Association between regular walking and periodontitis according to socioeconomic status: a cross-sectional study

Su-Jin Han1, Kwang-Hak Bae2, Hyo-Jin Lee3, Seon-Jip Kim4,5 & Hyun-Jae Cho4,5

Physical activity reduces the risk and mortality risk of inflammatory diseases. This study aimed to examine the relationship between regular walking and periodontitis in a Korean representative sample of adults according to socioeconomic status. Data acquired by the Sixth Korea National Health and Nutrition Examination Survey in 2014 and 2015 were used. The survey was completed by 11,921 (5,175 males; 6,746 females) participants (≥19 years). Individuals without values on periodontitis were excluded, and 9,728 participants remained. Multivariable logistic regression analysis was done using socio-demographic characteristics (age, gender, income, education), oral health-related variables (flossing, interdental brushing, community periodontal index), oral and general health status and behaviour (smoking, diabetes mellitus), and regular walking. In all models, subjects who walked regularly had significantly lower risks of periodontitis. After adjusting for age, gender, income, education, smoking, diabetes mellitus, flossing, and interdental brushing, the odds ratio for periodontitis in subjects who walked regularly was 0.793 (95% Confidence interval: 0.700–0.898). Non-regular walking groups showed similar social gradients. Risk of low socioeconomic status was not significant in the regular walking group after adjusting for age, gender, income, and education. This study found that regular walking is associated to lower prevalence of periodontitis and can attenuate the relationship between periodontitis and low socioeconomic status.

Periodontitis is an inflammatory chronic disease that leads to the destruction of connective tissue and supporting bone1–2. It is a major oral disease that threatens oral health, and its prevalence is increasing mainly because the society is aging3,4.

Physical activity provides many health benefits and improves the health-related quality of life5–7. Studies have shown that regular physical activity reduces the risk and mortality risk of many systemic diseases including cardiovascular disease, coronary heart disease, colon cancer, diabetes, osteoporosis, obesity, arthritis, and hypertension8–11.

Recently, Kortas et al.12 reported that walking may decrease oxidative stress. Hypertension, obesity, and diabetes mellitus are interlinked in regard to oxidative stress and inflammation13,14. Meta-analyses have reported that walking improves the glycaemic control as assessed by glycated haemoglobin (HbA1c) in patients with type 2 diabetes and that aerobic physical activity decreases the blood pressure of subjects with hypertension15,16. Oxidative stress can have critical effects on several diseases including periodontitis17. Many studies show that regular walking reduces inflammation in the body18–20. Therefore, studying the association between regular walking and periodontitis can be valuable.

Some cross-sectional epidemiologic studies confirm the link between physical activity and periodontitis21,22. However, there are no systematic large-scale epidemiological studies that have confirmed the effect of walking on...
periodontal disease. In addition, there is a report showing that the association between periodontitis and other inflammation-related diseases differs according to the socioeconomic status of the patient\(^2\). Therefore, it is necessary to study socioeconomic status as an effect modifier when studying the association between periodontitis and physical activity.

The objective of this study was to examine the relationship between regular walking and the prevalence of periodontitis in a Korean representative sample of adults according to their socioeconomic status.

**Methods**

This study used data acquired in the second and third years (2014–2015) of the Sixth Korea National Health and Nutrition Examination Survey (KNHANES VI). The KNHANES VI was a cross-sectional and nationally representative survey conducted by the Korea Centers for Disease Control and Prevention between 2013 and 2015. Data from the first year (2013) were not used because the variable for regular walking was used only in the second and third years (2014–2015) of the KNHANES VI. Written informed consents were obtained from all subjects with ethical approval by the KCDC Institutional Review Board (IRB number: 2014–12EXP-03-5C, 2015–01CON-02-6C).

The sampling protocol used was a complex, stratified, multistage probability cluster survey of a representative sample of the non-institutionalized civilian population of Korea. A total of 11,921 participants (5,175 males and 6,746 females), aged 19 years or older, completed the KNHANES VI in 2014 and 2015. Individuals without data on periodontitis and gender were excluded from the analysis. This reduced the sample to 9,728 which was the final number of individuals analysed in this study. From all the data collected by the KNHANES VI, we used the data on socio-demographic characteristics (age, gender, individual income, and level of education), oral health-related variables (dental flossing, interdental brushing, and community periodontal index [CPI]), oral and general health status and behaviour (smoking status and diabetes mellitus), and regular walking.

