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Health Behavior Changes and Mortality among Cancer Survivors

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Health Behavior Changes and Mortality among Cancer Survivors

A Dissertation

Submitted to the Department of Public Health
at the Graduate School of Yonsei University
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy in Public Health

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December 2021

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December 2021

Acknowledgments

The path toward this dissertation would not have been possible without the support and guidance I received from many people. It is a pleasure to thank those who helped me achieve this goal and made this dissertation possible.

I would like to first say a big thank you to my supervisor, Professor Sung-In Jang, for all the support and encouragement that he gave me. Professor Jang created a lot of opportunities, thus allowing me to widen my scope of experience and deepen my knowledge of health policies. His passion for constantly caring for the students and supervising them is admirable. I thank his endless support throughout my journey of PhD.

I am also grateful to Professor Eun-Cheol Park, who advised me to continue this path. His sincere advice and supervision were truly valuable and made it possible for me to come this far. Professor Park allowed me to widen my perspective in research and feel the joy of learning. I deeply appreciate him for supervising my dissertation and to him I feel great respect and gratitude.

To Professor Chung Mo Nam, I thank him for his enthusiasm and efforts to teach and guide me through biostatistics. It was an honor to be able to learn a lot from Professor Nam while in his biostatistics consulting room. I appreciate Professor Sohee Park for her considerable and meticulous teaching, which was an opportunity to grow further. She was the most sophisticated person I have ever seen, and it was a lot of joy to learn about cancer under her. I also thank Professor Jin Young Nam, as I cannot forget how she gave

sincere advice and support as both a professor and a senior in life. Her warm guidance and academic passion inspired me to go further. My words of thanks must be extended to Professor Jaeyong Shin, who supervised me into the world of projects. I also thank Professor Suk-Yong Jang, for his clear and succinct guidance.

A special thanks then go to my mentor Yun Kyung Kim, who left me with a lot of memorable moments. My time here would not have been as valuable if I was unable to meet her. She was a dependable supporter who always stood by my side and cheered me up. I appreciate Jae Hong Joo whom I spent all my semester together. His industriousness and sincerity inspire me all the time. I am grateful for his support, which gave me the will to endure the hardships. I thank Hyunkyu Kim for his knowledge and expertise, through which I was able to see my subject in a new perspective. Soo Hyun Kang was the friend who I could share my joy and difficulties with. The time that I spent with her was always so pleasant and consoling. I thank Selin Kim, as although she was my mentee, her faithfulness and optimism influenced me to become a positive leader. Bich Na Jang helped me to learn how to become a meticulous worker and I appreciate her supportive care as well. Hye Jin Joo always gave me considerable care and her vivacity filled my days up with positive energy. I thank Fatima Nari as she was always reassuring and encouraging. I appreciate Sarah Soyeon Oh and Jieun Jang for their valuable guidance throughout my research. Dong-Woo Choi was a broad-minded person and his leadership truly inspired me. I also thank Sung Hoon Jeong and Minah Park who made my time here more enjoyable.

I would also like to express appreciation towards my 310 roommates from biostatistics consulting. I thank Hyun-Soo Zhang, from whom I gained a significant understanding on biostatistics. It was an honor to be able to observe and learn his knowledge right beside him. I appreciate HyeJung Kang and Hoyol Jhang for their bright energies in room 310. I also thank Jaeheon Yu and Jiyeon Chun, as their enthusiasm gave me motivation and confidence. Overall, I thank all my colleagues from 404 and 318 roommates for leaving me with priceless memories as I walk towards a new beginning.

Last but certainly not least, I thank my mom, who is my number one fan. It was her unconditional love and support that gave strength to move forward. I am fortunate to have my dad, my biggest supporter, and my brother, Wonseok Jeong, who is not just my sibling but also a friend and a colleague that works in the same field. I will always cheer him up for everything he does. I am grateful more than I can express in words for the support and encouragement from my family. They are the most important people in my world, and without their help, I could not have finalized this dissertation. Lastly, I would also like to appreciate my aunt and my uncle for their care and my cousins, Heejeong, Cheouljun, and Jeeveon Moon for being with me and supporting me since my childhood. I am genuinely grateful for everyone else that encouraged and assisted me during my degree. Taking with me these invaluable experiences, I would like to move on to become a better person.

December, 2021

Wonjeong Jeong

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ABSTRACT

Health Behavior Changes and Mortality among Cancer Survivors

Background: Given the rapid growth of the population of cancer survivors, increased attention should be paid to the successful management of their health behaviors. For demonstrating the importance of managing health behaviors of cancer survivors to reduce mortality, in-depth investigation of health behaviors and mortality of cancer survivors is necessary. This study aimed to investigate the factors associated with health behavior changes, examine the effects of health behavior changes on mortality among cancer survivors, and develop validated nomograms.

Methods: Data from 9,300 adult cancer survivors, derived from the National Health Insurance Service–National Sample Cohort between 2002 and 2015 were included. Individuals who were still alive five years after cancer diagnosis were defined as cancer survivors. This study first analyzed the factors associated with health behavior changes among cancer survivors. Changes in health behavior, smoking status, and physical health, were analyzed comparing the participants' health behaviors before the diagnosis of their cancer and after their diagnosis of the cancer until a five-year survival period. A multinomial logistic regression analysis was performed. Second, this study investigated the association between health behavior changes and the risk of mortality among cancer survivors. Both all-cause mortality and cancer-related mortality risks were estimated using Cox proportional hazard regression. For the nomogram, the data were randomly

assigned into training data (for constructing the nomogram) and testing data (for validation), at a ratio of 3:1. Discrimination (Harrell's C-index) and calibration (Hosmer-Lemeshow test) were employed to validate the nomogram.

Results: Among 9,300 cancer survivors, 235 (2.5%) started smoking, 880 (9.5%) continued smoking, and 964 (10.4%) had post-diagnosis smoking cessation. Among them, 2,197 (23.6%) were consistently active in physical activity, 1,915 (20.6%) started physical activity, and 1,857 (20.0%) stopped physical activity. Individuals who had one type of unhealthy behavior had higher odds of having other unhealthy behaviors. Compared to nonsmokers, those who started or quit smoking had higher risk of all-cause mortality (Started smoking: HR=1.98, 95% CI=1.25-3.15, Quit smoking: HR=1.44, 95% CI=1.05-1.97). Those who were physically inactive had a higher risk of all-cause mortality than those who were continuously active (HR=1.45, 95% CI=1.05-2.02). For the nomogram, the C-index value was 0.79 in the training data and 0.81 in the testing data, and the Hosmer-Lemeshow test was not significant, which demonstrates a good fit.

Conclusions: This study found that unhealthy behaviors usually combined and individuals with unhealthy behavior had a higher risk of mortality. This highlights the importance of managing health behavior among cancer survivors. The development of a validated nomogram may provide useful insights for both official policies and existing practice in health care systems, which would benefit cancer survivors.

Key words: Cancer Survivors; Health Behavior; Healthy Lifestyle; Smoking;

Smoking Cessation; Physical Activity; Exercise; Mortality

I. Introduction

1. Background

With improvements in early detection and treatment of cancer, the long-term outcomes for cancer patients were improved which led to increased cancer survivors.^{1,2} Given the rapid growth of the population of cancer survivors, increased attention has been paid to their health problems.³ The cancer survivor population in the US has increased over the past half century to an estimated 18.1 million in 2020 and is projected to increase to more than 20 million by 2026.⁴ With the increasing incidence of cancer and improvement in survival, the number of cancer survivors in Korea continues to rise.⁵ Accordingly, cancer prevalence continues to increase, reaching approximately 1.87 million by the end of 2017, which leads to a rapid increase of cancer survival.⁶ The 5-year relative survival rate of cancer patients in South Korea improved substantially from 42.9% for the period 1993–1995 to 70.4% for the period 2013–2017.⁷ As the number of cancer survivors are expected to grow dramatically in the next decades, attention is increasing toward the cancer survivors.⁸

The concern about the quality of life of cancer survivors is increasing, and the health care neglect or physical and mental problems they experience owing to cancer treatment is increasing.⁹ Cancer survivors have many unique health care needs, including managing the sequelae of cancer treatment and monitoring for cancer recurrence.¹⁰

Moreover, cancer survivorship is associated with substantial medical expenditure and lost productivity.¹¹ The health care cost of cancer survivors was high even at long-term survivorship phase of more than 5 years after diagnosis, suggesting higher health care needs.⁵ The challenges for long-term survivors include psychosocial late effects that call for comprehensive management which primary care physicians plays a critical role in caring for long-term survivors.⁸ Comprehensive care of the cancer survivors must address appropriate health promotion and disease prevention strategies for other conditions.¹² It is essential to manage health condition of cancer survivors to reduce their physical and psychological distress.¹³

Cancer survivor's health behavior have important implications for their morbidity and mortality.¹⁴ As more people diagnosed with cancer are living longer, the implications of lifestyle behaviors, such as cigarette smoking, that worsen cancer prognosis are of major importance for public health.¹⁵ Healthy behaviors such as being physically active, adopting a healthy diet, not smoking, and limiting alcohol intake may prevent the onset and development of late effects and reduce the incidence of cancer recurrence and increased survival among cancer survivors.^{15,16} However, the prevalence of cigarette smoking among cancer survivors still remain high.^{4,17} Many cancer survivors continue to smoke, despite the knowledge that continued smoking leads to poor clinical outcomes and shorter survival times.^{4,18} Interestingly, previous study shows that more than 50% of cancer survivors who smoked attempted to quit smoking unsuccessfully.⁴ Considering the high proportion of quit attempts among cancer survivors those who were

unsuccessful, improvement and integration of smoking cessation is needed.⁴ Therefore, increasing attention is paid to such continued health problems and needs of increased cancer survivors for successful management of their health behaviors.⁵

Health behavior among cancer survivors often changes compared to the general population, those without cancer, as cancer diagnosis often serves as an impetus for making health behavior changes.¹⁴ Health behavior changes were indirectly influenced by the survivor's psychosocial resources, and could lead to their positive health outcomes.¹⁴ Previous studies show that cancer survivors had an increased chance of smoking cessation than general populations, and mortality risk was significantly lower among cancer survivors who had stopped smoking.¹⁹ Likewise, physical activity and a healthy lifestyle improved long-term health among cancer survivors more than among healthy population controls.¹⁶ Despite the high motivation for changes in the lifestyle of cancer survivors, guidelines for managing cancer survivors are insufficient. Some issues among cancer survivors are the uncertainty as to who will provide the cancer care, the oncologists or the primary care providers.²⁰ As cancer diagnosis is a difficult event in people's lives, it provides an opportunity for clinicians to help patients with cancer make healthy changes to their lifestyle.¹⁵

Unfortunately, few studies exist on the health behavior of cancer survivors in South Korea. Considering that proper advice and support could help cancer survivors with continuous healthy behavior, it is important to provide support to cancer survivors to change to healthy behavior, which could improve their long-term health outcomes.²¹

Previous studies showed that cancer survivors who had receive health information and support to promote physical activity showed increased physical activity compared to self-care groups.²² However, there are still a lack of guidelines for cancer survivors in South Korea. To systematically manage the health of cancer survivors, the Korean version of the cancer survivor health care model is needed.

Therefore, it is necessary to observe how cancer survivors manage their health in South Korea, and how this affects their health outcomes. This study first examine the factors associated with health behavior changes among cancer survivors to highlight the importance of managing their health behavior. Moreover, this study investigates the effects of health behavior changes and risk of mortality among cancer survivors to prevent their premature mortality by managing their health behavior. Considering the significant physical and psychological burden of cancer survivors, the in-depth investigation of the mortality of cancer survivors is necessary. We hypothesized that those who showed unhealthy behaviors such as being physically inactivity and smoking are usually combines, and those are highly associated with higher risk of mortality than those with healthy behaviors such as physically active and smoking. Consequently, this study examined the factors associated with changes in health behavior including smoking status and physical activity, and the risk of mortality according to health behavior changes among South Korean cancer survivors. Moreover, we aimed to develop a validated nomogram to predict the risk of survival for cancer survivors.

2. Study Objectives

This study aimed to investigate the factors associated with health behavior changes among cancer survivors. Furthermore, the effects of health behavior changes and the risk of mortality were investigated. Changes in health behavior include smoking status and physical activity, which were made by comparing their health behavior before and after cancer diagnosis. The detailed study objectives are as follows:

- (1) To investigate the factors associated with smoking status and physical activity change among cancer survivors.
- (2) To investigate the association between health behavior changes and the risk of mortality, as well as cancer-related mortality among cancer survivors.
- (3) To investigate whether other socioeconomic and health related characteristics result in increased mortality that are stratified with health behavior changes.
- (4) To investigate the association between health behavior changes and the risk of mortality among cancer survivors and their general population.
- (5) To develop a validated nomogram to predict the risk of 3-year survival for cancer survivors.

