Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Physical Activity Level and Predicted 10-Year Atherosclerotic Cardiovascular Disease Risk Among Korean Cancer Survivors: A Nationwide Population-Based Study

Won-Sang Jung
Dongseo University
Hana Ahn
Dongseo University
Eunjoo Lee
Konkuk University
Jae-Ho Choi
Konkuk University
Hun-Young Park
parkhy1980@konkuk.ac.kr

Konkuk University

Research Article

Keywords: physical activity, cancer survivors, cardiovascular disease, risk assessment, KNHANES

Posted Date: November 18th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11137041/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Physical Activity Level and Predicted 10-Year Atherosclerotic Cardiovascular Disease Risk Among Korean Cancer Survivors: A Nationwide Population-Based Study

Won-Sang Jung[1], Hana Ahn[1], Eunjoo Lee[2,3], Jae-Ho Choi[1,3], Hun-Young Park[2,3,*]

[1] Department of Senior Exercise Prescription, Dongseo University, Busan, Republic of Korea

[2] Laboratory of Applied Exercise Physiology, Department of Sports Medicine and Science, Graduate School, Konkuk University, Seoul, Republic of Korea

[3] Physical Activity and Performance Institute (PAPI), Konkuk University, Seoul, Republic of Korea

***Corresponding author:** Hun-Young Park, PhD

120 Neungdong-ro, Gwangjin-gu, Seoul 05029, Republic of Korea

Tel: +82-2-2049-6035, Fax: +82-452-6027, E-mail: parkhy1980@konkuk.ac.kr

ORCID: https://orcid.org/0000-0002-9901-7624

Abstract

Purpose: Cancer survivors carry a disproportionately high burden of cardiovascular disease (CVD), yet whether physical activity (PA) mitigates this excess risk remains unclear in Korean populations. This study examined the association between PA level and predicted 10-year atherosclerotic cardiovascular disease (ASCVD) risk among Korean cancer survivors.

Methods: We analyzed data from the Korea National Health and Nutrition Examination Survey (KNHANES) 2014–2021 (8 survey years), restricted to this period because the physical activity questionnaire was substantially revised in 2014. Adults aged 40–79 years without prior cardiovascular disease were included (N=29,146; 1,785 cancer survivors, 27,361 cancer-free controls). PA was quantified as metabolic equivalent task (MET)-minutes/week and categorized as inactive, insufficiently active, or sufficiently active (WHO criteria, ≥600 MET-min/week). Ten-year ASCVD risk was estimated using the Pooled Cohort Equations (PCE) and the Korean ASCVD risk prediction model (K-CVD). Survey-weighted logistic regression estimated adjusted odds ratios (aORs) for high predicted risk across PA categories among cancer survivors.

Results: Among cancer survivors, sufficient PA was associated with significantly lower odds of high predicted ASCVD risk compared with inactivity (PCE: aOR=0.59, 95% CI 0.45–0.78; K-CVD: aOR=0.51, 95% CI 0.37–0.69). A significant dose-response relationship was observed between log-transformed MET-minutes/week and high PCE risk (β=-0.071, $p<0.001$). The interaction between PA level and cancer survivorship status was not statistically significant (all $p>0.05$).

Conclusion: Higher physical activity was independently associated with lower predicted 10-year ASCVD risk among Korean cancer survivors, with a clear dose-response gradient. These findings support physical activity promotion as a component of cardiovascular risk reduction in cancer survivorship care.

Keywords: physical activity; cancer survivors; cardiovascular disease; risk assessment; KNHANES

Introduction

Improvements in early detection and treatment have steadily increased cancer survival in Korea, and the number of individuals living with a history of cancer continues to grow each year [1,2].

As survival extends, attention has increasingly shifted from short-term oncologic outcomes toward the long-term health consequences that cancer survivors face over years and decades of survivorship. Among these, cardiovascular disease (CVD) has emerged as one of the most significant non-cancer causes of morbidity and mortality in this population [3–5].

The elevated cardiovascular risk observed in cancer survivors arises from several overlapping mechanisms. First, many cancers and cardiovascular diseases share common risk factors, including smoking, obesity, physical inactivity, and aging, so individuals predisposed to cancer are often also predisposed to CVD [3,6]. Second, several widely used cancer treatments—including anthracycline chemotherapy, HER2-targeted agents, and thoracic radiotherapy—carry direct or indirect cardiotoxic effects that can manifest as left ventricular dysfunction, accelerated atherosclerosis, or arrhythmia, sometimes years after treatment completion [4,5,7]. Third, the physiological deconditioning that accompanies cancer treatment—reduced cardiorespiratory fitness, muscle wasting, and prolonged reductions in habitual activity—can itself impair cardiovascular reserve capacity independent of direct cardiotoxicity [6]. Population-based cohort studies from the United Kingdom and United States have confirmed that survivors of a wide range of adult cancers face elevated medium- and long-term risks of specific cardiovascular diseases and cardiovascular death relative to the general population [7,8]. Consistent with this international evidence, a recent nationwide, population-based analysis using KNHANES data reported that Korean cancer survivors have significantly higher predicted 10-year atherosclerotic cardiovascular disease (ASCVD) risk than cancer-free adults across three independently derived risk prediction models [1].