**Periodontal examination.** The periodontal status was evaluated using the CPI developed by the World Health Organization (WHO)\(^2\). A CPI probe that met the 1997 WHO guidelines was used on ten index teeth, two molars in each posterior sextant, and the upper right and lower left central incisors at six sites per tooth (mesiobuccal, midbuccal, distobuccal, mesiolingual, midlingual, and distolingual), and the periodontal pocket depth was measured. Probing was conducted by dentists who were trained in calibration. Five CPI scores could be recorded: CPI 0, normal; CPI 1, gingival bleeding; CPI 2, presence of gingival calculus; CPI 3, shallow periodontal pocket (≤ 3.5 mm and ≥ 5.5 mm); and CPI 4, deep periodontal pocket (≥ 5.5 mm). Periodontitis was defined as a CPI score of 3 or 4. Participants were classified into two groups: non-periodontitis and periodontitis.

**Regular walking.** The level of physical activity was measured based on the validated Korean version of the International Physical Activity Questionnaire (IPAQ)\(^25,26\). The specific questions for physical activity were ‘How many days did you walk during the last week?’ and ‘How many minutes did you walk on such a day?’. The respondents were classified as those who regularly walked if they had walked for ≥ 30 minutes, ≥ 5 times a week during the last seven days. The classification followed the KNHANES criteria\(^27\).

**Covariates.** The confounders of this study were the following major socio-demographic factors: gender, age, income, and education. The individual income was classified into four different groups: < 25% (the lowest quartile group), 25–49%, 50–74%, and 75–100% (the highest quartile group). The level of education was also classified into four groups based on the Korean education system: below primary school, middle school, high school, and college or higher education. The health behaviour covariates included were smoking, diabetes mellitus, the use of dental floss, and the use of interdental brush. Participants were categorized into two groups based on their smoking experience: ‘never smoker’ and ‘current or past smoker’. With respect to diabetes mellitus, participants were classified into three groups: normal, impaired fasting glucose, and diabetes mellitus.

**Statistical analysis.** Data were analysed using SPSS version 23.0 (SPSS, Chicago, IL). All data were weighted for statistical analyses to account for the complex multistage, stratified, and unequally weighted or clustered sampling design of the KNHANES VI. Appropriate sampling weighting factors were selected as specified from each national dataset. The chi-square test and independent t test were used to compare the characteristics of subjects in the periodontitis and non-periodontitis groups. Multivariate logistic regression analyses were applied to identify associations between regular walking and periodontitis after adjusting for potential confounders. Regression model 1 adjusted for age and gender. Individual income and level of education were added to regression model 2. Smoking and diabetes mellitus were added to regression model 3. Oral health behaviours were added to regression model 4. Other multivariate logistic regression analyses were performed to identify the association between periodontitis and socio-economic status after adjusting for potential confounders in the whole group, the non-regular walking group, and the regular walking group. In model 1, age and gender were adjusted for, and the effect of income on periodontitis was evaluated. The level of education was added to regression model 2. Smoking and diabetes mellitus were added to regression model 3. Oral health behaviours were added to regression model 4. P < 0.05 was considered to be statistically significant.

**Results**

The characteristics of the subjects according to age and gender are shown in Table 1. The subjects who had periodontitis (mean: 54.3 years old) were significantly older than those who did not have periodontitis (mean: 42.4 years old). The proportion of males was significantly higher in the periodontitis group (58.0%) than in the non-periodontitis group (45.5%). The individual income and level of education were significantly different between the two groups. The subjects, who did not have periodontitis, were wealthier and more educated comparing to those who had periodontitis. The proportion of current or past smokers was significantly higher in the
periodontitis group (54.0%) than in the non-periodontitis group (37.9%). With respect to oral-health behaviour, subjects who choose ‘yes’ for the use of dental floss and interdental brush were significantly lesser in the periodontitis group (interdental flossing: 13.5%, interdental brushing: 16.7%) than in the non-periodontitis group (interdental flossing: 27.8%, interdental brushing: 22.6%). Subjects who chose ‘yes’ for regular walking were also significantly lesser in the periodontitis group (35.8%) than the non-periodontitis group (43.3%).