II. Literature Review

1. Definition of Cancer Survivors

The term “cancer survivor” is used widely; however, there is still a lack of a consistent, operational definition of what it means to be a cancer survivor.²³ To empower patients to make decisions about their care and to push for better research and treatment, the phrase “cancer survivor” became widely used instead of “cancer patients” or “cancer victim”.²⁴ The term “cancer survivor” was first used by a pediatrician, Fitzhugh Mullan, who had published an article in the New England Journal of Medicine theorizing the concept of cancer survival.^{25,26} Dr Mullan believed that the simple concept of cure did not capture the long-term experience of cancer and he described survivorship as an independent phenomenon with unique challenges facing cancer survivors.²³ This idea has to counter the dichotomy “cured/not cured” and those who lived through the oncological disease and distinguished them from the general population.²⁶

Before the founding of the National Coalition for Cancer Survivorship (NCCS), the usual definition of cancer survival was clinical: someone who had been free of any sign of disease for a minimum five years.²⁷ The National Cancer Institute, defined a cancer survivor as “a person (is) considered to be a survivor from the time of diagnosis of cancer until end of life”.^{15,28} The original conception of cancer survivorship from Fitzhugh Mullan and the NCCS, and the population, which the definition covers, has been

widely interpreted over the years and continues to be an area of some discussion and debates about when a person becomes a cancer survivor: whether it is post-treatment, only applicable from 5 years post-diagnosis, or separate from end-of-life care.²⁴ As the survival period is increasing, with more than 10 years of survival such as for breast cancer, the discussion about the definition of a cancer survivor as a person from the time of diagnosis until the end of life has been increased.²⁹ Currently, the NCCS define a cancer survivor as “from the time diagnosis and for the balance of life” and has been expanded to include family, friends and caregivers.²⁷ Therefore, many recent studies define cancer survivors as those who are diagnosed with cancer and who are still alive regardless of a cure or not (Table 1).²⁶

Table 1. Definition of Cancer survivors ²⁶

No.	Source	Year	Definition of cancer survivors
1	Mullan F. (1985) Seasons of survival: reflections of a physician with cancer. <i>New England Journal of Medicine</i> , 313(4):270-273 ²⁵	1985	Three phases of cancer survivorship: 1) the period after diagnosis and during primary treatments is defined "acute survivorship". 2) "extended survivorship" is individuals may experience other concerns like their health or the quality of received care. 3) "permanent survivorship" characterized the period when patients are living with cancer as chronic disease or when individuals are in remission thanks to ongoing treatment.
2	National Coalition for Cancer Survivorship ²⁷	1986	Person from the moment of diagnosis and for the balance of his or her life, regardless of the ultimate cause of death. The definition then expanded to include family members, friends, and caregivers of individuals with cancer.
3	LiveStrong Foundation (Centers for Disease Control and Prevention and the Lance Armstrong Foundation) ²⁶	2004	Cancer survivorship is the experience to live with, through and beyond cancer
4	Deimling GT, Bowman KF, Wagner LJ, et al. (2007) Cancer survivorship and identity among long-term survivors. <i>Cancer Investigation</i> , 25(8):758-765 ³⁰	2007	Patients with cancer after diagnosis and treatment, who have survived cancer for 5 years of longer
5	Torp S, Nielsen RA, Gudbergsson Saevar, et al. (2012) Sick leave patterns among 5-year cancer survivors: a registry-based retrospective cohort study. <i>Journal of Cancer Survivorship</i> , 6:315-323 ³¹	2012	Person for 5 consecutive years following a first lifetime diagnosis of cancer

Table 1. Definition of Cancer survivors (Continued) ²⁶

No.	Source	Year	Definition of cancer survivors
6	Bryand AK, Banegas MP, Martinez ME, et al. (2017) Trends in radiation therapy among cancer survivors in the United States, 2000-2030. <i>Cancer Epidemiology, Biomarkers & Prevention</i> , 26(6):963 ³²	2017	Person who were alive 5 years or more following their cancer diagnosis
7	Kang DW, Lee EY, An KY, et al. (2018) Associations between physical activity and comorbidities in Korean cancer survivors. <i>Journal of Cancer Survivorship</i> , 12:441-449 ³³	2018	Participants who had ever been diagnosed with any type of cancer
8	Ko A, Kim K, Son JS, et al. (2019) Association of pre-existing depression with all-cause, cancer-related, and noncancer-related mortality among 5-year cancer survivors: a population-based cohort study. <i>Scientific Reports</i> , 9:18334 ³⁴	2019	Person who were alive 5 years after the first cancer diagnosis date were defined as 5 year cancer survivors
9	Talluri R, Domgue Joel, Gritz ER, et al. (2020) Assessment of trend in cigarette smoking cessation after cancer diagnosis among US adults, 2000 to 2017. <i>JAMA Network Open</i> , 3(8):e2012164 ¹⁵	2020	Person considered to be survivors from the time of diagnosis until the end of life

2. Health Behavior Changes among Cancer Survivors

1) Change in Smoking status

As the number of survivors and their length of survival expand, long-term health issue for the cancer survivors are fast emerging as a public health concern.^{35,36} The practice of healthy lifestyle behaviors may reduce the risk for disease and functional decline.³⁷ Smoking cessation is of paramount importance for primary prevention, and is also essential for reducing the risk of a second primary cancer, multiple adverse treatment, and increasing survival among cancer survivors.³⁶ For successful smoking cessation, behavioral and psychological issues should be considered ahead.

Previous studies stated that a large proportion of smoker survivors were willing to cut down smoking by approximately 70%, and about 40% of survivors received support for smoking cessation.²¹ Similarly, the smoking cessation rate increased as time passed after cancer diagnosed.^{21,38} This shows that smoking cessation was highly associated with a higher level of fear of cancer recurrence, which contributed to a high awareness toward good health behavior such as smoking cessation.²¹

However, according to research by the US National Health Interview Survey, 13.2% of US adult cancer survivors were still current smokers.¹⁵ Other high rates of continued smoking have also been observed in another study, in which only one-third of the cancer survivors who are currently smoking intend to quit smoking.^{15,39} A possible explanation for the low smoking cessation rate is that cancer survivors tried to quit

smoking as they felt obliged or pressured by health care providers, and not because they felt ready to quit.³⁹

Considering cancer survivors' struggle to quit smoking, they should be provided with continuous advice and support, since repetitive advice has been proven to help smokers succeed in cessation.²¹ A previous study showed a higher prevalence of current smoking among rural survivors (25%) compared to urban cancer survivors (16%), owing to a lack of support from others and a lack of accessibility to the counseling program.⁴⁰ Therefore, it is important to create the environment in which they can quit smoking. Furthermore, it is essential to help them to quit smoking spontaneously by continuous support.

2) Change in Physical activity

Most cancer survivors reported high interest in exercise-related interventions, which resulted in an amelioration of health outcomes and quality of life.^{35,37} Despite the challenges after cancer diagnoses and treatment, survivors can be motivated to make behavioral improvement.^{35,36} Exercise is consistently associated with improved quality of life, and is also effective in improving physical functioning (oxygen capacity, cardiorespiratory fitness, or strength measures), anthropometric measures (weight status, body fat and waist circumferences) and health related biomarkers (blood pressure, heart rate, hemoglobin concentration, and circulating hormonal levels) among cancer survivors.³⁶ Therefore, physical activity positively changes their health outcomes.

However, many cancer survivors do not meet current public health guidelines for health behaviors because 60% are overweight, and 62% are insufficiently active.³⁵ Similarly, while most older cancer survivors are nonsmokers, their physical activity behaviors tend to be suboptimal.³⁷ One Canadian study found that the majority of cancer survivors were not meeting the physical activity guidelines with activity rates of 42% overall.⁴¹ These results show that despite recognizing that physical activity is important, management of their physical activity is still insufficient.

As noted, improved physical function was dependent on their ability to successfully modify unhealthy behaviors.³⁷ One study stated that physical activity tends to be associated with an all-cause mortality.⁴² According to a report from the Norwegian Countries Study, there was a 64% decrease in all-cause mortality risk among post-menopausal breast cancer survivors in those who were in the highest group of physical activity than the lowest group.^{42,43} Moreover, the benefits of moderate to high levels of physical activity are decreased cancer-specific and all-cause mortality regardless of whether they had prior cancer or not.⁴⁴ However, most cancer survivors emphasized that interventions should be tailored to address the unique needs of survivors, for example, survivors reported that they needed guidelines as they were restricted in their abilities owing to physical limitations from cancer, leading to the need of more specific guidelines for cancer survivors.⁴⁵

Table 2. Summary of Previous Literature about Health Behavior Changes among Cancer survivors

No.	Source	Population	Sample size (N)	Risk behaviors measured	Summary
1	Tseng TS, Lin HY, Mooday-Thomas S, et al. (2012) Who tends to continue smoking after cancer diagnosis: the National Health and Nutrition Examination Survey 1999-2008. <i>BMC Public Health</i> , 12:784 ³⁸	Cancer survivors aged 20 or older who smoked more than 100 cigarettes	2,374	Smoking behavior	Around 50.6% of cancer survivors smoked regularly prior to their cancer diagnosis and only 36.1% of them quit smoking after their cancer diagnosis
2	Klosky JL, Howell CR, Li Z, et al. (2012) Risky health behavior among adolescents in the childhood cancer survivor study cohort. <i>Journal of Pediatric Psychology</i> , 37(6):634-646 ⁴⁶	Those who diagnosed leukemia, lymphoma, central nervous system malignancy, kidney cancer, neuroblastoma, malignant bone tumor, or soft tissue sarcoma	702 survivors and 303 sibling	Smoking behaviors (Cigarette use), Drug and alcohol consumption	15% use cigarette and 17% had binge drinking among cancer survivors
3	Valle CG, Tate DF, Mayer DK, et al. (2013) A randomized trial of a Facebook-based physical activity intervention for young adult cancer survivors. <i>Journal of Cancer Survivorship</i> , 7:355-368 ²²	Young adult cancer survivors	86	Physical activity	Moderate to vigorous physical activity has increased among intervention group compared to self-care group
4	Huang JS, Dilon L, Terrones L, et al. (2014) Fit4Life: a weight loss intervention for children who have survived childhood leukemia. <i>Pediatric Blood & Cancer</i> , 61:894-900 ⁴⁷	Childhood leukemia survivors	38	Physical activity	Moderate to vigorous physical activity increased among those who received web and phone counseling compared to controls

Table 2. Summary of Previous Literature about Health Behavior Change among Cancer survivors (Continued)

No.	Source	Population	Sample size (N)	Risk behaviors measured	Summary
5	Belanger LJ, Mummery K, Clark AM, et al. (2014) Effects of targeted print materials on physical activity and quality of life in young adult cancer survivors during and after treatment: an exploratory randomized controlled trial. <i>Journal of Adolescent and Young Adults Oncology</i> , 3(2):83-91 ⁴⁸	Young adult cancer survivors	212	Physical activity	≤300 physical activity minutes/week at baseline, increased effectively after treatment (chemotherapy, surgery, and radiation)
6	Park JJ, Park HA. (2015) Prevalence of cigarette smoking among adult cancer survivors in Korea. <i>Yonsei Medical Journal</i> , 56(2):556-562 ⁴⁹	Those who has been diagnosed with cancer by a physician regardless of time duration since diagnosis	23,770	Smoking behavior	53.4% of the cancer survivors continued to smoke after their cancer diagnosis
7	Kang SJ. (2015) The association of physical activity and colorectal and breast cancer: the fifth Korea National Health and Nutrition Examination Survey (2008-2011). <i>Journal of Exercise Rehabilitation</i> , 11(3):155-160 ⁵⁰	Breast and colorectal cancer survivors	Breast cancer (n=10,167) Colorectal cancer (n=17,270)	Physical activity	Colorectal cancer survivors were less active than people without cancer

3. Guideline for Cancer Survivor's Health Behavior

Lifestyle interventions targeted at having healthy behaviors have great potential in improving outcomes among cancer survivors. The combination of efforts to control tobacco products, optimized physical activity and dietary patterns, and targeted obesity represents the most compelling opportunity to reduce the global incidence of and mortality from cancer during and post-cancer care.⁵¹ The role of physical activity in cancer prevention is well recognized, with publication by the World Cancer Research Fund/American Institute for Cancer Research and the 2018 Physical Activity Guidelines for Americans Report highlights its importance of global health.⁵² While the National Cancer Institute has funded supplements to Cancer Centers to promote and sustain tobacco cessation treatment programs to routinely address cessation services for cancer survivors.⁵³ However, limited evidence-based intervention is tailored for this group and literature on how best to deliver health intervention to the survivors is limited.^{45,54}

The American Cancer Society (ACS) published the following guidelines on nutrition and physical activity during and after cancer treatment: to (1) achieve and maintain a healthy body weight; (2) engage in regular physical activity; and (3) achieve a dietary pattern high in vegetables, fruits, and whole grains.^{55,56} Previous studies show that adherence of the ACS guidelines was highly associated with a lower risk of cancer mortality and overall mortality among cancer survivors.^{55,57,58} Similarly, rehabilitation and

exercise interventions reduce the negative impact of treatment-related symptoms and improve functions of individuals living with and beyond cancers.⁵⁹

The National Comprehensive Cancer Network (NCCN) have published recommendations for cancer survivors regarding maintaining a healthy body weight, engaging in regular physical activity, consuming a healthy diet, minimizing alcohol intake, and avoiding tobacco products.⁶⁰ Survivors expressed their wishes to receive intervention for health behaviors as well as information on the late effects of cancer treatment immediately after treatment such as assistance with improving motivation and managing the physical and psychological consequences of cancer so that they could most effectively make health behavior changes.⁴⁵

Cancer survivors are often highly motivated to seek information about physical activity, dietary supplements to improve their treatment outcomes, quality of life, and overall survivals.⁵⁶ Despite growing evidence and recommendations for better integration of healthy behaviors, the care gap is well characterized internationally and contributes to a growing morbidity burden as the population of cancer survivors continues to increase.⁵⁹ Therefore, various reports and guidelines are needed on the information for cancer survivors themselves and for healthcare providers to provide cancer survivors and their families with the best possible information to them to make better informed choices about their health behaviors.⁵⁶

4. Mortality among Cancer Survivors

1) Increasing survival of Cancer Survivors

Although examination technology improved and lifestyle changed, the incidence of cancer continued to increase between 1999–2011, but decreased by 2.6% per year since 2011.⁶¹ With the increasing numbers of cancer patients, they have shown a growing willingness to participate in check-up screenings, and technology improvements in diagnostic and treatment methods; therefore, it is reasonable to speculate that the number of cancer survivors is increasing.⁶² In the Korean National Cancer Registry study, the 5-year observed survival rate of cancer patients in South Korea is 65.2% for the period of 2014–2018, which showed a substantial improvement from 39.4% for the period 1993–1995 (Table 3).⁶³ The 5-year observed survival rate was highest in thyroid cancer (98.5%), which follows by breast cancer (91.4%), and prostate cancer (79.8%) for the period of 2014–2018.