Physical activity (PA) is among the most consistently modifiable determinants of cardiovascular health identified in the general population. Large international cohort studies, including the Prospective Urban Rural Epidemiology (PURE) study spanning 17 countries, have demonstrated graded, dose-dependent reductions in cardiovascular events and mortality with increasing PA volume [9]. Meta-analytic evidence similarly supports a strong inverse association between PA and incident cardiovascular disease and its major risk factors [10], and harmonized dose-response analyses indicate that cardiovascular and all-cause mortality risk continues to decline well beyond minimum recommended activity thresholds, without a clear upper plateau across most of the observed range [11]. These findings underpin current international guidelines, including the World

Health Organization's 2020 guidelines on physical activity and sedentary behaviour, which recommend at least 150–300 minutes of moderate-intensity (or equivalent) aerobic activity per week for all adults, explicitly including individuals living with chronic conditions such as cancer [12,13].

Exercise oncology has developed in parallel as a distinct field emphasizing PA as a core component of cancer survivorship care. International multidisciplinary consensus guidelines now recommend regular moderate-to-vigorous aerobic and resistance exercise for most cancer survivors, both during and after treatment [14,15]. Observational and interventional evidence indicates that PA is associated with reduced treatment-related toxicity, improved cardiorespiratory fitness, and, in some cancer types, lower recurrence and mortality risk [15–17]. Specific to cardiovascular outcomes, exercise has been shown to reduce the risk of cardiovascular events among women treated for non-metastatic breast cancer [18], and exercise therapy has been proposed as a strategy to directly counteract treatment-related cardiovascular toxicity [19]. Despite this growing body of evidence, most studies linking PA to cardiovascular outcomes in cancer survivors have been conducted in Western populations or within specific cancer types (particularly breast cancer), and it remains unclear whether—and to what extent—the cardioprotective association between PA and predicted ASCVD risk observed in the general population is preserved across the broader, heterogeneous population of cancer survivors in Korea.

The present study addresses this gap by using the same nationally representative KNHANES data source and the same 10-year ASCVD risk prediction framework as the aforementioned nationwide study of Korean cancer survivors [1], but shifting the analytic focus from cancer survivorship status itself to PA level as the primary exposure of interest. We hypothesized that higher PA would be associated with lower predicted 10-year ASCVD risk among Korean cancer survivors in a dose-dependent manner, and we further examined whether the magnitude of this association differed between cancer survivors and cancer-free adults, and across major cancer types.

Methods

Study Design and Data Source

This cross-sectional study used data from KNHANES, a nationally representative, stratified, multistage probability survey conducted annually by the Korea Disease Control and Prevention

Agency (KDCA) since 1998 [20,21]. We pooled eight consecutive survey years (2014–2021). Data from 2010–2013 were excluded because the physical activity questionnaire underwent a substantial structural revision in 2014 with the full adoption of the Global Physical Activity Questionnaire (GPAQ) [22,23], which separately assesses occupational and leisure-time activity and narrowed the definition of walking to transport-related walking only. Empirical comparison confirmed a marked discontinuity in measured activity volume across this transition that was not explained by seasonal or pandemic-related factors, precluding valid pooling of the two measurement eras for a PA-focused analysis. Consistent with KDCA analytic guidance for multi-year pooled analyses, an integrated sample weight was calculated as the annual interview-and-examination weight divided by 8, and the original strata and primary sampling unit variables were retained for variance estimation.

Study Population

Eligible participants were aged 40–79 years, corresponding to the validated age range of the risk prediction models used. We excluded individuals with a prior history of myocardial infarction, angina, or stroke, and those with missing data on blood pressure, total cholesterol, HDL-cholesterol, fasting glucose, or smoking status. After applying these criteria, the final analytic sample comprised 29,146 participants (1,785 cancer survivors and 27,361 cancer-free controls) (Fig. 1).

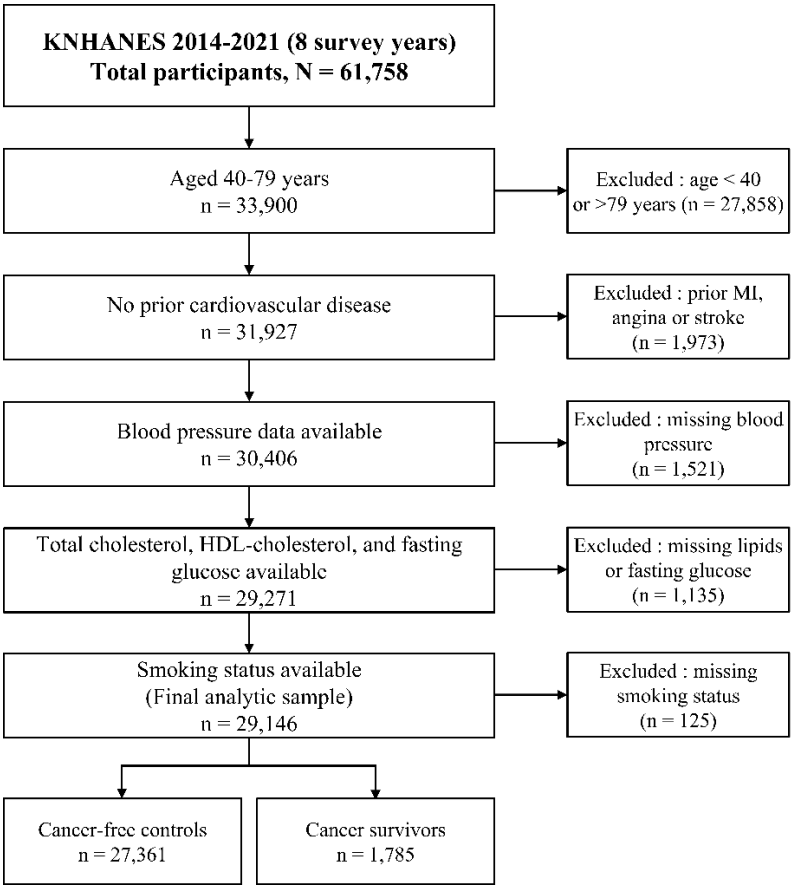


Fig. 1 Flow diagram of study participant selection.