Table 2 shows the results of the logistic regression analyses to determine the presence of multivariable associations between periodontitis and regular walking after adjusting for age, gender, individual income, level of education, smoking, diabetes mellitus, and oral-health behaviour. The four logistic regression models were designed to

| Table 1. The characteristics of subjects in total group and by periodontitis. *Results were obtained by independent t-test. †Results were obtained by chi-square test. CI means Confidence interval. | Total group | Periodontitis |
|---|---|---|
| Unweighted N | Weighted % (95% CI) | Unweighted N | Weighted % (95% CI) | Unweighted N | Weighted % (95% CI) | P-value |
| Age (years) | 9728 | 45.9 (45.3–46.5) | 6533 | 42.4 (41.7–43.0) | 3195 | 54.3 (53.6–55.1) | <0.001* |
| Gender | | | | | | | |
| Male | 4110 | 49.2 (48.1–50.2) | 2466 | 45.5 (44.1–46.8) | 1644 | 58.0 (56.3–59.7) | <0.001† |
| Female | 5618 | 50.8 (49.8–51.9) | 4067 | 54.5 (53.2–55.9) | 1551 | 42.0 (40.3–43.7) | |
| Income | | | | | | | |
| Low | 2318 | 24.7 (23.1–26.3) | 1470 | 23.4 (21.7–25.2) | 848 | 27.7 (25.5–30.1) | <0.001† |
| Middle low | 2423 | 25.2 (23.8–26.7) | 1572 | 24.5 (22.8–26.2) | 851 | 27.0 (25.1–29.1) | <0.001† |
| Middle high | 2486 | 25.0 (23.6–26.5) | 1735 | 25.8 (24.2–27.4) | 751 | 23.2 (21.3–25.3) | |
| High | 2446 | 25.1 (23.1–27.2) | 1723 | 26.3 (24.1–28.7) | 723 | 22.0 (19.7–24.6) | |
| Education | | | | | | | |
| ≤Elemental school | 1999 | 15.5 (14.3–16.8) | 1069 | 11.5 (10.4–12.6) | 930 | 25.2 (22.9–27.7) | <0.001† |
| Middle school | 966 | 8.9 (8.2–9.7) | 525 | 6.9 (6.2–7.6) | 441 | 13.8 (12.2–15.5) | <0.001† |
| High school | 2993 | 38.0 (36.6–39.5) | 2113 | 39.5 (37.8–41.2) | 880 | 34.5 (32.2–36.8) | |
| ≥University or college | 2940 | 37.6 (35.8–39.4) | 2289 | 42.2 (40.2–44.2) | 651 | 26.5 (23.8–29.4) | |
| Smoking | | | | | | | |
| Never | 5728 | 57.4 (56.3–58.6) | 4164 | 62.1 (60.6–63.6) | 1564 | 46.0 (44.1–48.0) | <0.001† |
| Current or past | 3553 | 42.6 (41.4–43.7) | 2085 | 37.9 (36.4–39.4) | 1468 | 54.0 (52.0–55.9) | |
| Diabetes mellitus | | | | | | | |
| Normal | 914 | 8.4 (7.8–9.2) | 447 | 5.7 (5–6.4) | 467 | 15.3 (13.8–16.9) | <0.001† |
| Impaired fasting glucose | 1895 | 21.9 (20.7–23.1) | 1119 | 18.8 (17.5–20.1) | 776 | 29.6 (27.5–31.8) | <0.001† |
| Diabetes | 5447 | 69.7 (68.3–71) | 4014 | 75.6 (74–77.1) | 1433 | 55.1 (52.9–57.4) | |
| Interdental flossing | | | | | | | |
| No | 7234 | 76.4 (75.1–77.6) | 4593 | 72.2 (70.7–73.7) | 2641 | 86.5 (84.7–88.0) | <0.001† |
| Yes | 2047 | 23.6 (22.4–24.9) | 1658 | 27.8 (26.3–29.3) | 389 | 13.5 (12.0–15.3) | |
| Interdental brushing | | | | | | | |
| No | 7504 | 79.1 (78.0–80.2) | 4931 | 77.4 (76.0–78.7) | 2753 | 83.3 (81.3–85.2) | <0.001† |
| Yes | 1777 | 20.9 (19.8–22.0) | 1320 | 22.6 (21.3–24.0) | 457 | 16.7 (14.8–18.7) | |
| Regular walking | | | | | | | |
| No | 3541 | 41.1 (39.6–42.5) | 2477 | 43.3 (41.6–45.0) | 1064 | 35.8 (33.5–38.1) | <0.001† |
| Yes | 5355 | 58.9 (57.5–60.4) | 3516 | 56.7 (55.0–58.4) | 1839 | 64.2 (61.9–66.5) | |
adjust for covariates hierarchically. In all models, subjects who walked regularly showed significantly lower risks of periodontitis than subjects who did not. The adjusted odds ratio (OR) was 0.793 with 95% confidence interval (CI) of 0.699–0.898 for regular walking in model 4.