Table 3. Trends in 5-year Observed survival of common sites, both sexes ⁶³

Unit: %

Incidence rank	Site	Period of diagnosis					
		`93~`95	`96~`00	`01~`05	`06~`10	`11~`15	`14~`18
	All cancers	39.4	41.3	49.7	60.8	65.8	65.2
1	Stomach	39.8	42.7	52.5	62.3	69.2	70.2
2	Thyroid	91.8	92.3	96.2	98.2	98.6	98.5
3	Lung	10.9	11.8	14.5	18.0	24.7	29.1
4	Colon and rectum	50.4	52.6	60.0	66.9	69.0	67.1
5	Breast	7.2	81.6	86.7	89.4	90.9	91.4
6	Liver	10.7	12.9	18.9	26.2	31.9	64.3
7	Prostate	42.4	50.9	63.3	75.4	79.1	79.8
8	Pancreas	9.5	7.7	7.5	7.7	9.8	11.5
9	Gall bladder etc.	16.5	18.1	20.3	23.7	25.4	25.4
10	Kidney	59.0	61.6	68.2	73.2	77.2	78.9

*Observed survival rate is the actual percentage of patient still alive at some specified time after diagnosis of cancer. It considered death from all-causes, cancer or others.

The 10-year observed survival of cancer patients is 58.0% for the period of 2009–2013, which increased from 33.0% for the period 1993–1995 (Table 4).⁶³ The 10-year observed survival rate was highest in thyroid cancer (97.0%), which follows by breast cancer (84.3%), and kidney cancer (67.2%) for the period of 2014-2018.

Table 4. Trends in 10-year Observed survival of common sites, both sexes ⁶³

Unit: %

Incidence rank	Site	Period of diagnosis				
		`93~`95	`96~`00	`01~`05	`06~`10	`09~`13
	All cancers	33.0	64.6	42.4	53.3	58.0
1	Stomach	33.1	35.9	44.7	53.6	58.5
2	Thyroid	87.1	88.1	93.5	96.5	97.0
3	Lung	7.8	8.2	9.9	12.6	15.6
4	Colon and rectum	40.9	43.3	50.6	57.6	59.8
5	Breast	67.8	72.3	79.1	83.1	84.3
6	Liver	6.7	7.6	11.7	17.4	20.5
7	Prostate	22.4	29.6	44.9	58.0	61.2
8	Pancreas	7.5	5.8	5.5	5.5	6.5
9	Gall bladder etc.	12.6	13.7	15.3	17.8	18.8
10	Kidney	49.7	52.4	59.5	64.3	67.2

* Observed survival rate is the actual percentage of patient still alive at some specified time after diagnosis of cancer. It considered death from all-causes, cancer or others.

Cancer survival rates are higher in developed countries where many of these countries have achieved the most progress: in the US and Germany the age-standardized cancer death rate has fallen by 20%; in France by 25%; and in Italy by 28%.⁶⁴ In South Korea, age-standardized cancer death rate has fallen by 33% in 2017 compared to 1990, which shows that there was a deep decrease of cancer mortality in South Korea (Figure 1).

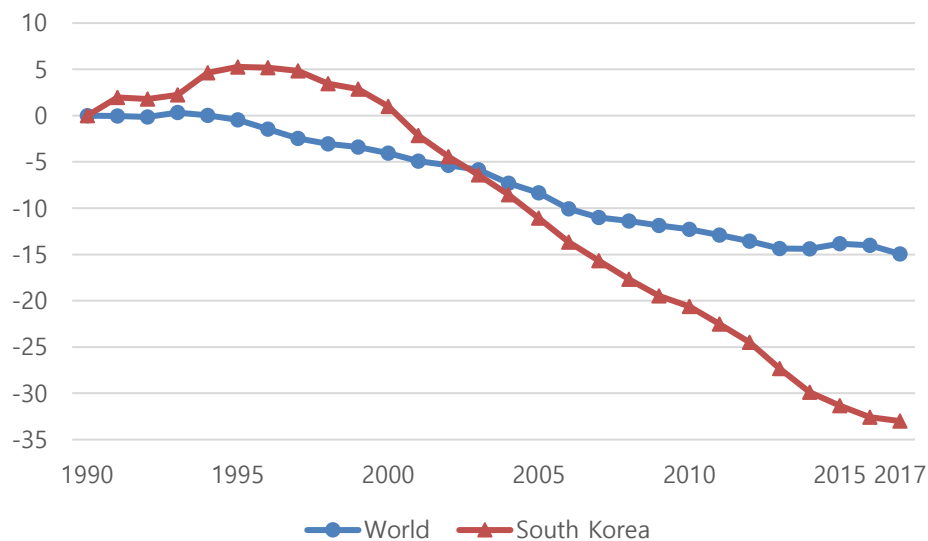


Figure 1. Change of Age-standardized Cancer Mortality rate (Unit: %) ⁶⁴

2) Factors influencing the Mortality of Cancer Survivors

The occurrence of cancer is often associated with unhealthy behaviors, such as smoking, poor diet, and a sedentary lifestyle. Changing such unhealthy behaviors also help reduce cancer treatment sequelae, recurrence, and the risk of other health outcomes such as mortality.⁵ Health behavior could play a significant role in modifying the progression of disease, as well as their mortality.⁵ Notably, lifestyle choice is a multidimensional construct with many interpersonal, and environmental factors influencing an individual's health behaviors.¹⁶ Cancer diagnosis are often viewed as a teachable moment for behavior change as the diagnosis could motivate individuals to learn, adopt, and maintain positive health behaviors, which improve a cancer survivor's

health outcomes.¹⁶ However, cancer survivors often remain inactive because of the persistent effects of the cancer treatment, as well as clinicians' advice to avoid activity and rest.⁵ Most cancer survivors are advised to avoid inactivity, and the recommendation for most exercises is the same as the age-appropriate guidelines for the general population without cancer.⁵

Previous studies state that cancer survivors were more likely to cease smoking than the general populations, which associated with the 36% reduced mortality risk than continuous smoking among cancer survivors.¹⁹ Furthermore, low physical activity was associated with 22% increased risk of breast cancer mortality, and for all-cause mortality, physical activity, previous comorbidities, and BMI was significantly associated.⁶⁵

The proportion of cancer survivors are also at risk of pre-frailty or frailty, such as low energy expenditure, fatigue, and weakness.^{66,67} This phenotype is mostly described among older adults, but cancer survivors are at risk of accelerated aging.⁶⁶ Previous studies showed that at a mean age of 33.6 ± 8.1 years, pre-frailty was present among 22.2% and frailty was present among 7.9% of adult survivors of childhood cancer, which increased the risk of other chronic diseases and death.^{66,68} Considering aging and frailty is difficult to change, cancer survivors are encouraged to participate in healthy behaviors which are relatively easy to change.

Table 5. Summary of Previous Literature about Mortality among Cancer survivors

No.	Source	Population	Sample size (N)	Risk behaviors measured	Summary
1	Bertram LC, Stefanick ML, Saquib N, et al. (2011) Physical activity, additional breast cancer events, and mortality among early-stage breast cancer survivors: findings from the WHEL Study. <i>Cancer Causes & Control</i> , 22:427-435 ⁴²	Breast cancer survivors	2,361	Physical activity	Mortality risk for any cause was lower in 24.7-107 Met-hours/week group compared to 0-2.5 Met-hours/week among breast cancer survivors
2	Schmid D, Leitzmann MF. (2014) Association between physical activity and mortality among breast cancer and colorectal cancer survivors: a systematic review and meta-analysis. <i>Annals of Oncology</i> , 25(7):1293-1311 ⁶⁹	Breast or colorectal cancer survivors	49,095	Physical activity	Most active survivors had lower rates of death among breast and colon cancer survivors
3	Nelson SH, Marinac CR, Patterson RE, et al. (2016) Impact of very low physical activity, BMI, and comorbidities on mortality among breast cancer survivors. <i>Breast Cancer research and treatment</i> , 155:551-557 ⁶⁵	Breast cancer survivors	9,513	Physical activity	Low physical activity was significantly associated 22% increased risk of breast cancer mortality

Table 5. Summary of Previous Literature about Mortality among Cancer survivors (Continued)

No.	Source	Population	Sample size (N)	Risk behaviors measured	Summary
4	Passarelli MN, Newcomb PA, Hampton JM, et al. (2016) Cigarette smoking before and after breast cancer diagnosis: mortality from breast cancer and smoking-related disease. <i>Journal of Clinical Oncology</i> , 34(12):1315-1322 ⁷⁰	Breast cancer survivors	20,691	Smoking behavior	Compared to women who continued smoking after diagnosis, those who quit smoking after diagnosis had lower mortality from breast cancer and respiratory cancer
5	Wang Y, Tao H, Paxton RJ, et al. (2019) Post-diagnosis smoking and risk of cardiovascular, cancer, and all-cause mortality in survivors of 10 adult cancers: a prospective cohort study. <i>American Journal of Cancer Research</i> , 9(11):2493-2514 ⁷¹	Cancer survivors who diagnosed with 10 most common cancers	35,093	Smoking behavior	Survivors who reported smoking had a 73%, 75%, 85% higher risk for cardiovascular disease, cancer, and all-cause mortality, respectively when compared to nonsmokers
6	Heberg J, Simonsen MK, Thomsen T, et al. (2020) Smoking cessation prolongs survival in female cancer survivors - the Danish nurse cohort. <i>European Journal of Oncology Nursing</i> , 47:101796 ¹⁹	Cancer survivors and cancer-free women	46,334	Smoking behavior	Mortality risk was significantly lower among cancer survivors who stopped smoking compared to persistent smokers

III. Material and Methods

1. Framework of the Study Design

This study aimed to examine the factors associated with health behavior (smoking and physical activity) changes among cancer survivors to emphasize the importance of managing their health behaviors. Furthermore, this study investigates the effects of health behavior changes on mortality among cancer survivors to highlight the importance of preventing their premature mortality by managing their health behaviors. Cancer survivors were defined as those who had survived for 5 years after their diagnosis of any type of cancer. Since each cancer survivor has a different cancer diagnosis date, the 5-year survival date was calculated respectively. Health behavior changes were investigated by comparing their health behavior before and after cancer diagnosis. The health behavior before cancer diagnosis were calculated using the first examined health behavior before diagnosis of cancer, and the health behavior after cancer diagnosis were calculated using the last examined health behavior from their cancer diagnosis until the 5-year survivals mark.

1) Health Behavior Changes among Cancer Survivors

Among cancer survivors with a 5-year survival period, this study analyzed the factors associated with smoking status and physical activity. Health behaviors were

calculated by comparing their health behaviors before cancer diagnosis and after their cancer diagnosis until a 5-year survival period. For each cancer survivors, the 5-year survival date was calculated respectively, from the date of diagnosis of cancer until the 5-year survival mark (Figure 2).

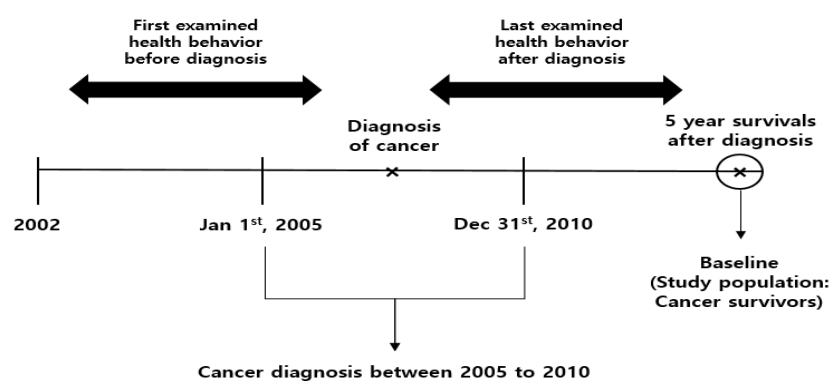


Figure 2. Timeline of the study about Health Behavior Changes among Cancer survivors

2) Effects of Health Behavior Changes on Mortality among Cancer Survivors

Among 5-year cancer survivors, the data were analyzed for the mortality within the follow-up period or by the end of it (Dec 31st, 2015). Since the 5-year survival date was obtained for each cancer diagnosis date, the 5-year survival date was different and follow up were considered from each 5-year survival date to the date of death or December 31, 2015. Health behavior changes were made by comparing their health behavior before and after cancer diagnosis until 5-year survivals (Figure 3).