Cancer Survivor Ascertainment

Cancer survivorship was defined as a self-reported physician diagnosis of stomach, liver, colorectal, breast, cervical, lung, or thyroid cancer, or other/multiple cancer, obtained from the KNHANES health interview module. Cancer-free controls reported no history of any of these diagnoses.

Physical Activity Assessment

PA was assessed via GPAQ items covering vigorous- and moderate-intensity activity performed in occupational and leisure-time domains, and transport-related walking [22,23]. For each domain, weekly duration (days × minutes/day) was calculated and occupational and leisure-time components were summed within intensity category. Total volume was expressed as MET-minutes/week using standard MET values (vigorous activity=8.0, moderate activity and walking=4.0). Participants were categorized as inactive (0 MET-min/week), insufficiently active (>0 and <600 MET-min/week), or sufficiently active (≥600 MET-min/week), consistent with

WHO PA guidelines [12]. As with all self-reported activity measures, this approach is subject to recall and social desirability bias relative to device-based measurement [24].

Outcome Assessment: 10-Year ASCVD Risk

Ten-year ASCVD risk was estimated using two independently derived risk prediction models: (1) the Pooled Cohort Equations (PCE), derived from US cohorts and recommended by the 2013 American College of Cardiology/American Heart Association guideline [25], applying sex-specific coefficients for White individuals as commonly done in prior Korean validation studies; and (2) the Korean ASCVD risk prediction model (K-CVD), derived and validated in a Korean population-based cohort [26]. Both models incorporate age, systolic blood pressure and antihypertensive treatment status, total and HDL-cholesterol, current smoking, and diabetes status; the K-CVD model additionally incorporates triglycerides (men), urine protein, and lipid-lowering medication use (women). High predicted risk was defined as ≥7.5% for the PCE, consistent with clinical treatment thresholds, and as the top quintile of the risk score distribution for K-CVD. A third Korean-derived model (the Korean Risk Prediction Model, KRPM) [27], originally developed as a population-specific recalibration of the PCE using Korean Heart Study data and building on earlier Korean coronary heart disease prediction work [28], was considered during protocol development but ultimately not included in the primary analysis after internal validation checks against independent published benchmarks [29] raised concerns about the stability of the publicly reported model coefficients when applied outside their original derivation cohort; this is noted as a methodological limitation.

Covariates

Antihypertensive treatment status was defined from self-reported current treatment for hypertension; diabetes was defined as fasting glucose ≥126 mg/dL or current diabetes medication use. Household income (quintile), education level, marital status, body mass index (BMI), and alcohol consumption were included as covariates, consistent with the covariate set used in the companion analysis of cancer survivorship and ASCVD risk in this population [1].

Statistical Analysis

All analyses accounted for the complex, stratified, multistage sampling design of KNHANES using survey-weighted procedures (R survey package), incorporating strata, primary sampling

units, and the integrated sample weight described above. Baseline characteristics were compared between cancer survivors and controls using survey-weighted t-tests (continuous variables) and chi-square tests (categorical variables). Within cancer survivors, survey-weighted logistic regression was used to estimate unadjusted and adjusted odds ratios (aORs) with 95% confidence intervals for high predicted ASCVD risk across PA categories (reference: inactive), adjusting for income, education, marital status, BMI, and alcohol consumption. Dose-response relationships were examined by modeling log-transformed (MET-minutes/week + 1) as a continuous exposure. To assess whether the PA–ASCVD risk association differed by cancer survivorship status, an interaction term between PA category and survivorship status was included in a model fit to the full sample. Exploratory, age-adjusted analyses stratified by cancer type examined whether the association between sufficient PA and high predicted risk was consistent across major cancer types. A two-sided $p<0.05$ was considered statistically significant. Analyses were conducted in R (version 4.x). No artificial intelligence (AI) tools were used for data cleaning, variable derivation, statistical code writing, or manuscript preparation. All variable definitions, analytic decisions, and interpretations were reviewed and verified by the authors, who take full responsibility for the accuracy and integrity of the reported results.