Table 3 shows the results of the logistic regression analyses for multivariable associations between periodontitis and socio-economic status in the entire study group, non-regular walking, and regular walking groups. Response variable: Individual Income. Model 1 was adjusted for age and gender. Model 2 was adjusted for age, gender, and level of education. Model 3 was adjusted for age, gender, level of education, smoking, and diabetes mellitus. Model 4 was adjusted for age, gender, level of education, smoking, diabetes mellitus, dental flossing, and interdental brushing. Bold denotes statistical significance at \( P < 0.05 \). OR means odds ratio. CI means confidence interval.

Table 2. Multivariable association between regular walking and periodontitis. Response variable: Periodontitis. Explanatory variable: Regular walking. Model 1 was adjusted for age and gender. Model 2 was adjusted for age, gender, individual income, and level of education. Model 3 was adjusted for age, gender, individual income, level of education, smoking, and diabetes mellitus. Model 4 was adjusted for age, gender, individual income, level of education, smoking, diabetes mellitus, dental flossing, and interdental brushing. Bold denotes statistical significance at \( P < 0.05 \). OR means odds ratio. CI means confidence interval.

Table 3. Multivariable association between individual income and periodontitis in the entire study group, non-regular walking, and regular walking groups. Response variable: Periodontitis. Explanatory variable: Individual Income. Model 1 was adjusted for age and gender. Model 2 was adjusted for age and gender. Model 2 was adjusted for age, gender, and level of education. Model 3 was adjusted for age, gender, level of education, smoking, and diabetes mellitus. Model 4 was adjusted for age, gender, level of education, smoking, diabetes mellitus, dental flossing, and interdental brushing. Bold denotes statistical significance at \( P < 0.05 \). OR means odds ratio. CI means confidence interval.

Discussion
This cross-sectional study assessed the effects of regular walking on periodontitis. Our study showed a significant association between regular walking and lower prevalence of periodontitis. Only one other study reported the relationship between walking and periodontitis. In this study done by Merchant et al., walking was assessed separately from other forms of physical activity, and walking was reported to be inversely associated with periodontitis after adjusting for age and smoking. However, this study only used data from people from the United States, and its subjects were health professionals. Using this, it is difficult to generalize the relationship between

| Regular walking | Model 1 | Model 2 | Model 3 | Model 4 |
|-----------------|---------|---------|---------|---------|
| Yes, OR (95% CI)| 0.762 (0.678–0.857) | 0.759 (0.674–0.855) | 0.787 (0.695–0.892) | 0.793 (0.699–0.898) |
| No              | Reference | Reference | Reference | Reference |