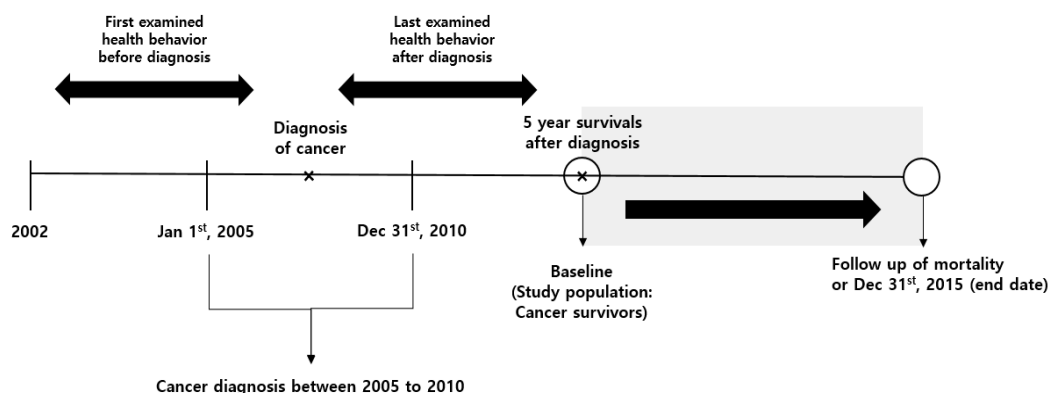


Figure 3. Timeline of the study about Mortality among Cancer survivors

2. Data and Study Population

The data for this study were obtained from the 2002–2015 National Health Insurance Service National Sample Cohort (NHIS-NSC). The NHIS-NSC data include all medical claims from approximately 2% of the South Korean population, by random sampling stratified. The following period for 13 years until 2015, a newborn representative was added annually, and deceased or emigrated representatives were excluded. NHIS data include socioeconomic characteristics, birth and death information, medical treatments, medical care institutions and general health examinations.⁷² Information about the cause of death was collected from Statistics Korea and information regarding participants's district of residence can be provided by the NHIS after the

committee's review.^{72,73} The sole purpose of constructing this data was to provide representative and useful information regarding Korean citizens' utilization of health insurance and health examinations for public health researchers and policy makers.⁷²

From these participants, individuals over the age of 20 years were included in this study. We extracted 30,128 individuals who were diagnosed with cancer from 2005 to 2010, using the International Classification of Disease, 10th revision (ICD-10) code: C00-C97. The code of C50-C58, C60-C63 were provided as C- for the sample cohort, which is considered as sensitive information, but still included in the study participants. We then only included 22,629 individuals who were still alive for 5 years after diagnosed with cancer, and defined them as a "cancer survivors".^{26,27} Those who were unable to provide information about health behavior because the data was not collected annually were also excluded. Consequently, a total of 9,300 individuals were included as cancer survivors.

For the matched cohort of which the results are given in the Appendix 6 to 12, the control group was selected by performing 1:2 propensity score matching (matching variables: sex, age, income, Charlson Comorbidity Index (CCI) score, and the year of cohort entry) to include general populations who were not diagnosed with cancer from 2005 to 2010. The year of cancer diagnosis from 2005 to 2010 were considered as the year of cohort entry for the cancer survivors, and for the general population, those without cancer, the year of cohort entry was matched with the cancer survivors' year of cancer diagnosis, based on the year in which the most claims were made between 2005

and 2010. A total of 27,537 individuals were included in the matched design study which were available in the Appendix 6 (case: 9,179, control: 18,358).

3. Variables

1) Health Behavior Changes among Cancer Survivors

The health behavior changes, which include smoking status and physical activity change, were the dependent variables in this analysis. The changes were calculated from the health behavior before diagnosis of their cancer to after their diagnosis of the cancer until 5-year survivals. As the data was not collected annually, the first response before cancer diagnosis was used as a status of smoking and physical activity before diagnosis. The last response from after cancer diagnosis to 5 years after their diagnosis were considered as a health behavior after diagnosis. For the smoking status, individuals who reported as being a current smoker were placed in the smoking group, which was seen before cancer diagnosis and from cancer diagnosis to 5-year survivals each. Smoking statuses were finally categorized into “started smoking”, “continued smoking”, “quit smoking”, and “nonsmoking” using answers to having smoked before cancer diagnosis and smoking for up to 5 years from cancer diagnosis. For the physical activity, those who were physically active at least once a week were categorized as the physically active group, which was seen before cancer diagnosis and from cancer diagnosis to 5-year survivals each. As the questions about physical activity was subdivided into walking,

moderate physical activity, and vigorous physical activity after the year of 2009, the answer of moderate physical activity was used by confirming the distribution of respondents for the response after 2009. Physical activity was finally categorized into “continuously active”, “increase”, “decrease”, and “inactive” using answers to whether they were physically active before cancer diagnosis or not and whether they were physically active for up to 5 years from cancer diagnosis. Change in alcohol consumption was not considered in this study, as alcohol consumption was highly associated with smoking status, hence, controlling both alcohol consumption change simultaneously with smoking status change was no longer significant, which was also shown in previous studies.⁷⁴

The controlled for covariates while investigating both analyses were sex, age, income, region, medical insurance, disability, alcohol consumption, BMI,⁷⁵ cancer type, CCI Score, diabetes before cancer, hypertension before cancer, and year of cancer diagnosis. The controlled variables used in this study are described in depth in Table 6. Smoking status was additionally adjusted when physical activity was the dependent variable. Physical activity was additionally adjusted when smoking status was the dependent variable.

2) Effects of Health Behavior Changes on Mortality among Cancer Survivors

The risk of all-cause and cancer-related mortality was the dependent variables of this analysis. As only 5-year cancer survivor were included, the mortality occurred after 5

years after diagnosis cancer. For the cancer-related mortality, death codes were classified according to ICD-10 code.

The primary independent variable was the health behavior changes, including changes of smoking status and physical activity. The controlled for covariates while investigating both analyses were sex, age, income, region, medical insurance, disability, alcohol consumption, BMI,⁷⁵ cancer type, CCI Score, diabetes before cancer, hypertension before cancer, and year of cancer diagnosis. The controlled variables employed in this study are described in depth in Table 6:

Table 6. Controlled variables

Variable	Description
Sex	Male, Female
Age	<50, 50-59, 60-69, ≥70
Income*	Low, Middle, High
Region	Metropolitan, City, Rural
Medical Insurance	Insurance (Corporate), Insurance (Regional), Medical aid
Disability	Yes, No
Alcohol Consumption	0 time, 1-2 times a week, ≥3 times a week
BMI**	Underweight, Normal, Overweight, Obesity
Cancer type	Stomach / Colorectal / Lung cancer / Liver / Other cancer
Charlson Comorbidity Index	None, One, Two, Three or more
Diabetes before cancer	Yes, No
Hypertension before cancer	Yes, No
Year of Cancer diagnosis	2005, 2006, 2007, 2008, 2009, 2010

* Low: 0-3rddecile, Middle: 4-7thdecile, High: 8-10thdecile.

** Underweight: Less than 18.5, Normal: 18.5-22.9, Overweight: 23-24.9, Obesity: more than 25⁷⁵.

Cancer type was categorized into stomach cancer (ICD-10: C16), colorectal cancer (ICD-10: C18-C20), lung cancer (ICD-10: C33-C34), liver cancer (ICD-10: C22), and other cancer indicating the top five incidence of cancer in South Korea. As National Health Insurance Service (NHIS) provide some cancer excluding the information about cancer type, which considered as sensitive information, breast cancer could not include as top five incidence of cancer in this study due to lack of information.⁶³ Cancer type was calculated by the first diagnosed cancer for each individual. Alcohol consumption and BMI were calculated with the response after their diagnosis of cancer. For the diabetes before cancer and hypertension before cancer, diabetes (ICD-10: E10, E11) and hypertension (ICD-10: I10-I15) were measured through the period before their diagnosis of cancer date.

Regarding CCI, Quan's updated, and validated method of Charlson's Comorbidity Index was used with the weighted various comorbidities associated with mortality. Quan's updated Charlson index shows a good ability to discriminate outcome with regard to mortality, its performance predicts health resource use, such as length of stay, service utilization, and cost, requires further investigation.⁷⁶ As our study measure CCI of individuals after their diagnosis of cancer until their 5 year survivals, cancer was not included in the CCI score as all individuals were diagnosed with cancer. Moreover, as AIDS/HIV were not included, as the data of AIDS/HIV were not provided for the sample cohort which considered as sensitive information. The CCI score employed in this study are described in depth in Table 7.

Table 7. Quan's Method for weighted index of Charlson's Comorbidity Index ⁷⁶

Assigned Weight	Condition
1	Myocardial infarction
	Congestive heart failure
	Peripheral vascular disease
	Cerebrovascular disease
	Dementia
	Chronic pulmonary disease
	Rheumatologic disease
	Peptic ulcer disease
	Mild liver disease
	Diabetes without chronic complications
2	Diabetes with chronic complications
	Hemiplegia or paraplegia
	Renal disease
3	Moderate or severe liver disease

**AIDS/HIV were not included, as the data of AIDS/HIV were not provided for the sample cohort which considered as sensitive information.*

4. Statistical Methods

The chi-square test was used to investigate the general characteristics of the study population, namely, cancer survivors. General characteristics were reported through frequencies and percentages. For the matched cohort given in Appendix 6, to assess the covariate balance between cancer survivors and general populations, the general characteristics were also compared with standardized difference, where a difference of <0.1 is generally considered negligible.⁷⁷

A multinomial logistic regression analysis was performed to calculate the factors associated with health behavior changes, including smoking status change and physical activity change, among cancer survivors. Multinomial logistic regressions were used when the dependent variables contained more than two categories. Results are reported as the adjusted Odds Ratio (OR) with a 95% Confidence Interval (CI). The incidence rate of mortality (and 95% CI) was calculated on the basis of a generalized linear model with a Poisson distribution and expressed as the number of mortality per 100,000 person years.⁷⁷ A Cox proportional hazard regression was used to calculate the association between health behavior changes and the risk of mortality among cancer survivors, determined by the adjusted Hazard Ratio (HR) and 95% CI. The Cox proportional hazard model has achieved widespread use in the analysis of time-to event (e.g. time to death) data with censoring and covariates, which may change the value over time.^{78,79} The Cox proportional hazard model specifies that $\lambda(t|\mathbf{Z}) = \lambda_0(t)e^{\beta'\mathbf{Z}}$, where β is a set of

unknown regression parameters, Z is a vector of covariates of interest, and $\lambda_0(t)$ is a baseline hazard function.^{79,80} In this study, time-zero was set to the date of 5 years after their cancer diagnosis for the cancer survivors. Survival time was defined by the number of days from the 5-year survival date (time-zero) to the date of death or December 31, 2015, whichever came first.

For the matched cohort which appear in the Appendix tables (Appendix 6 to 12), 1:2 propensity score matching (matching variables: sex, age, income, CCI score, and the year of cohort entry) was performed to include those without cancer as a general population. Multinomial logistic regressions were performed to examine the association between cancer survivors and health behavior changes among populations with cancer survivors and their general populations. A Cox proportional hazard regression was used to calculate the association between cancer survivors and the risk of mortality among populations with cancer survivors and their general populations.

To construct the nomogram, the data were randomly divided into either the training or testing data in the split ratio of 3:1. The nomogram was conducted based on the Cox proportional hazard regression using training data, and testing data were used to conduct the validation of the model that predict the survival risk. For the nomogram, we aimed for a main model with 10 predictors.⁸¹ To confirm the predictive accuracy of the nomogram, we assessed the nomogram model performance by examining discrimination (Harrell's C-Index) and calibration (Hosmer-Lemeshow test). Harrell's C-Index was used to reflect the predictive accuracy and discrimination ability of each factor and of the

nomogram, with values near 1 that indicate the risk scores are good at determining.⁸² The Hosmer-Lemeshow test was generated to test the calibration of the nomogram that was used to examine the goodness-of-fit.⁸² Hosmer-Lemeshow test was originally developed for the logistic regression model, it was extended for survival data.⁸³ In this study, the Hosmer-Lemeshow test for the Cox proportion hazard regression model was used. The Hosmer-Lemeshow with $P\text{-value} > 0.05$ demonstrates a good fit. For the analysis, the R package rms, and survival were used. All data analyses used SAS Enterprise Guide 7.1 (SAS Institute Inc., Cary, NC, USA) and R studio 1.0.136 software (R Studio Inc., Boston, MA, USA).

5. Ethics Statement

This study was reviewed and approved by the Institutional Review Board of the Yonsei University Health System (IRB number: 4-2021-1294) and adheres to the tenets of the Declaration of Helsinki.

IV. Results

1. General Characteristics of the Study Population

Table 8 presents the general characteristics of the cancer survivors according to the smoking status change. Among 9,300 cancer survivors, 235 (2.5%) started smoking, 880 (9.5%) continued smoking, 964 (10.4%) quit smoking after their diagnosis, and 7,221 (77.6%) were nonsmokers.

Smoking was more common among males than females (Male; Started smoking: 91.9%, Continued smoking: 94.7%, Quit smoking: 91.3%). The relationship between sex and smoking status change was statistically significant. Those who continued smoking were more common in those under the age of 50 (39.9%) than other age groups (50–59: 26.7%, 60–69: 24.2%, ≥ 70 : 9.2%). The relationship between age and changes of smoking status was statistically significant.

Stomach cancer (11.2%) was the most common, followed by colorectal cancer (11.1%), liver cancer (8.9%), and lung cancer (5.2%) among cancer survivors. Among lung cancer survivors, 21 (4.3%) started smoking, 64 (13.1%) continued to smoke, and 75 (15.4%) quit smoking. The relationship between cancer type and changes of smoking status was statistically significant.