Results

Baseline Characteristics

Cancer survivors were older than cancer-free controls (weighted mean age 60.2 vs. 55.2 years, $p<0.001$), more often female (63.4% vs. 50.7%, $p<0.001$), and less likely to be current smokers (7.4% vs. 17.6%, $p<0.001$) or frequent alcohol consumers (43.8% vs. 56.7%, $p<0.001$) (Table 1). Mean BMI was slightly lower among survivors (23.7 vs. 24.2 kg/m², $p<0.001$). Survivors were somewhat more likely to have less than a high-school education (24.7% vs. 17.7% with ≤elementary education, $p<0.001$) but showed no significant difference in household income distribution ($p=0.30$). A smaller proportion of survivors reported a current non-married status (2.1% vs. 4.7%, $p<0.001$), consistent with prior observations of selective participation among healthier or more socially supported survivors in national survey samples. Notably, weighted mean PA volume did not differ significantly between groups (854 vs. 862 MET-min/week, $p=0.84$), although the distribution across PA categories differed modestly (cancer survivors: 33.8% inactive, 22.4% insufficiently active, 43.8% sufficiently active; controls: 37.2%, 22.1%, 40.7%,

respectively; p=0.038).

Characteristic	Controls (n=27,361)	Cancer Survivors (n=1,785)	p
Age, years, mean (SE)	55.2 (0.10)	60.2 (0.27)	<0.001
Female, %	50.7	63.4	<0.001
BMI, kg/m², mean (SE)	24.2 (0.03)	23.7 (0.09)	<0.001
Current smoker, %	17.6	7.4	<0.001
Frequent alcohol consumption, %	56.7	43.8	<0.001
Diabetes, %	10.4	10.2	0.87
Antihypertensive treatment, %	23.0	27.6	0.06
≤Elementary education, %	17.7	24.7	<0.001
≥College education, %	34.8	27.5	<0.001
Household income, upper 40% (Q4–Q5), %	40.7	43.5	0.30
Not currently married, %	4.7	2.1	<0.001
PA, MET-min/week, mean (SE)	861.7 (13.2)	854.2 (39.7)	0.84
Inactive, %	37.2	33.8	
Insufficiently active, %	22.1	22.4	
Sufficiently active, %	40.7	43.8	0.038*

**Chi-square test across the three-category distribution. Abbreviations: BMI, body mass index; PA, physical activity; SE, standard error.*

Among cancer survivors, the distribution of specific cancer diagnoses (unweighted) was: thyroid, 378 (21.2%); other/unspecified, 389 (21.8%); stomach, 260 (14.6%); breast, 247 (13.8%); colorectal, 172 (9.6%); cervical, 155 (8.7%); multiple concurrent cancers, 91 (5.1%); lung, 52 (2.9%); and liver, 41 (2.3%).

Predicted ASCVD Risk by Cancer Survivorship Status

Consistent with the companion nationwide analysis [1], cancer survivors had significantly higher predicted 10-year ASCVD risk than controls by both models (PCE: 9.5% vs. 7.6%, p<0.001; K-CVD: 2.5% vs. 2.0%, p<0.001), and a higher proportion met the high-risk threshold (PCE-high: 42.6% vs. 33.5%; K-CVD-high: 22.7% vs. 14.6%).

Physical Activity Level and Predicted ASCVD Risk Among Cancer Survivors

Among cancer survivors, both unadjusted and adjusted models showed a graded, inverse association between PA level and high predicted ASCVD risk (Table 2). After adjustment for

income, education, marital status, BMI, and alcohol consumption, sufficiently active survivors had 41% lower odds of high PCE-predicted risk (aOR=0.59, 95% CI 0.45–0.78, p<0.001) and 49% lower odds of high K-CVD-predicted risk (aOR=0.51, 95% CI 0.37–0.69, p<0.001) compared with inactive survivors. Insufficiently active survivors also showed significantly lower odds of high PCE-predicted risk (aOR=0.63, 95% CI 0.46–0.86, p=0.004), although the corresponding association with K-CVD-predicted risk did not reach statistical significance (aOR=0.88, 95% CI 0.64–1.22, p=0.46).

PA Level	PCE-high aOR (95% CI)	p	K-CVD-high aOR (95% CI)	p
Inactive (ref)	1.00	—	1.00	—
Insufficiently active	0.63 (0.46–0.86)	0.004	0.88 (0.64–1.22)	0.46
Sufficiently active	0.59 (0.45–0.78)	<0.001	0.51 (0.37–0.69)	<0.001

Adjusted for income, education, marital status, body mass index, and alcohol consumption. Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; PA, physical activity.

Fig. 2 Adjusted ORs for high 10-year ASCVD risk according to physical activity level