| OR (95% CI) | Total | Regular walking |
|------------|-------|-----------------|
| Model 1    |       |                 |
| Low        | 1.518 (1.262–1.826) | 1.566 (1.24–1.978) | 1.389 (1.031–1.87) |
| Middle low | 1.423 (1.2–1.687)  | 1.390 (1.122–1.723) | 1.380 (1.049–1.816) |
| Middle high| 1.095 (0.925–1.296) | 1.031 (0.839–1.267) | 1.096 (0.839–1.43) |
| High       | Reference | Reference | Reference |

| Model 2    |       |                 |
| Low        | 1.418 (1.169–1.72) | 1.481 (1.165–1.883) | 1.301 (0.958–1.767) |
| Middle low | 1.341 (1.125–1.597) | 1.332 (1.073–1.653) | 1.314 (0.991–1.742) |
| Middle high| 1.039 (0.87–1.242)  | 1.001 (0.813–1.233) | 1.065 (0.811–1.399) |
| High       | Reference | Reference | Reference |

| Model 3    |       |                 |
| Low        | 1.414 (1.147–1.742) | 1.423 (1.098–1.844) | 1.366 (0.995–1.874) |
| Middle low | 1.333 (1.102–1.612) | 1.282 (1.013–1.621) | 1.376 (1.029–1.841) |
| Middle high| 1.045 (0.863–1.266)  | 0.982 (0.783–1.231) | 1.13 (0.85–1.501) |
| High       | Reference | Reference | Reference |

| Model 4    |       |                 |
| Low        | 1.388 (1.125–1.711) | 1.394 (1.074–1.810) | 1.345 (0.977–1.850) |
| Middle low | 1.314 (1.087–1.589) | 1.267 (1.001–1.603) | 1.362 (1.018–1.821) |
| Middle high| 1.037 (0.855–1.258)  | 0.981 (0.782–1.232) | 1.114 (0.836–1.484) |
| High       | Reference | Reference | Reference |
walking and periodontitis. We used the KNHANES VI complex sample data, and defined regular walking by
the IPAQ. When age, gender, individual income, level of education, smoking, and diabetes mellitus were adjusted
(Model 4 of Table 2), the OR of developing periodontitis while regularly walking was 0.793 (95% CI: 0.699–0.898).

This showed that regular walking had a preventive effect on periodontitis.

Bawadi et al.21 studied the relationship between periodontitis, physical activity, and healthy diet by randomly
selecting 340 subjects and asking about their socio-demographic and clinical characteristics, anthropometric
measurements, dietary assessment, and level of physical activity using the IPAQ. The subjects were divided into
three categories: low, moderate, and high physical activity. The high physical active group had a significantly lower
average plaque index, average gingival index, and average clinical attachment loss. They suggested that decreased
physical activity and poor diet were significantly associated with periodontitis.

Al-Zahrani et al.22 also reported the relationship between physical activity and the prevalence of periodontitis.
They used the NHANES III subjects (n = 2,521) and suggested that a high level of physical activity can prevent
periodontitis. Anderson et al.28 evaluated the relationship between physical activity and periodontal pathogens.
They reported that physical activity had a positive association with the antibodies in the orange and blue complex
related to healthy periodontal states. Although they did not use regular walking as a separate effect modifier,
these results are similar to the findings of our study and support the hypothesis that physical activity reduces the
prevalence of periodontitis.

Three main mechanisms may explain the association between regular walking and periodontitis: oxidative
stress, inflammation, and insulin resistance. Firstly, regular walking may decrease oxidative stress, obesity, dis-
ese that are prone to people who do not even exercise lightly such as walking, decreased in infiltration of oxi-
dized lipids into the lining of the blood vessel, which result in oxidative stresses in the blood vessel walls.30–32.
Secondly, regular walking could reduce vascular inflammatory markers.33 Metabolic syndrome, prone to obesity,
is the chronic inflammation caused by increased production of reactive oxygen species34. Regular walking is very
effective in preventing metabolic syndrome35. Thirdly, regular walking have been reported to reduce HbA1c in
diabetic patients15 and to significantly reduce the systolic blood pressure of subjects participating in the 6-month
gait program36. Consequentially, these reduce the risk of developing periodontal diseases to have indirect com-
mon pathway that causes a reduction in inflammatory mediators37. As such, the effect of regular walking, in
physical activity, was announced.

