
</tr>
<tr>
<td><strong>WORKING YEARS in the NAVY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4</td>
<td>4 (5.3)</td>
<td>12 (36.4)</td>
</tr>
<tr>
<td>5-9</td>
<td>30 (39.5)</td>
<td>3 (9.1)</td>
</tr>
<tr>
<td>10-14</td>
<td>29 (38.2)</td>
<td>7 (21.2)</td>
</tr>
<tr>
<td>15-19</td>
<td>6 (7.9)</td>
<td>3 (9.1)</td>
</tr>
<tr>
<td>20 –</td>
<td>7 (9.2)</td>
<td>8 (24.2)</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;23 (normal)</td>
<td>29 (38.2)</td>
<td>17 (51.5)</td>
</tr>
<tr>
<td>≥23, &lt;25 (overweight)</td>
<td>20 (26.3)</td>
<td>6 (18.2)</td>
</tr>
<tr>
<td>≥25 (obese)</td>
<td>27 (35.5)</td>
<td>10 (30.3)</td>
</tr>
</tbody>
</table>

**RESULTS**

General sociodemographic characteristics of the subjects are presented in Table 1 (below). Age of the subjects ranged from 22 to 57 years and mean ± standard deviation (SD) was 33.5±7.7 years. In comparison, the submarine crew tended to be younger than the Command personnel. Among the ranks, the Petty Officer comprised 79.8% of the subjects. The average working years of the subjects in the navy were 12.3±7.8 years. Seventy-eight percent of the submarine crew worked five to 14 years in the navy, whereas working years of the Command personnel distributed evenly across categories. The BMI was out of the normal range (overweight or obese) in 57.8% of the subjects. The proportion of the overweight or obese subjects was higher in the submarine crew than in the Command personnel.

The mean daily ambulatory activity (steps/day) of the subjects was illustrated by their respective units in Figure 1 (Page 415). During the stationed period, the crew of Submarine A walked 9,036±1,825 steps/day on average, while those of Submarine B walked 7,232±2,520 steps/day. In contrast, the ambulatory activity of the submarine crew during deployment greatly declined to around 2,000 steps/day in both submarines. The mean daily walked steps/day of the Submarine Command personnel fluctuated within the range of 6,206-10,090 steps/day. Command personnel walked 7,773±2,198 steps/day on average.

The ambulatory activity of the submarine crew across the categories of deployed or stationed status, age, rank and BMI was compared in Table 2 (Page 416). The submarine crew walked significantly more steps during the stationed period compared with the deployed period. Age, rank and the BMI did not significantly affect the ambulatory activity of the submarine crew in this study.

**DISCUSSION**

After a meticulous search of internet medical journal databases, we found that this was the first study published to examine
FIGURE 1 – Mean daily ambulatory activity (steps/day) of the study subjects by their respective units.
Due to the confined space of the 209-class submarine, the ambulatory activity of submarine crew greatly decreased to around 2,000-3,000 steps/day range on deployment. There is no adequate space for exercise or walking aboard the submarine. Personnel cannot even fully stretch arms and legs without contacting adjacent objects or persons. These adverse working and residential conditions caused significant physical inactivity in the submarine crew.

In general, there has been no consensus on the definition of physical inactivity, or sedentarism so far [2,13]. However, using <5,000 steps/day as a sedentary lifestyle index proposed by Tudor-Locke et al. [14,15], the ambulatory activity of submarine crews during deployment clearly falls into the sedentary category. The pattern of physical inactivity experienced by the submarine crews is periodic in nature because it is experienced only during deployment. Additionally, the sedentary status is kept for 24 hours a day because crew members are not able to leave the submarine on deployment. The degree of inactivity is rather intense among submarine crews compared with other occupational groups [16]. More research is needed to elucidate how this type of physical inactivity affects the health of submarine crews in the long-term perspective.

The level of ambulatory activity was distinct between Submarine A and B. An important factor determining overall physical activity of the group was the group level concern the crews and commanders had regarding their health. In this study, the crew in Submarine A was more actively engaged in physical activity while being stationed to compensate for the sedentary status during deployment.

Considering the recommended daily activity of healthy adults (more than 9,000-11,000 steps/day) [15], the Submarine Command personnel did not appear to walk enough. Because most of the Submarine Command personnel who participated in the study were office workers, they would not be in physically active status during working hours [16]. Therefore, they need to invest more hours in sports activities or exercise after work to reach an adequate level of activity.

In this study, we used a pedometer to measure walking steps in the subjects because walking is known to be the most common form of daily activity [17,18]. The pedometer is a reliable tool for measuring ambulatory activity as aggregated evidence of conver-
gent and construct validity indicate [3,5]. Though the pedometer used in our study had a rather wider range of measurement errors compared with the Yamax Digi-walker model (recommended maximal permissible rate of step miscounting is 0.3%), an internationally recognized tool [4], we believe these errors are acceptable. Unfortunately, however, physical activities other than walking (such as swimming, cycling and weight training) were hardly reflected in measured steps.

In this study, we found that the submarine crew in the ROK Navy was exposed to the high risk of physical inactivity during deployment. Based on the study results, we recommend that the Submarine Command allow the crew to have enough time for active exercise while being stationed. Because the ROK Navy has a rather short history of operating submarine forces (approximately 17 years), we are not certain about the existence of any long-term health effects due to physical inactivity at the current point. Future research is needed in this area to guarantee safe working conditions in the submarine.

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REFERENCES