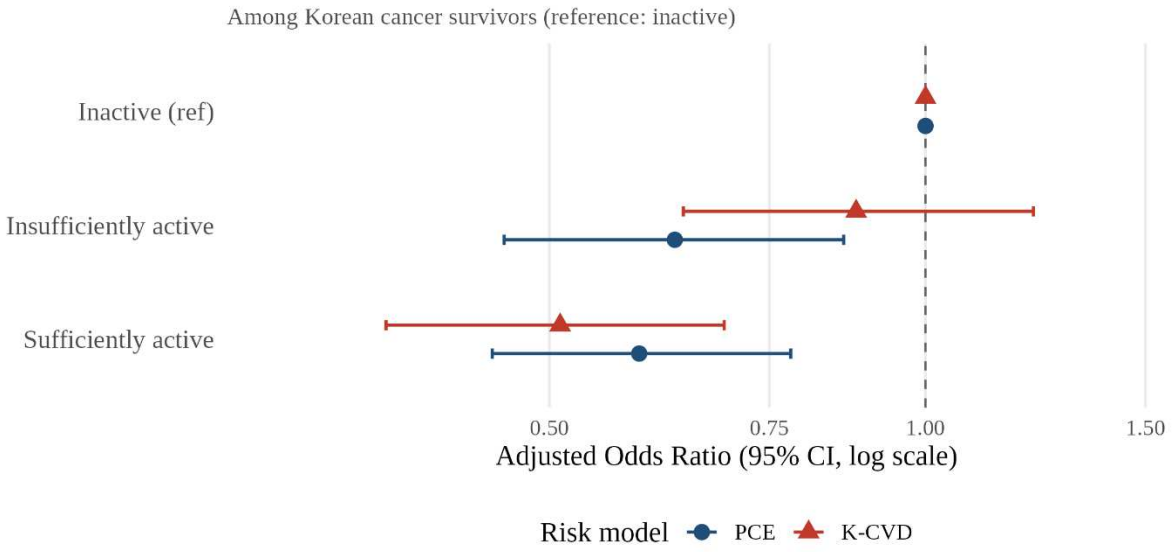


Fig. 2 Adjusted odds ratios (95% CI) for high predicted 10-year ASCVD risk according to physical activity level among Korean cancer survivors, by risk model (PCE, K-CVD). Reference group: inactive.

Dose-Response Relationship

Modeling MET-minutes/week continuously (log-transformed) confirmed a significant inverse dose-response relationship with high PCE-predicted risk among cancer survivors (β=-0.071,

SE=0.018, p<0.001), indicating that ASCVD risk declined progressively with increasing activity volume rather than only at a categorical threshold. This pattern is consistent with dose-response relationships reported between PA and cardiovascular outcomes in general-population cohorts, in which risk reduction continues across a wide range of activity volumes without a clear upper plateau [11].

Interaction Between Physical Activity and Cancer Survivorship Status

In the full sample (survivors and controls combined), the interaction terms between PA category and cancer survivorship status were not statistically significant for high PCE-predicted risk (insufficiently active × survivor: p=0.068; sufficiently active × survivor: p=0.20), indicating no strong statistical evidence that the magnitude of the PA–ASCVD risk association differed between cancer survivors and cancer-free adults.

Cancer Type-Specific Analysis

In exploratory, age-adjusted analyses stratified by cancer type (Fig. 3), sufficient physical activity (vs. not sufficiently active) was associated with lower odds of high predicted risk for most cancer types, consistent in direction with the overall finding, but confidence intervals were wide and most site-specific estimates did not reach statistical significance given limited sample sizes (n=41–389 per cancer type). The association reached nominal significance for thyroid cancer survivors (K-CVD: aOR=0.26, 95% CI 0.08–0.78, p=0.017) and survivors of multiple concurrent cancers (K-CVD: aOR=0.16, 95% CI 0.03–0.79, p=0.026). Estimates for less common cancers (liver, n=41; lung, n=52) were particularly imprecise and should be interpreted with caution. These site-specific findings are hypothesis-generating and require confirmation in larger, adequately powered samples.