Table 8. General characteristics of the Cancer survivors according to Smoking status

Variables	Total	Smoking status								P-value
		Started smoking		Continued smoking		Quit smoking		Nonsmoking		
Total	9,300 (100.0)	235 (2.5)	880 (9.5)	964 (10.4)	7,221 (77.6)					
Physical activity										0.1706
Continuously active	2,197 (23.6)	48 (20.4)	230 (26.1)	249 (25.8)	1,670 (23.1)					
Increase	1,915 (20.6)	54 (23.0)	182 (20.7)	190 (19.7)	1,489 (20.6)					
Decrease	1,857 (20.0)	47 (20.0)	165 (18.8)	209 (21.7)	1,436 (19.9)					
Inactive	3,331 (35.8)	86 (36.6)	303 (34.4)	316 (32.8)	2,626 (36.4)					
Sex										<0.0001
Male	4,556 (49.0)	216 (91.9)	833 (94.7)	880 (91.3)	2,627 (36.4)					
Female	4,744 (51.0)	19 (8.1)	47 (5.3)	84 (8.7)	4,594 (63.6)					
Age										<0.0001
< 50	2,688 (28.9)	79 (33.6)	351 (39.9)	260 (27.0)	1,998 (27.7)					
50-59	2,659 (28.6)	55 (23.4)	235 (26.7)	283 (29.4)	2,086 (28.9)					
60-69	2,547 (27.4)	62 (26.4)	213 (24.2)	298 (30.9)	1,974 (27.3)					
≥70	1,406 (15.1)	39 (16.6)	81 (9.2)	123 (12.8)	1,163 (16.1)					
Income										0.0003
Low	1,835 (19.7)	46 (19.6)	176 (20.0)	183 (19.0)	1,430 (19.8)					
Middle	3,189 (34.3)	89 (37.9)	360 (40.9)	325 (33.7)	2,415 (33.4)					
High	4,276 (46.0)	100 (42.6)	344 (39.1)	456 (47.3)	3,376 (46.8)					
Region										0.0551
Metropolitan	3,233 (34.8)	73 (31.1)	287 (32.6)	314 (32.6)	2,559 (35.4)					
City	2,298 (24.7)	54 (23.0)	230 (26.1)	269 (27.9)	1,745 (24.2)					
Rural	3,769 (40.5)	108 (46.0)	363 (41.3)	381 (39.5)	2,917 (40.4)					
Medical Insurance										0.0066
Insurance (Corporate)	6,520 (70.1)	156 (66.4)	631 (71.7)	720 (74.7)	5,013 (69.4)					
Insurance (Regional)	2,724 (29.3)	77 (32.8)	243 (27.6)	235 (24.4)	2,169 (30.0)					
Medical aid	56 (0.6)	2 (0.9)	6 (0.7)	9 (0.9)	39 (0.5)					
Disability										0.0052
Yes	671 (7.2)	28 (11.9)	70 (8.0)	82 (8.5)	491 (6.8)					
No	8,629 (92.8)	207 (88.1)	810 (92.0)	882 (91.5)	6,730 (93.2)					

Table 8. General characteristics of the Cancer survivors according to Smoking status (Continued)

Variables	Total		Smoking status								P-value
			Started smoking		Continued smoking		Quit smoking		Nonsmoking		
Alcohol Consumption											<0.0001
0 time	6,545	(70.4)	101	(43.0)	305	(34.7)	535	(55.5)	5,604	(77.6)	
1-2 times a week	1,868	(20.1)	75	(31.9)	337	(38.3)	278	(28.8)	1,178	(16.3)	
≥3 times a week	887	(9.5)	59	(25.1)	238	(27.0)	151	(15.7)	439	(6.1)	
BMI											0.0049
Underweight	295	(3.2)	5	(2.1)	37	(4.2)	36	(3.7)	217	(3.0)	
Normal	3,489	(37.5)	83	(35.3)	350	(39.8)	307	(31.8)	2,749	(38.1)	
Overweight	2,430	(26.1)	62	(26.4)	228	(25.9)	279	(28.9)	1,861	(25.8)	
Obesity	3,086	(33.2)	85	(36.2)	265	(30.1)	342	(35.5)	2,394	(33.2)	
Cancer type											<0.0001
Stomach cancer	1,045	(11.2)	29	(12.3)	129	(14.7)	187	(19.4)	700	(9.7)	
Colorectal cancer	1,030	(11.1)	23	(9.8)	103	(11.7)	135	(14.0)	769	(10.6)	
Lung cancer	488	(5.2)	21	(8.9)	64	(7.3)	75	(7.8)	328	(4.5)	
Liver cancer	826	(8.9)	28	(11.9)	136	(15.5)	95	(9.9)	567	(7.9)	
Other cancer	5,911	(63.6)	134	(57.0)	448	(50.9)	472	(49.0)	4,857	(67.3)	
Charlson Comorbidity Index (CCI)											0.4132
0	1,116	(12.0)	30	(12.8)	108	(12.3)	119	(12.3)	859	(11.9)	
1	2,222	(23.9)	54	(23.0)	229	(26.0)	203	(21.1)	1,736	(24.0)	
2	2,289	(24.6)	50	(21.3)	209	(23.8)	241	(25.0)	1,789	(24.8)	
≥3	3,673	(39.5)	101	(43.0)	334	(38.0)	401	(41.6)	2,837	(39.3)	
Diabetes before cancer											0.0128
Yes	1,791	(19.3)	62	(26.4)	150	(17.0)	179	(18.6)	1,400	(19.4)	
No	7,509	(80.7)	173	(73.6)	730	(83.0)	785	(81.4)	5,821	(80.6)	
Hypertension before cancer											<0.0001
Yes	3,660	(39.4)	90	(38.3)	263	(29.9)	382	(39.6)	2,925	(40.5)	
No	5,640	(60.6)	145	(61.7)	617	(70.1)	582	(60.4)	4,296	(59.5)	
Year of Cancer diagnosis											0.001
2005	791	(8.5)	22	(9.4)	93	(10.6)	75	(7.8)	601	(8.3)	
2006	1,539	(16.5)	42	(17.9)	159	(18.1)	139	(14.4)	1,199	(16.6)	
2007	1,702	(18.3)	51	(21.7)	177	(20.1)	152	(15.8)	1,322	(18.3)	
2008	1,849	(19.9)	52	(22.1)	167	(19.0)	193	(20.0)	1,437	(19.9)	
2009	1,800	(19.4)	44	(18.7)	151	(17.2)	202	(21.0)	1,403	(19.4)	
2010	1,619	(17.4)	24	(10.2)	133	(15.1)	203	(21.1)	1,259	(17.4)	

Table 9 shows the general characteristics of cancer survivors according to the physical activity change. Among 9,300 cancer survivors, 2,197 (23.6%) were consistently active, 1,915 (20.6%) increased physical activity after diagnosis, 1,857 (20.0%) decreased physical activity, and 3,331 (35.8%) were physically inactive.

Physical activity was more common among males than females (Male; Continuously active: 61.6%, Increase: 46.0%, Decrease: 51.6%). The relationship between sex and physical activity change was statistically significant. Those who were physically active after their cancer diagnosis were more common in those under the age of 50 (Continuously active: 34.3%, Increase: 34.1%) group compared to other age groups (Continuously active; 50-59: 31.9%, 60-69: 25.2%, ≥ 70 : 8.6%, Increase; 50-59: 29.0%, 60-69: 24.5%, ≥ 70 : 12.4%). The relationship between age and changes of smoking status was statistically significant.

Among liver cancer survivors, 209 (25.3%) were continuously active, 168 (20.3%) increase physical activity, and 180 (21.8%) decrease physical activity. 24.8% of stomach cancer survivors, 24.9% of colorectal cancer survivors, and 22.1% of lung cancer survivors were continuously active (Increase; Stomach cancer: 18.9%, Colorectal cancer: 17.4%, Lung cancer: 20.7%). The relationship between cancer type and change of physical activity was not statistically significant.

Table 9. General characteristics of the Cancer survivors according to Physical activity

Variables	Total	Physical Activity								P-value
		Continuously active		Increase		Decrease		Inactive		
Total	9,300 (100.0)	2,197 (23.6)	1,915 (20.6)	1,857 (20.0)	3,331 (35.8)					
Smoking status	0.1706									
Started smoking	235 (2.5)	48 (2.2)	54 (2.8)	47 (2.5)	86 (2.6)					
Continued smoking	880 (9.5)	230 (10.5)	182 (9.5)	165 (8.9)	303 (9.1)					
Quit smoking	964 (10.4)	249 (11.3)	190 (9.9)	209 (11.3)	316 (9.5)					
Nonsmoking	7,221 (77.6)	1,670 (76.0)	1,489 (77.8)	1,436 (77.3)	2,626 (78.8)					
Sex	<0.0001									
Male	4,556 (49.0)	1,353 (61.6)	881 (46.0)	958 (51.6)	1,364 (40.9)					
Female	4,744 (51.0)	844 (38.4)	1,034 (54.0)	899 (48.4)	1,967 (59.1)					
Age	<0.0001									
< 50	2,688 (28.9)	754 (34.3)	653 (34.1)	459 (24.7)	822 (24.7)					
50-59	2,659 (28.6)	700 (31.9)	555 (29.0)	564 (30.4)	840 (25.2)					
60-69	2,547 (27.4)	553 (25.2)	470 (24.5)	548 (29.5)	976 (29.3)					
≥70	1,406 (15.1)	190 (8.6)	237 (12.4)	286 (15.4)	693 (20.8)					
Income	<0.0001									
Low	1,835 (19.7)	351 (16.0)	393 (20.5)	381 (20.5)	710 (21.3)					
Middle	3,189 (34.3)	692 (31.5)	711 (37.1)	568 (30.6)	1,218 (36.6)					
High	4,276 (46.0)	1,154 (52.5)	811 (42.3)	908 (48.9)	1,403 (42.1)					
Region	<0.0001									
Metropolitan	3,233 (34.8)	874 (39.8)	636 (33.2)	685 (36.9)	1,038 (31.2)					
City	2,298 (24.7)	637 (29.0)	502 (26.2)	462 (24.9)	697 (20.9)					
Rural	3,769 (40.5)	686 (31.2)	777 (40.6)	710 (38.2)	1,596 (47.9)					
Medical Insurance	<0.0001									
Insurance (Corporate)	6,520 (70.1)	1,654 (75.3)	1,379 (72.0)	1,296 (69.8)	2,191 (65.8)					
Insurance (Regional)	2,724 (29.3)	538 (24.5)	524 (27.4)	552 (29.7)	1,110 (33.3)					
Medical aid	56 (0.6)	5 (0.2)	12 (0.6)	9 (0.5)	30 (0.9)					
Disability	<0.0001									
Yes	671 (7.2)	114 (5.2)	130 (6.8)	135 (7.3)	292 (8.8)					
No	8,629 (92.8)	2,083 (94.8)	1,785 (93.2)	1,722 (92.7)	3,039 (91.2)					
Alcohol Consumption	<0.0001									
0 time	6,545 (70.4)	1,324 (60.3)	1,317 (68.8)	1,365 (73.5)	2,539 (76.2)					
1-2 times a week	1,868 (20.1)	626 (28.5)	418 (21.8)	318 (17.1)	506 (15.2)					
≥3 times a week	887 (9.5)	247 (11.2)	180 (9.4)	174 (9.4)	286 (8.6)					

Table 9. General characteristics of the Cancer survivors according to Physical activity (Continued)

Variables	Total	Physical Activity								P-value	
		Continuously active		Increase		Decrease		Inactive			
BMI											<0.0001
Underweight	295 (3.2)	44 (2.0)	70 (3.7)	54 (2.9)	127 (3.8)						
Normal	3,489 (37.5)	795 (36.2)	742 (38.7)	645 (34.7)	1,307 (39.2)						
Overweight	2,430 (26.1)	616 (28.0)	503 (26.3)	493 (26.5)	818 (24.6)						
Obesity	3,086 (33.2)	742 (33.8)	600 (31.3)	665 (35.8)	1,079 (32.4)						
Cancer type											0.0946
Stomach cancer	1,045 (11.2)	259 (11.8)	197 (10.3)	215 (11.6)	374 (11.2)						
Colorectal cancer	1,030 (11.1)	256 (11.7)	179 (9.3)	209 (11.3)	386 (11.6)						
Lung cancer	488 (5.2)	108 (4.9)	101 (5.3)	92 (5.0)	187 (5.6)						
Liver cancer	826 (8.9)	209 (9.5)	168 (8.8)	180 (9.7)	269 (8.1)						
Other cancer	5,911 (63.6)	1,365 (62.1)	1,270 (66.3)	1,161 (62.5)	2,115 (63.5)						
Charlson Comorbidity Index (CCI)											<0.0001
0	1,116 (12.0)	300 (13.7)	265 (13.8)	200 (10.8)	351 (10.5)						
1	2,222 (23.9)	590 (26.9)	462 (24.1)	447 (24.1)	723 (21.7)						
2	2,289 (24.6)	526 (23.9)	493 (25.7)	429 (23.1)	841 (25.2)						
≥3	3,673 (39.5)	781 (35.5)	695 (36.3)	781 (42.1)	1,416 (42.5)						
Diabetes before cancer											<0.0001
Yes	1,791 (19.3)	416 (18.9)	301 (15.7)	434 (23.4)	640 (19.2)						
No	7,509 (80.7)	1,781 (81.1)	1,614 (84.3)	1,423 (76.6)	2,691 (80.8)						
Hypertension before cancer											<0.0001
Yes	3,660 (39.4)	765 (34.8)	712 (37.2)	786 (42.3)	1,397 (41.9)						
No	5,640 (60.6)	1,432 (65.2)	1,203 (62.8)	1,071 (57.7)	1,934 (58.1)						
Year of Cancer diagnosis											0.0557
2005	791 (8.5)	191 (8.7)	149 (7.8)	162 (8.7)	289 (8.7)						
2006	1,539 (16.5)	390 (17.8)	286 (14.9)	314 (16.9)	549 (16.5)						
2007	1,702 (18.3)	392 (17.8)	358 (18.7)	363 (19.5)	589 (17.7)						
2008	1,849 (19.9)	409 (18.6)	363 (19.0)	377 (20.3)	700 (21.0)						
2009	1,800 (19.4)	415 (18.9)	388 (20.3)	345 (18.6)	652 (19.6)						
2010	1,619 (17.4)	400 (18.2)	371 (19.4)	296 (15.9)	552 (16.6)						

2. Factors Associated with Health Behavior Changes

Table 10 shows the results of factors associated with smoking status change among cancer survivors. Compared to those who were physically active, those who were physically inactive had higher odds of smoking (Started smoking: OR=2.03, 95% CI=1.38-2.97, Continued smoking: OR=1.70, 95% CI=1.38-2.11, Quit smoking: OR=1.52, 95% CI=1.25-1.86).