Based on these mechanisms, people with regular walking deficiency are prone to obesity and hypertension16,
and these diseases are closely related to periodontal disease.38,39,40. Although walking is not enough to reduce ox-
idative stress, inflammation, and insulin resistance immediately, the regular walking which we define was at least 1
time 30 minutes and more 5 days a week. This definition of regular walking was not easily achievable by ordinary
people and this regular walking could be effective on prevention of obesity and hypertension38,40.

In our study, the results of logistic regression analyses showed that subjects who walked regularly had significa-
cantly lower risk (OR: 0.793, CI: 0.699–0.898) of periodontitis than those who did not. This result confirms that
regular walking can have a positive effect on the health of the whole body, as well as oral health specifically.

We also found that regular walking may attenuate the relationship between periodontitis and low socioeco-
omeconomic status. The non-regular walking groups were significantly associated with the low social and economic
status seen in the below median income group. This was maintained even after all confounders had been adjusted
for. No significant association was found between the social and economic status seen in the lowest income
groups in the regular walking group after the confounders had been adjusted for in models 2, 3, and 4 of Table 3.
These results can be interpreted as showing that regular walking alleviates the relationship between periodontitis
and low socioeconomic status by reducing periodontitis since the ORs decreased in the regular walking group
when compared with the non-regular walking group.

Generally, Periodontal disease is associated with health inequalities. People, who have high socio-economic
 statuses show a tendency to maintain good oral health whereas, those who have low socio-economic statuses
show a susceptibility to periodontitis.41 Economic inequality, in addition to predicting general morbidity and
mortality, is also strongly related to unhealthy behaviours and habits.42

The socioeconomic status and other systemic factors, including physical activity, could be important factors
associated with periodontitis.43 However, oral health experts generally offer advice only on plaque control to
people with periodontitis. Considering the results of this study, it may be clinically helpful to advice patients with
periodontitis on the benefits of physical activity, especially regular walking.

There is no previous study that explores the association between the regular walking and periodontal heath
inequalities. The results of this study suggest that promoting regular walking can promote oral health. However,
future studies are needed because causal relationships between regular walking and periodontal health could
not be discussed in this study. This would be useful for establishing a guideline for decreasing health inequalities
with regard to periodontitis.

The following are the limitations of this study. Firstly, it had a cross-sectional design which does not allow
determining the direction of the causal relationship between regular walking and periodontitis. Further stud-
ies that adopt a prospective design are needed for the same. Longitudinal studies should be done to verify the
presence of a direct role of physical activity in preventing periodontitis and to determine its interactions with
other factors that are known to affect periodontitis. Secondly, this survey was limited to Koreans and can hinder
the generalization of the results. Thirdly, since the study was based on self-reported health status and physical
activity, there might have been bias. Finally, since periodontitis was evaluated using the CPI, periodontitis could
be over- or underestimated.44 Generally, periodontal statuses are assessed by using clinical attachment level and
pocket depth. However, CPI is an epidemiologic tool developed by WHO. The measurement of regular walking
in the KNHANES data was based on IPAQ that has been widely used and has acceptable validity. Moreover, the
data covers a large number of subjects, and the complex sampling design was considered during all analyses to
overcome shortcomings.
Walking is a simple, safe, and cost-effective health behaviour that can reduce the prevalence of chronic diseases and reduce the cost of health care. Our study supported the hypothesis that regular walking is associated with lower prevalence of periodontitis. We also found that regular walking can attenuate the relationship between periodontitis and low socioeconomic status.

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**Author Contributions**

All authors contributed to this paper. S.J. Han carried out the data analysis and wrote the entire manuscript. K.H. Bae took part in the study design, revised the manuscript, and implemented the literature study. H.J. Lee have searched and wrote about previous studies about health inequalities. S.J. Kim have checked and modified the manuscript format by journal style of Scientific Reports. H.J. Cho coordinated the study and helped to draft the manuscript. All authors reviewed the manuscript.

**Additional Information**

**Competing Interests:** The authors declare no competing interests.

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