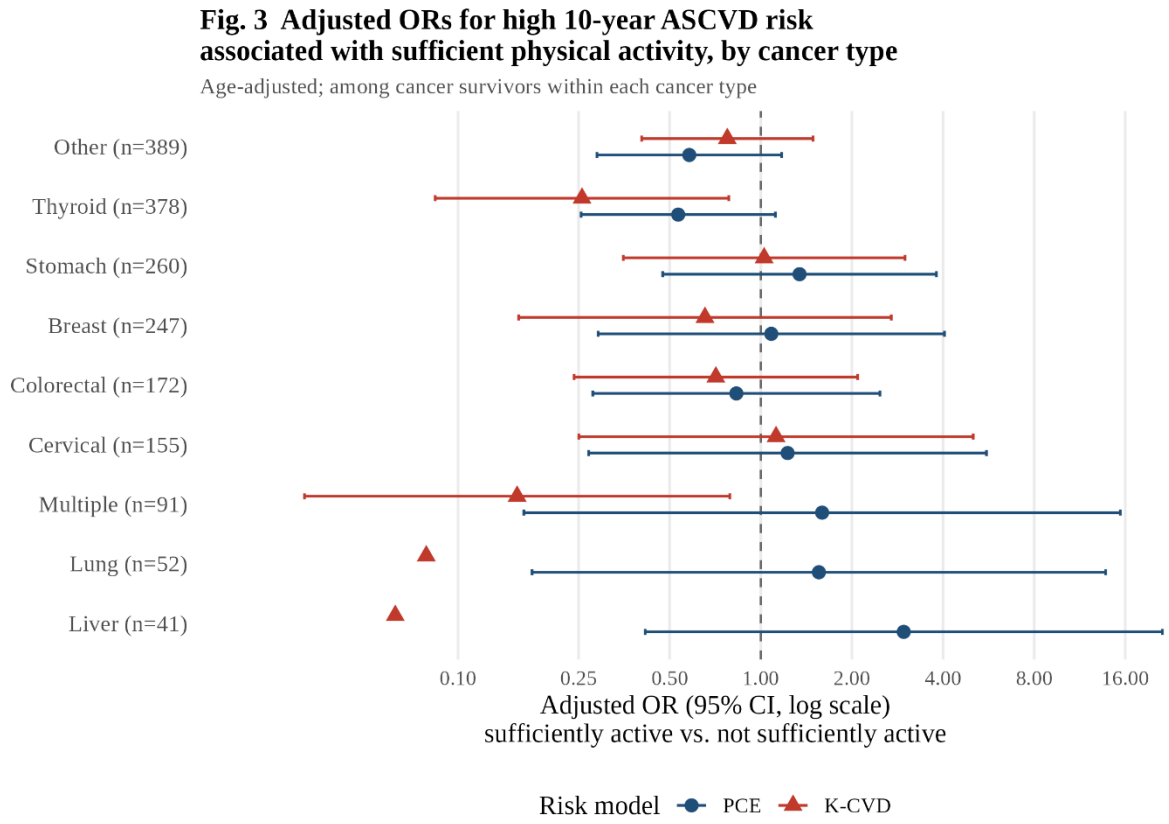


Fig. 3 Age-adjusted odds ratios (95% CI) for high predicted 10-year ASCVD risk associated with sufficient physical activity (vs. not sufficiently active), by cancer type and risk model (PCE, K-CVD).

Discussion

In this nationally representative sample of Korean adults, higher physical activity was independently associated with lower predicted 10-year ASCVD risk among cancer survivors, with a clear dose-response gradient and consistent findings across two independently derived risk prediction models. These associations persisted after adjustment for socioeconomic and lifestyle covariates and did not differ significantly from the corresponding association observed in cancer-free adults, suggesting that the cardioprotective association of physical activity is preserved in this population.

These findings extend a companion nationwide analysis that identified an elevated predicted ASCVD risk burden among Korean cancer survivors relative to cancer-free adults [1], by identifying physical activity as a modifiable factor associated with lower risk within the survivor population itself. The magnitude of the association observed here—41–49% lower odds of high

predicted risk with sufficient activity—is broadly consistent with the cardioprotective associations of physical activity reported in general-population cohorts internationally, including the multinational PURE study [9] and pooled meta-analytic estimates of PA and cardiovascular disease risk [10], and aligns with the graded dose-response relationship reported between device-measured activity and mortality outcomes [11]. It is also consistent with cancer-specific evidence, such as the reduced risk of cardiovascular events observed among physically active breast cancer survivors in Western cohorts [18], extending this pattern to a broader set of cancer types in a Korean population. These findings complement, rather than duplicate, a recent large nationwide Korean cohort study that used National Health Insurance Service claims data to link pre- and post-diagnosis physical activity changes to incident cardiovascular events (myocardial infarction, heart failure) among 269,943 cancer survivors [34]. Whereas that study demonstrated the long-term protective association of sustained or initiated physical activity against hard cardiovascular endpoints over extended follow-up, the present cross-sectional analysis offers a complementary perspective: a validated, clinically actionable estimate of absolute 10-year ASCVD risk derived from a single health examination, which may be more readily incorporated into routine survivorship care encounters where longitudinal claims-based follow-up is not feasible.

Several biologically plausible mechanisms may underlie this association. Regular physical activity favorably modifies traditional cardiovascular risk factors, including blood pressure, lipid profile, insulin sensitivity, and adiposity—the same intermediate pathways captured by the risk prediction models used in this study. Beyond these traditional pathways, physical activity may also help preserve cardiorespiratory fitness and cardiovascular reserve capacity that are otherwise eroded by cancer treatment-related deconditioning [6], and exercise-based interventions have been proposed as a direct countermeasure to treatment-related cardiovascular toxicity through effects on vascular and cardiac function [19]. Because our outcome was a composite risk score rather than a single biomarker, the present findings likely reflect the aggregate benefit of physical activity across several of these pathways simultaneously.

From a clinical and public health perspective, these findings support the integration of physical activity counseling into routine survivorship care, consistent with international exercise oncology consensus guidelines recommending regular moderate-to-vigorous aerobic and resistance exercise for most cancer survivors [14,15]. The absence of a significant interaction between PA and

survivorship status suggests that existing general-population physical activity targets, such as the WHO's recommended 150–300 minutes of moderate-intensity activity per week [12], may be a reasonable starting point for cardiovascular risk reduction counseling in cancer survivors, pending confirmation in prospective cancer-survivor-specific studies. This is further supported by broader cancer-survivorship dietary and lifestyle guidance that similarly emphasizes regular physical activity as a component of comprehensive risk reduction [30].

Notably, mean physical activity volume did not differ substantially between cancer survivors and controls in this sample, and survivors were, if anything, modestly more likely to meet the sufficient-activity threshold. This contrasts with the common assumption that cancer survivors are uniformly less active than the general population and may reflect several non-mutually-exclusive explanations: survivorship-care-related lifestyle counseling, selection related to functional status required to participate in a national health examination survey (a form of healthy-survivor bias), or heterogeneity across cancer types, treatment recency, and time since diagnosis that could not be captured in this cross-sectional analysis. Future studies incorporating time since diagnosis and treatment history would help clarify these patterns.

The cancer type-specific analyses, while limited by sample size, suggested a broadly consistent direction of association across most cancer types, with the strongest and most precise associations observed for thyroid cancer and survivors of multiple concurrent cancers. Given the generally favorable prognosis and long survivorship duration typical of thyroid cancer in Korea, this subgroup may offer a particularly relevant target population for future physical activity intervention studies with sufficient statistical power.