Females had the lower odds of smoking than males (Started smoking: OR=0.05, 95% CI=0.03-0.09, Continued smoking: OR=0.03, 95% CI=0.02-0.05, Quit smoking: OR=0.05, 95% CI=0.04-0.07). As age increased, the odds of continued smoking was lower than those who were under 50 years (50-59: OR=0.58, 95% CI=0.47-0.71, 60-69: OR=0.39, 95% CI=0.31-0.49, ≥ 70 : OR=0.28, 95% CI=0.20-0.38). Compared to those who were in the high-income group, those with low income had higher odds of smoking (Started smoking: OR=1.71, 95% CI=1.17-2.51, Continued smoking: OR=2.02, 95% CI=1.61-2.53, Quit smoking: OR=1.26, 95% CI=1.02-1.55).

Those who drank alcohol had higher odds of started smoking (1–2 times a week: OR=2.01, 95% CI=1.45-2.79, ≥ 3 times a week: OR=3.20, 95% CI=2.25-4.53) and higher odds of continued smoking (1–2 times a week: OR=2.63, 95% CI=2.18-3.18, ≥ 3 times a week: OR=4.14, 95% CI=3.35-5.13) than those who never drink alcohol.

Table 10. Results of Multinomial logistic regressions on factors associated with Smoking status ^a

Variables	Smoking status					
	Started smoking		Continued smoking		Quit smoking	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Physical activity						
Continuously active	1.00		1.00		1.00	
Increase	1.87	(1.24 - 2.82)	1.37	(1.09 - 1.73)	1.28	(1.03 - 1.59)
Decrease	1.60	(1.05 - 2.45)	1.32	(1.04 - 1.68)	1.36	(1.10 - 1.68)
Inactive	2.03	(1.38 - 2.97)	1.70	(1.38 - 2.11)	1.52	(1.25 - 1.86)
Sex						
Male	1.00		1.00		1.00	
Female	0.05	(0.03 - 0.09)	0.03	(0.02 - 0.05)	0.05	(0.04 - 0.07)
Age						
< 50	1.00		1.00		1.00	
50-59	0.55	(0.37 - 0.80)	0.58	(0.47 - 0.71)	0.89	(0.72 - 1.09)
60-69	0.44	(0.29 - 0.65)	0.39	(0.31 - 0.49)	0.74	(0.59 - 0.92)
≥70	0.51	(0.32 - 0.81)	0.28	(0.20 - 0.38)	0.54	(0.41 - 0.71)
Income						
Low	1.71	(1.17 - 2.51)	2.02	(1.61 - 2.53)	1.26	(1.02 - 1.55)
Middle	1.54	(1.14 - 2.09)	1.82	(1.52 - 2.18)	1.18	(1.00 - 1.39)
High	1.00		1.00		1.00	
Region						
Metropolitan	1.00		1.00		1.00	
City	1.15	(0.79 - 1.66)	1.21	(0.99 - 1.49)	1.25	(1.03 - 1.51)
Rural	1.25	(0.91 - 1.71)	1.14	(0.94 - 1.37)	1.04	(0.87 - 1.24)
Medical Insurance						
Insurance (Corporate)	1.00		1.00		1.00	
Insurance (Regional)	1.41	(1.04 - 1.89)	1.25	(1.04 - 1.50)	0.95	(0.80 - 1.13)
Medical aid	2.00	(0.43 - 9.27)	1.98	(0.71 - 5.53)	2.21	(0.93 - 5.24)
Disability						
Yes	1.38	(0.89 - 2.12)	1.01	(0.75 - 1.36)	0.97	(0.74 - 1.26)
No	1.00		1.00		1.00	
Alcohol Consumption						
0 time	1.00		1.00		1.00	
1-2 times a week	2.01	(1.45 - 2.79)	2.63	(2.18 - 3.18)	1.30	(1.09 - 1.56)
≥3 times a week	3.20	(2.25 - 4.54)	4.14	(3.35 - 5.13)	1.48	(1.19 - 1.84)

Table 10. Results of Multinomial logistic regressions on factors associated with Smoking status (Continued) ^a

Variables	Smoking status					
	Started smoking		Continued smoking		Quit smoking	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
BMI						
Underweight	0.78	(0.31 - 2.00)	1.53	(1.00 - 2.35)	1.42	(0.94 - 2.15)
Normal	1.00		1.00		1.00	
Overweight	0.99	(0.70 - 1.41)	0.84	(0.69 - 1.03)	1.25	(1.03 - 1.51)
Obesity	0.95	(0.69 - 1.32)	0.66	(0.54 - 0.80)	1.14	(0.95 - 1.37)
Cancer type						
Stomach cancer	1.00		1.00		1.00	
Colorectal cancer	0.83	(0.47 - 1.47)	0.88	(0.65 - 1.20)	0.74	(0.56 - 0.96)
Lung cancer	1.79	(0.98 - 3.27)	1.37	(0.95 - 1.99)	1.03	(0.75 - 1.43)
Liver cancer	1.00	(0.57 - 1.74)	1.07	(0.79 - 1.45)	0.58	(0.43 - 0.78)
Other cancer	1.12	(0.73 - 1.71)	0.96	(0.76 - 1.22)	0.61	(0.49 - 0.75)
Charlson Comorbidity Index (CCI)						
0	1.00		1.00		1.00	
1	0.98	(0.61 - 1.56)	1.23	(0.93 - 1.61)	0.97	(0.75 - 1.26)
2	0.96	(0.59 - 1.55)	1.29	(0.97 - 1.71)	1.15	(0.89 - 1.49)
≥3	1.10	(0.69 - 1.77)	1.55	(1.17 - 2.04)	1.28	(0.99 - 1.65)
Diabetes before cancer						
Yes	1.56	(1.10 - 2.20)	0.98	(0.78 - 1.23)	0.82	(0.67 - 1.00)
No	1.00		1.00		1.00	
Hypertension before cancer						
Yes	0.77	(0.56 - 1.05)	0.69	(0.57 - 0.83)	0.85	(0.72 - 1.01)
No	1.00		1.00		1.00	
Year of Cancer diagnosis						
2005	1.00		1.00		1.00	
2006	1.10	(0.64 - 1.90)	1.02	(0.75 - 1.39)	1.08	(0.79 - 1.49)
2007	1.33	(0.79 - 2.25)	1.16	(0.85 - 1.57)	1.11	(0.81 - 1.52)
2008	1.38	(0.81 - 2.33)	1.19	(0.87 - 1.61)	1.45	(1.07 - 1.96)
2009	1.20	(0.70 - 2.07)	1.13	(0.83 - 1.55)	1.60	(1.18 - 2.17)
2010	0.77	(0.42 - 1.41)	1.10	(0.80 - 1.51)	1.83	(1.35 - 2.48)

^a Reference group is Nonsmoking.

Table 11 shows the results of the factors associated with physical activity change among cancer survivors. Compared to those who had never smoked, those who smoked had higher odds of physically inactivity (Started smoking: OR=2.07, 95% CI=1.41-3.02, Continued smoking: OR=1.76, 95% CI=1.05-1.67, Quit smoking: OR=1.54, 95% CI=1.26-1.88).

Females had higher odds of physically inactive than males (Decrease: OR=1.59, 95% CI=1.36-1.85, Inactive: OR=2.77, 95% CI=2.40-3.19). As age increased, the odds of physically inactive (50-59: OR=1.02, 95% CI=0.88-1.19, 60-69: OR=1.54, 95% CI=1.30-1.81, ≥ 70 : OR=3.12, 95% CI=2.51-3.88) and the odds of decrease physical activity (50-59: OR=1.21, 95% CI=1.02-1.43, 60-69: OR=1.44, 95% CI=1.19-1.74, ≥ 70 : OR=2.15, 95% CI=1.68-2.75) was higher than those who were under 50 years.

Compared to those who were in the high-income group, those who were in the low-income group had higher odds of physically inactivity (Decrease: OR=1.32, 95% CI=1.11-1.58, Inactive: OR=1.56, 95% CI=1.33-1.83). Those who lived in the rural area had higher odds of physically inactive than those who lived in the metropolitan (Decrease: OR=1.23, 95% CI=1.06-1.43, Inactive: OR=1.76, 95% CI=1.54-2.01). Moreover, those who had a disability had higher odds of physically inactivity than those without disability (Inactive: OR=1.52, 95% CI=1.20-1.93).

Table 11. Results of Multinomial logistic regressions on factors associated with Physical activity^a

Variables	Physical activity					
	Increase		Decrease		Inactive	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Smoking status						
Started smoking	1.86	(1.23 - 2.80)	1.59	(1.04 - 2.43)	2.07	(1.41 - 3.02)
Continued smoking	1.35	(1.05 - 1.67)	1.32	(1.05 - 1.67)	1.76	(1.05 - 1.67)
Quit smoking	1.30	(1.05 - 1.62)	1.39	(1.12 - 1.72)	1.54	(1.26 - 1.88)
Nonsmoking	1.00		1.00		1.00	
Sex						
Male	1.00		1.00		1.00	
Female	2.01	(1.72 - 2.34)	1.59	(1.36 - 1.85)	2.77	(2.40 - 3.19)
Age						
< 50	1.00		1.00		1.00	
50-59	0.89	(0.76 - 1.05)	1.21	(1.02 - 1.43)	1.02	(0.88 - 1.19)
60-69	0.99	(0.82 - 1.19)	1.44	(1.19 - 1.74)	1.54	(1.30 - 1.81)
≥70	1.45	(1.14 - 1.86)	2.15	(1.68 - 2.75)	3.12	(2.51 - 3.88)
Income						
Low	1.49	(1.25 - 1.78)	1.32	(1.11 - 1.58)	1.56	(1.33 - 1.83)
Middle	1.42	(1.24 - 1.64)	1.03	(0.89 - 1.19)	1.42	(1.25 - 1.61)
High	1.00		1.00		1.00	
Region						
Metropolitan	1.00		1.00		1.00	
City	1.08	(0.92 - 1.26)	0.93	(0.79 - 1.08)	0.91	(0.79 - 1.06)
Rural	1.54	(1.33 - 1.78)	1.23	(1.06 - 1.43)	1.76	(1.54 - 2.01)
Medical Insurance						
Insurance (Corporate)	1.00		1.00		1.00	
Insurance (Regional)	1.15	(0.99 - 1.33)	1.21	(1.05 - 1.40)	1.41	(1.24 - 1.61)
Medical aid	1.93	(0.67 - 5.59)	1.39	(0.46 - 4.22)	2.48	(0.94 - 6.59)
Disability						
Yes	1.31	(1.01 - 1.72)	1.24	(0.95 - 1.62)	1.52	(1.20 - 1.93)
No	1.00		1.00		1.00	

Table 11. Results of Multinomial logistic regressions on factors associated with Physical activity (Continued) ^a

Variables	Physical activity					
	Increase		Decrease		Inactive	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Alcohol Consumption						
0 time	1.00		1.00		1.00	
1-2 times a week	0.87	(0.74 - 1.02)	0.62	(0.52 - 0.73)	0.66	(0.57 - 0.77)
≥3 times a week	0.97	(0.77 - 1.21)	0.77	(0.61 - 0.96)	0.87	(0.71 - 1.06)
BMI						
Underweight	1.63	(1.10 - 2.42)	1.40	(0.92 - 2.13)	1.53	(1.06 - 2.21)
Normal	1.00		1.00		1.00	
Overweight	0.89	(0.76 - 1.04)	0.98	(0.83 - 1.15)	0.81	(0.70 - 0.94)
Obesity	0.89	(0.76 - 1.04)	1.11	(0.95 - 1.29)	0.91	(0.79 - 1.05)
Cancer type						
Stomach cancer	1.00		1.00		1.00	
Colorectal cancer	0.97	(0.74 - 1.27)	1.00	(0.77 - 1.31)	1.08	(0.85 - 1.37)
Lung cancer	1.23	(0.88 - 1.72)	0.99	(0.71 - 1.39)	1.14	(0.85 - 1.54)
Liver cancer	1.16	(0.88 - 1.55)	1.20	(0.91 - 1.58)	1.08	(0.84 - 1.40)
Other cancer	1.13	(0.91 - 1.39)	0.98	(0.80 - 1.21)	0.99	(0.82 - 1.19)
Charlson Comorbidity Index (CCI)						
0	1.00		1.00		1.00	
1	0.84	(0.68 - 1.04)	1.00	(0.81 - 1.25)	0.90	(0.74 - 1.10)
2	0.98	(0.79 - 1.21)	0.98	(0.78 - 1.22)	1.05	(0.86 - 1.29)
≥3	0.94	(0.76 - 1.17)	1.02	(0.82 - 1.28)	1.06	(0.87 - 1.30)
Diabetes before cancer						
Yes	0.73	(0.61 - 0.87)	1.07	(0.90 - 1.27)	0.79	(0.67 - 0.92)
No	1.00		1.00		1.00	
Hypertension before cancer						
Yes	1.16	(1.00 - 1.35)	1.12	(0.97 - 1.30)	1.09	(0.95 - 1.24)
No	1.00		1.00		1.00	
Year of Cancer diagnosis						
2005	1.00		1.00		1.00	
2006	0.88	(0.68 - 1.15)	0.89	(0.68 - 1.15)	0.82	(0.65 - 1.04)
2007	1.12	(0.86 - 1.46)	0.99	(0.76 - 1.28)	0.86	(0.68 - 1.09)
2008	1.05	(0.81 - 1.36)	0.95	(0.73 - 1.22)	0.93	(0.74 - 1.17)
2009	1.09	(0.84 - 1.42)	0.84	(0.65 - 1.08)	0.84	(0.67 - 1.06)
2010	1.13	(0.87 - 1.46)	0.79	(0.61 - 1.02)	0.82	(0.65 - 1.04)

^a Reference group is Continuously active.

3. Results of Incidence Rates of Mortality among Cancer Survivors

Table 12 shows the results of incidence rates of all-cause mortality in the cancer survivors. Among 9,300 cancer survivors, 351 all-cause mortalities were identified during 245571.9 person years. For those who had started smoking, the incidence rate was 356.1 per 100,000 person year (21 all-cause mortalities during 5895.9 person years), 155.3 per 100,000 person year (36 all-cause mortalities during 23172.2 person years) for those who continued smoking, and 211.8 per 100,000 person year (53 all-cause mortalities during 25022.4 person years) for those who quit smoking.

For those who were continuously active, the incidence rate was 88.4 per 100,000 person year (52 all-cause mortalities during 58810.4 person years), 172.6 per 100,000 person year (84 all-cause mortalities during 48667.2 person years) for those who decreased physical activity, and 180.1 per 100,000 person year (157 all-cause mortalities during 87174.8 person years) for those who were physically inactive.

Table 12. Incidence rates of All-cause Mortality in the Cancer survivors cohort

Exposure	Number of Subjects	Number of Death	Person years	Incidence rate (95% CI) per 100,000 person years	
Total	9,300	351	245571.9		
Smoking status					
Started smoking	235	21	5895.9	356.1	(228.1 - 555.9)
Continued smoking	880	36	23172.2	155.3	(111.4 - 216.6)
Quit smoking	964	53	25022.4	211.8	(160.7 - 279.1)
Nonsmoking	7,221	241	191481.3	125.8	(110.7 - 143.1)
Physical activity					
Continuously active	2,197	52	58810.4	88.4	(67.2 - 116.4)
Increase	1,915	58	50919.5	113.9	(87.7 - 147.8)
Decrease	1,857	84	48667.2	172.6	(138.7 - 214.7)
Inactive	3,331	157	87174.8	180.1	(153.5 - 211.3)

4. Results of Health Behavior Changes and Mortality among Cancer Survivors

Table 13 shows the results of health behavior changes on all-cause mortality as well as cancer-related mortality among cancer survivors. Compared to those who were nonsmoking, those who started or quit smoking had a higher risk of all-cause mortality (Started smoking: HR=1.98, 95% CI=1.25-3.15, Quit smoking: HR=1.44, 95% CI=1.05-1.97). The risk of cancer-related mortality was not statistically significant. These results were shown in the results of the risk of mortality among cancer patients before 5 years from diagnosis given in Appendix 1, which show that those who continued smoking or quit smoking had a higher risk of cancer-related mortality than nonsmokers before their 5 year survivals (Continued smoking: HR=1.58, 95% CI=1.05-2.37, Quit smoking: HR=1.65, 95% CI=1.18-2.31). Table 13 also shows that those who were physically inactive had a higher risk of all-cause mortality than those who continuously active (Inactive: HR=1.45, 95% CI=1.05-2.02).

Females had a lower risk of both all-cause mortality and cancer-related mortality than males (All-cause mortality: HR=0.42, 95% CI=0.32-0.54, Cancer-related mortality: HR=0.40, 95% CI=0.28-0.57). As age increased, the risk of all-cause mortality and cancer-related mortality increased more than those under 50 years old (All-cause mortality; 50-59: HR=2.59, 95% CI=1.50-4.50, 60-69: HR=5.87, 95% CI=3.50-9.83, ≥ 70 : HR=13.65, 95% CI=8.06-23.09, Cancer-related mortality; 50-59: HR=2.73, 95%

CI=1.39-5.37, 60-69: HR=5.85, 95% CI=3.08-11.12, ≥ 70 : HR=10.67, 95% CI=5.48-20.80). Compared to those whose CCI score is 0, those who had more than 3 had a higher risk of all-cause mortality (HR=2.17, 95% CI=1.24-3.79).

Table 13. Results of association between Health Behaviors Changes and the Mortality among Cancer survivors

Variables	All-cause Mortality		Cancer-related Mortality	
	Adjusted HR	95% CI	Adjusted HR	95% CI
Smoking status				
Started smoking	1.98	(1.25 - 3.15)	1.55	(0.77 - 3.11)
Continued smoking	1.08	(0.75 - 1.58)	0.71	(0.39 - 1.29)
Quit smoking	1.44	(1.05 - 1.97)	1.52	(1.00 - 2.29)
Nonsmoking	1.00		1.00	
Physical activity				
Continuously active	1.00		1.00	
Increase	1.20	(0.82 - 1.75)	1.13	(0.70 - 1.84)
Decrease	1.46	(1.03 - 2.07)	1.34	(0.86 - 2.10)
Inactive	1.45	(1.05 - 2.02)	1.08	(0.70 - 1.66)
Sex				
Male	1.00		1.00	
Female	0.42	(0.32 - 0.54)	0.40	(0.28 - 0.57)
Age				
< 50	1.00		1.00	
50-59	2.59	(1.50 - 4.50)	2.73	(1.39 - 5.37)
60-69	5.87	(3.50 - 9.83)	5.85	(3.08 - 11.12)
≥ 70	13.65	(8.06 - 23.09)	10.67	(5.48 - 20.80)
Income				
Low	1.04	(0.78 - 1.39)	0.95	(0.64 - 1.43)
Middle	1.03	(0.81 - 1.31)	0.93	(0.66 - 1.30)
High	1.00		1.00	
Region				
Metropolitan	1.00		1.00	
City	1.24	(0.92 - 1.67)	1.42	(0.96 - 2.12)
Rural	1.12	(0.86 - 1.45)	1.13	(0.79 - 1.62)
Medical Insurance				
Insurance (Corporate)	1.00		1.00	
Insurance (Regional)	1.13	(0.90 - 1.41)	1.16	(0.85 - 1.58)
Medical aid	0.83	(0.20 - 3.42)	0.89	(0.12 - 6.62)

Table 13. Results of association between Health Behaviors Changes and the Mortality among Cancer survivors (Continued)

Variables	All-cause Mortality		Cancer-related Mortality	
	Adjusted HR	95% CI	Adjusted HR	95% CI
Disability				
Yes	0.89	(0.62 - 1.27)	0.67	(0.38 - 1.19)
No	1.00		1.00	
Alcohol Consumption				
0 time	1.00		1.00	
1-2 times a week	0.60	(0.43 - 0.85)	0.45	(0.27 - 0.75)
≥3 times a week	0.81	(0.58 - 1.13)	0.80	(0.51 - 1.28)
BMI				
Underweight	1.67	(1.19 - 2.34)	1.28	(0.64 - 2.57)
Normal	1.00		1.00	
Overweight	0.77	(0.59 - 1.02)	0.81	(0.55 - 1.19)
Obesity	0.77	(0.59 - 1.00)	0.89	(0.62 - 1.27)
Cancer type				
Stomach cancer	1.00		1.00	
Colorectal cancer	0.84	(0.55 - 1.30)	0.81	(0.43 - 1.51)
Lung cancer	1.17	(0.73 - 1.88)	1.89	(1.04 - 3.45)
Liver cancer	1.92	(1.27 - 2.90)	1.96	(1.09 - 3.53)
Other cancer	1.01	(0.74 - 1.39)	1.04	(0.66 - 1.65)
Charlson Comorbidity Index (CCI)				
0	1.00		1.00	
1	1.48	(0.82 - 2.69)	1.39	(0.70 - 2.74)
2	1.44	(0.80 - 2.58)	1.17	(0.59 - 2.30)
≥3	2.17	(1.24 - 3.79)	1.33	(0.70 - 2.56)
Diabetes before cancer				
Yes	1.25	(0.98 - 1.59)	1.09	(0.76 - 1.56)
No	1.00		1.00	
Hypertension before cancer				
Yes	0.95	(0.75 - 1.20)	0.86	(0.63 - 1.19)
No	1.00		1.00	
Year of Cancer diagnosis				
2005	1.00		1.00	
2006	0.82	(0.57 - 1.17)	0.79	(0.47 - 1.31)
2007	0.66	(0.46 - 0.95)	0.68	(0.41 - 1.13)
2008	0.55	(0.38 - 0.80)	0.70	(0.42 - 1.15)
2009	0.36	(0.24 - 0.54)	0.40	(0.23 - 0.71)
2010	0.14	(0.08 - 0.25)	0.17	(0.08 - 0.37)

5. Results of the Subgroup Analysis for the Risk of Mortality according to Smoking Status

Figure 4 shows the results of the subgroup analysis for the risk of all-cause mortality according to smoking status change, while controlling physical activity change, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, CCI, diabetes before cancer, hypertension before cancer and year of cancer diagnosis, which was given in Appendix 2 as a table. Among individuals who were continuously active, those who quit smoking had a higher risk of all-cause mortality than nonsmokers (HR=3.03, 95% CI=1.46-6.31). Male who start or quit smoking had a higher risk of all-cause mortality than nonsmokers (Started smoking: HR=2.08, 95% CI=1.30-3.32, Quit smoking: HR=1.44, 95% CI=1.04-2.01).

In the low-income level group, those who quit smoking had a higher risk of all-cause mortality than nonsmokers (HR=1.93, 95% CI=1.02-3.64). Among individuals who live in the rural area, compared to nonsmokers, those who started or quit smoking had a higher risk of all-cause mortality (Started smoking: HR=2.20, 95% CI=1.20-4.03, Quit smoking: HR=1.56, 95% CI=1.01-2.42). For individuals without previous diabetes, those who started or quit smoking had a higher risk of all-cause mortality than nonsmokers (Started smoking: HR=2.46, 95% CI=1.42-4.28, Quit smoking: HR=1.69, 95% CI=1.19-2.42). The results were also shown in those without previous hypertension (Started smoking: HR=2.18, 95% CI=1.10-4.31, Quit smoking: HR=1.60, 95% CI=1.02-2.51).

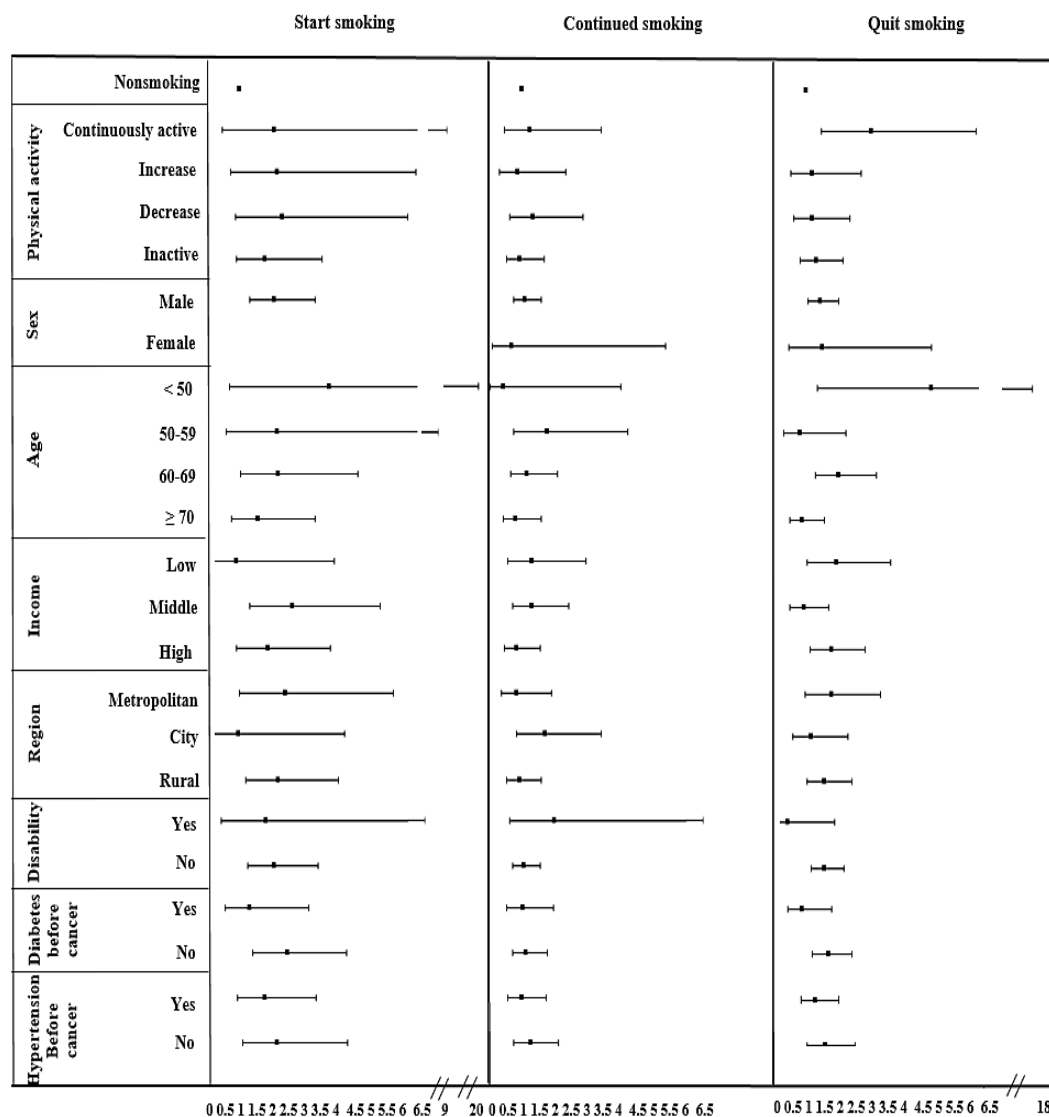


Figure 4. Subgroup analysis of the association between Risk of All-cause Mortality and covariates, according to Smoking status. Adjusted for physical activity, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and year of cancer diagnosis. Reference group is “Nonsmoking”, which refers to those who do not smoke ever.