Strengths and Limitations

This study has several strengths, including the use of a large, nationally representative sample, standardized objective risk prediction models, and complex survey design-adjusted analysis. Several limitations should be considered. First, the cross-sectional design precludes causal inference; physical activity level and predicted risk were measured concurrently, and reverse causation (e.g., illness-related reduction in activity) cannot be excluded. Second, physical activity was self-reported and subject to recall and social desirability bias relative to device-based measurement [24]. Third, because the physical activity questionnaire changed substantially in

2014, we restricted the analytic period to 2014–2021 to ensure measurement consistency; this improves internal validity for the physical activity exposure but reduces the analytic period relative to the companion cancer-survivorship analysis and may limit generalizability to earlier periods. Fourth, outcomes were model-predicted 10-year ASCVD risk scores rather than observed cardiovascular events; while these models have been validated for discrimination in Korean populations, none has been shown to perfectly capture absolute risk, and a third candidate model (KRPM) was excluded after internal checks suggested instability in the publicly available coefficients when applied to this dataset, warranting cautious interpretation of any single risk model in isolation. Fifth, information on cancer stage, treatment modality (e.g., chemotherapy, radiotherapy), and time since diagnosis was not available, precluding examination of how these factors might modify the PA–risk association. Sixth, cancer type-specific analyses were exploratory and underpowered for most sites given limited subgroup sample sizes (n=41–389); these estimates should be considered hypothesis-generating rather than confirmatory. Finally, residual confounding by unmeasured factors cannot be excluded.

Conclusion

Among Korean cancer survivors, higher physical activity was associated with a graded reduction in predicted 10-year ASCVD risk, an association consistent across two risk prediction models and not significantly different from that observed in cancer-free adults. These findings support the integration of physical activity promotion into cardiovascular risk reduction strategies for cancer survivors and highlight the need for longitudinal studies examining physical activity, cancer treatment characteristics, and incident cardiovascular events in this growing population.

References

1. [Companion study] Predicted 10-Year Atherosclerotic Cardiovascular Disease Risk Among Korean Cancer Survivors: A Nationwide Population-Based Study Using Three Risk Models. [Journal, in review/press – complete citation to be added by authors]

2. Jung KW, Won YJ, Hong S, Kong HJ, Lee ES (2022) Prediction of Cancer Incidence and Mortality in Korea, 2022. Cancer Res Treat 54:345-351

3. Armenian SH, Lacchetti C, Barac A et al (2017) Prevention and monitoring of cardiac dysfunction in survivors of adult cancers: American Society of Clinical Oncology clinical practice guideline. J Clin Oncol 35:893-911

4. Mehta LS, Watson KE, Barac A et al (2018) Cardiovascular Disease and Breast Cancer: Where These Entities Intersect: A Scientific Statement From the American Heart Association. Circulation 137:e30-e66

5. Zamorano JL, Lancellotti P, Rodriguez Munoz D et al (2016) 2016 ESC Position Paper on cancer treatments and cardiovascular toxicity developed under the auspices of the ESC Committee for Practice Guidelines. Eur Heart J 37:2768-2801

6. Koelwyn GJ, Khouri M, Mackey JR, Douglas PS, Jones LW (2012) Running on empty: cardiovascular reserve capacity and late effects of therapy in cancer survivorship. J Clin Oncol 30:4458-4461

7. Strongman H, Gadd S, Matthews A et al (2019) Medium and long-term risks of specific cardiovascular diseases in survivors of 20 adult cancers: a population-based cohort study using multiple linked UK electronic health records databases. Lancet 394:1041-1054

8. Sturgeon KM, Deng L, Bluethmann SM et al (2019) A population-based study of cardiovascular disease mortality risk in US cancer patients. Eur Heart J 40:3889-3897

9. Lear SA, Hu W, Rangarajan S et al (2017) The effect of physical activity on mortality and cardiovascular disease in 130,000 people from 17 high-income, middle-income, and low-income countries: the PURE study. Lancet 390:2643-2654

10. Wahid A, Manek N, Nichols M et al (2016) Quantifying the Association Between Physical Activity and Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis. J Am Heart Assoc 5:e002495

11. Ekelund U, Tarp J, Steene-Johannessen J et al (2019) Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. BMJ 366:l4570

12. Bull FC, Al-Ansari SS, Biddle S et al (2020) World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med 54:1451-1462

13. 2018 Physical Activity Guidelines Advisory Committee (2018) 2018 Physical Activity Guidelines Advisory Committee Scientific Report. U.S. Department of Health and Human Services, Washington, DC

14. Schmitz KH, Campbell AM, Stuiver MM et al (2019) Exercise is medicine in oncology: Engaging clinicians to help patients move through cancer. CA Cancer J Clin 69:468-484

15. Campbell KL, Winters-Stone KM, Wiskemann J et al (2019) Exercise Guidelines for Cancer Survivors: Consensus Statement From International Multidisciplinary Roundtable. Med Sci Sports Exerc 51:2375-2390

16. Cormie P, Zopf EM, Zhang X, Schmitz KH (2017) The Impact of Exercise on Cancer Mortality, Recurrence, and Treatment-Related Adverse Effects. Epidemiol Rev 39:71-92

17. Hayes SC, Newton RU, Spence RR, Galvão DA (2019) The Exercise and Sports Science Australia position statement: Exercise medicine in cancer management. J Sci Med Sport 22:1175-1199

18. Jones LW, Habel LA, Weltzien E et al (2016) Exercise and Risk of Cardiovascular Events in Women With Nonmetastatic Breast Cancer. J Clin Oncol 34:2743-2749

19. Scott JM, Nilsen TS, Gupta D, Jones LW (2018) Exercise Therapy and Cardiovascular Toxicity in Cancer. Circulation 137:1176-1191

20. Kweon S, Kim Y, Jang MJ et al (2014) Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). Int J Epidemiol 43:69-77

21. Oh K, Kim Y, Kweon S et al (2021) Korea National Health and Nutrition Examination Survey, 20th anniversary: accomplishments and future directions. Epidemiol Health 43:e2021025

22. Armstrong T, Bull F (2006) Development of the World Health Organization Global Physical Activity Questionnaire (GPAQ). J Public Health 14:66-70

23. Bull FC, Maslin TS, Armstrong T (2009) Global physical activity questionnaire (GPAQ): nine country reliability and validity study. J Phys Act Health 6:790-804

24. Prince SA, Adamo KB, Hamel ME, Hardt J, Connor Gorber S, Tremblay M (2008) A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. Int J Behav Nutr Phys Act 5:56

25. Goff DC Jr, Lloyd-Jones DM, Bennett G et al (2014) 2013 ACC/AHA guideline on the assessment of cardiovascular risk: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 63:2935-2959

26. Park S, Kim YG, Ann SH, Cho YR, Kim SJ, Han S, Park GM (2023) Prediction of the 10-year risk of atherosclerotic cardiovascular disease in the Korean population. Epidemiol Health 45:e2023052. https://doi.org/10.4178/epih.e2023052

27. Jung KJ, Jang Y, Oh DJ et al (2015) The ACC/AHA 2013 pooled cohort equations compared to a Korean Risk Prediction Model for atherosclerotic cardiovascular disease. Atherosclerosis 242:367-375. https://doi.org/10.1016/j.atherosclerosis.2015.07.033

28. Jee SH, Jang Y, Oh DJ et al (2014) A coronary heart disease prediction model: the Korean Heart Study. BMJ Open 4:e005025

29. Bae JH, Moon MK, Oh S, Koo BK, Cho NH, Lee MK (2020) Validation of risk prediction models for atherosclerotic cardiovascular disease in a prospective Korean community-based cohort. Diabetes Metab J 44:458-469. https://doi.org/10.4093/dmj.2019.0061

30. Rock CL, Thomson C, Gansler T et al (2020) American Cancer Society guideline for diet and physical activity for cancer prevention. CA Cancer J Clin 70:245-271

31. D'Agostino RB Sr, Vasan RS, Pencina MJ et al (2008) General cardiovascular risk profile for use in primary care: the Framingham Heart Study. Circulation 117:743-753

32. Muntner P, Colantonio LD, Cushman M et al (2014) Validation of the atherosclerotic cardiovascular disease Pooled Cohort risk equations. JAMA 311:1406-1415

33. Friedenreich CM, Neilson HK, Farris MS, Courneya KS (2016) Physical Activity and Cancer Outcomes: A Precision Medicine Approach. Clin Cancer Res 22:4766-4775

34. Jung W, Cho IY, Jung J et al (2024) Changes in Physical Activity and Cardiovascular Disease Risk in Cancer Survivors: A Nationwide Cohort Study. JACC CardioOncol 6:879-889. https://doi.org/10.1016/j.jaccao.2024.09.013

Statements and Declarations

Funding: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Competing Interests: The authors declare no competing interests.

Author Contributions: All authors contributed to the study conception and design. Data extraction, statistical analysis, and interpretation were performed by Won-Sang Jung, Hana Ahn, and Jae-Ho Choi. Eunjoo Lee and Hun-Young Park contributed to interpretation of the risk-model results and critical revision of the manuscript for important intellectual content. The first draft of the manuscript was written by Won-Sang Jung, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics Approval: This study used publicly available, de-identified secondary data from the Korea National Health and Nutrition Examination Survey (KNHANES), conducted by the Korea Disease Control and Prevention Agency (KDCA). KNHANES was approved by the KDCA Research Ethics Review Committee for each applicable survey year included in this analysis (2014: approval no. 2013-12EXP-03-5C; 2015–2017: data collection was exempt from deliberation under Article 2 of the Bioethics and Safety Act, as KNHANES is a government-run survey conducted for public welfare; 2018: approval no. 2018-01-03-P-A; 2019: approval no. 2018-01-03-C-A; 2020: approval no. 2018-01-03-2C-A; 2021: approval no. 2018-01-03-5C-A), and all participants provided written informed consent at the time of the original survey. As this study involved secondary analysis of publicly available, de-identified data, separate institutional review board approval was not required.

Consent to Participate: Not applicable (secondary analysis of de-identified, publicly available survey data; informed consent was obtained from all participants by KNHANES at the time of original data collection).

Consent to Publish: Not applicable (no individual person's data, images, or identifying information are included in this manuscript).

Availability of Data and Material: The datasets analyzed in this study are publicly available from the Korea Disease Control and Prevention Agency KNHANES data portal (https://knhanes.kdca.go.kr) upon registration, in accordance with KNHANES data access policy.

Code Availability: The R code used for data extraction, variable derivation, and statistical analysis is available from the corresponding author upon reasonable request.