6. Results of the Subgroup Analysis for the Risk of Mortality according to Physical Activity

Figure 5 shows the results of the subgroup analysis for the risk of all-cause mortality according to physical activity change, while controlling smoking status change, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, CCI, diabetes before cancer, hypertension before cancer, and year of cancer diagnosis (Appendix 4 as a table). Among nonsmokers, those who were physically inactive after their cancer diagnosis had a higher risk of all-cause mortality than those who were continuously active (Decrease: HR=1.56, 95% CI=1.01-2.40, Inactive: HR=1.68, 95% CI=1.12-2.53). For the individuals who were aged 50–59, those who decreased physical activity had a higher risk of all-cause mortality than individuals who were continuously active (HR=2.40, 95% CI=1.05-5.49). Individuals who live in the city, those who were physically inactive after their cancer diagnosis had a higher risk of all-cause mortality than those who were continuously active (Decrease: HR=3.33, 95% CI=1.54-7.21, Inactive: HR=2.38, 95% CI=1.11-5.11).

For individuals without disability, those who were physically inactive had a higher risk of all-cause mortality than individuals who were physically active (HR=1.46, 95% CI=1.04-2.05). Among individuals with previous diabetes, those who were physically inactive had a higher risk of all-cause mortality than individuals who were physically active (HR=1.93, 95% CI=1.07-3.48).

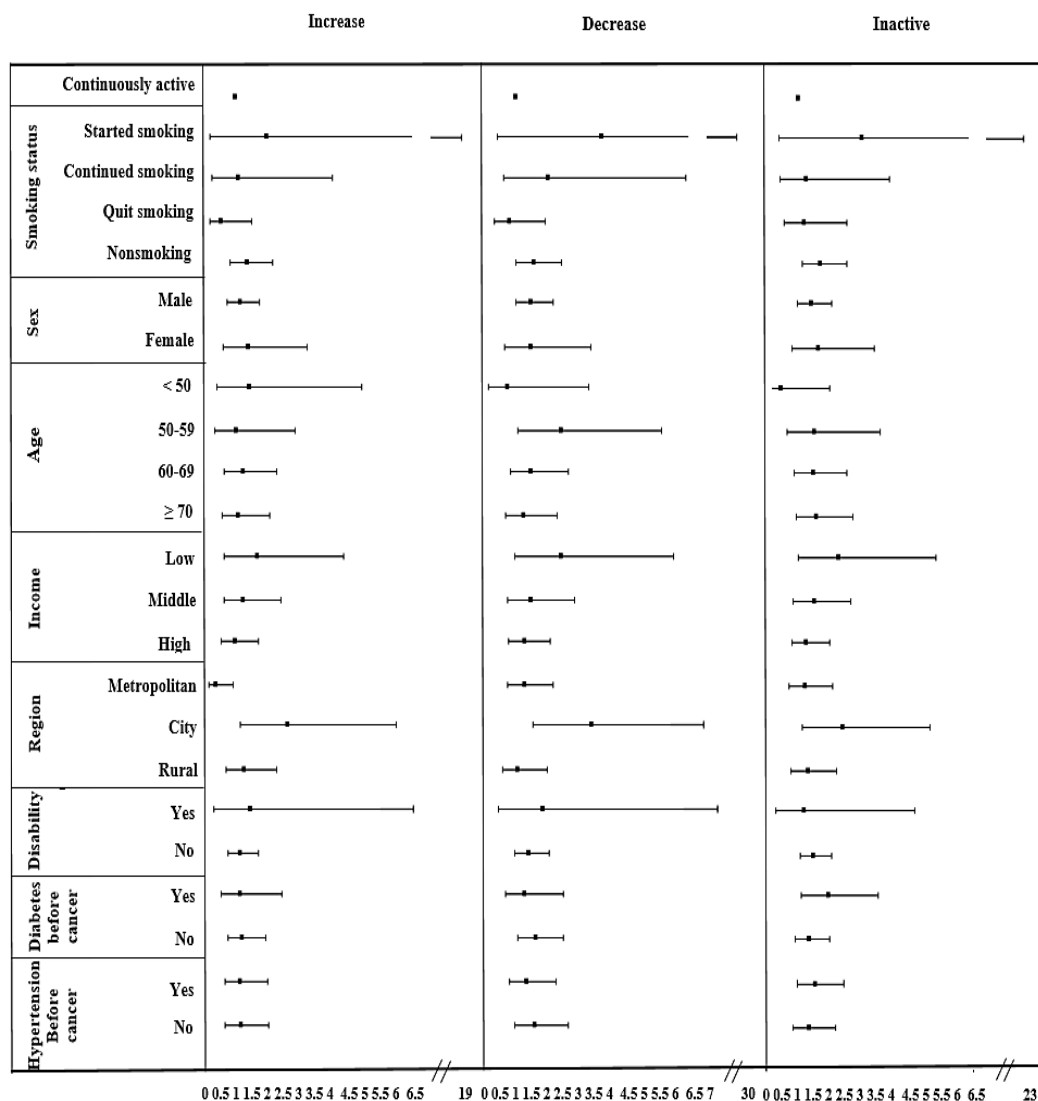


Figure 5. Subgroup analysis of the association between Risk of All-cause Mortality and covariates, according to Physical activity. Adjusted for smoking status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and year of cancer diagnosis. Reference group is “Continuously active”, which refers to those who did physical activity continuously.

7. Development and Validation of Nomogram to Predict the Risk of Survival for Cancer Survivors

The 3-year survival nomogram is presented in Figure 6. The total points are calculated by summing up the points for each factor. The higher total points based on the sum of the assigned number of points for each factor in the nomogram were associated with a higher mortality risk. The predicted probabilities of a 3-year survival rate can be obtained by projecting the location of the total points to the bottom scales. For example, a patient who quit smoking, was physically inactive, male aged between 60–69, lives in the city, with medical aid, no disability, having normal weight, no chronic disease (0 for CCI score), and with diabetes before cancer diagnosis would have a total of 178.5 points (3 points for quitting smoking, 23.5 points for physical inactivity, 41 points for sex, 67 points for age, 2.5 points for region, 12 for medical insurance, 7.5 for disability, 20 for BMI, 0 for CCI score, and 2 for diabetes before cancer diagnosis), had a predicted 3-year survival of 93%.

The C-index value was 0.79 in the training data and 0.81 in the testing data. The nomogram's performance was not significantly different between the training and testing data. Moreover, the Hosmer-Lemeshow test was not significant (P -value >0.05), which demonstrates a good fit.

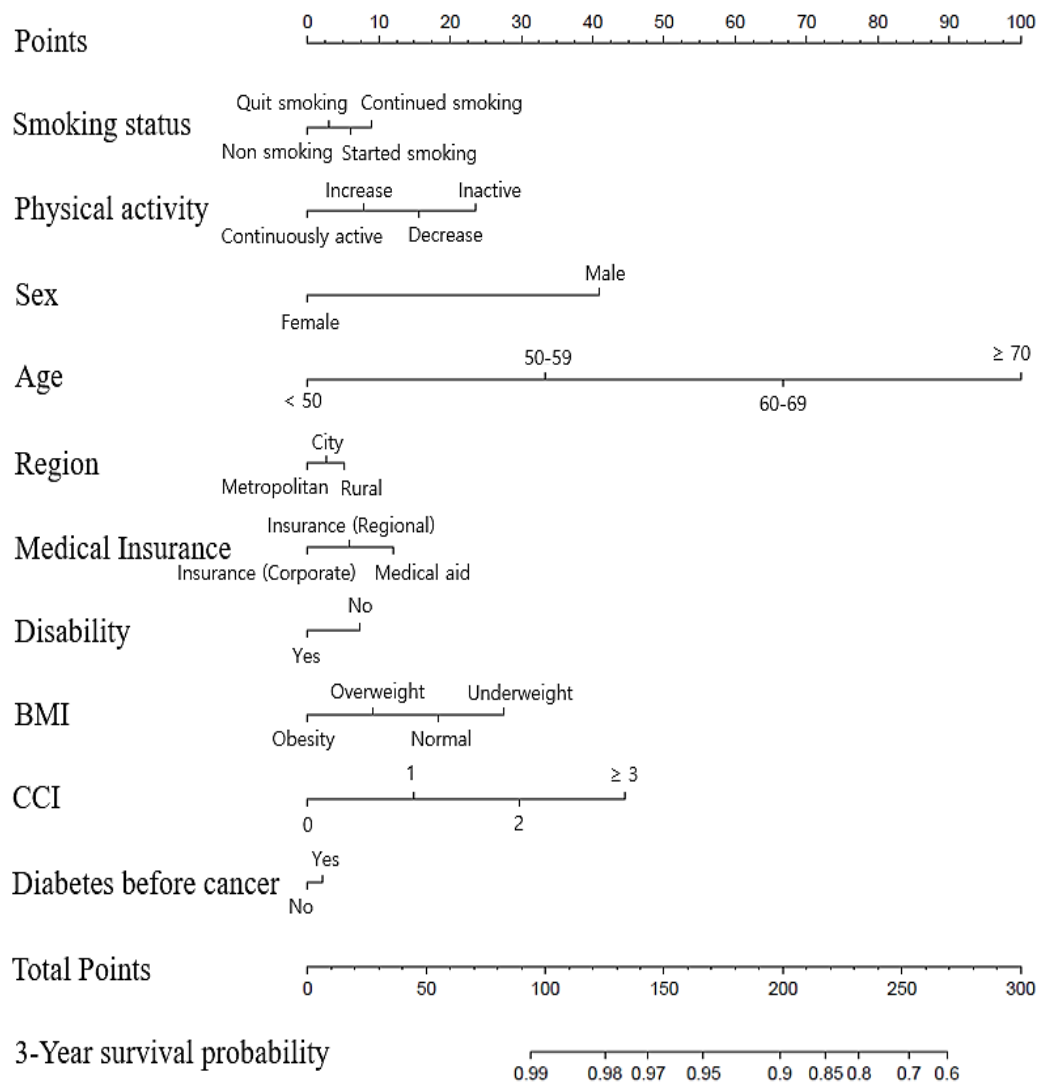


Figure 6. A Nomogram for Predicting Survival of Cancer survivors. For developing and validating nomogram, smoking status, physical activity, sex, age, region, medical insurance, disability, BMI, Charlson Comorbidity Index (CCI), diabetes before cancer were adjusted.

V. Discussion

1. Discussion of the Study Methods

Ultimately, this study aimed to examine the factors associated with health behavior changes among cancer survivors. Furthermore, this study investigate the impact of health behavior changes on the risk of morality among cancer survivors. The health behavior changes were divided into smoking status change and physical activity change. Validated nomogram was developed to provide the information to predict the risk of survival for cancer survivors. Additionally, we showed the results of health behavior changes and the risk of mortality among cancer survivors compared with their general population using the matched cohort design which was shown in the Appendix tables (Appendix 6 to 12).

A major strengths of our investigation is the use of nationally representative data. The NHIS-NSC is a population-based cohort established by the NHIS in South Korea, which were able to representative approximately 2% of South Korean populations. Moreover, the data are large-scale, extensive and stable because it is constructed based on nationwide health insurance data generated by the government or public institutions' involvement.⁷² Therefore, as the sole purpose of constructing the cohort was to provide health researchers and policy makers with representative data, this data could provide useful informations regarding citizen's utilitzations of health insurance and health

examinations and create higher value-added policies.⁷²

This study included data collected over a period of nearly 14 years, from 2002 to 2015, and considering that 5-year cancer survivors needed at least 5 years of follow-up times, the long follow-up time could enable inference about a long-term associations. Moreover, as this study include almost 14 years for analysis, we could provide more specific information on their health condition, before and after their cancer diagnosis. We could include those who already had a diabetes or hypertension diagnosis before cancer diagnosis, and also include the CCI score at their after cancer diagnosis. Including more detailed information about their health condition could provide useful informations. Still, few studies have used a dataset of this size and follow-up times to investigate the cancer survivors' health behavior and develop the validated nomogram predicting the risk of survival for cancer survivors in South Korea. Therefore, our study could provide the information and evidence for the guidance by showing the factors associated with health behavior changes, and the results of increased mortality risk after their 5 year survivals among cancer survivors with unhealthy behaviors. Moreover, validated nomogram could provide the useful insight into the health policies.

The nomogram is a well-known visualization model that graphically describes the complete model in a single graph. A nomogram is a tool to prognostic scores to predict clinical outcomes, which incorporates differenct factors to develop a graphic continuous scoring system and calculates accurately the risk probability of the outcomes entirely based on individuals characteristics.⁸⁴ As this study validate the nomogram with

the suitable methods, this could provide the proper information for the cancer survivors. Moreover, as the nomogram is well visualized, its could help people to understand easily the risk of survivals without professional knowledge, which could easily motivate cancer survivors to have better health conditions especially those that are changeable.

Both multinomial logistic regression and the Cox proportional hazard regression was used to identify the target associations. As our study include various study designs, proper statistical anylsis is necessary. Therefore, we used the multinomial logistic regression to analyze the factors associated with health behavior changes and the Cox proportional hazard regression to analyze the association between health behavior changes and the risk of mortality. This could provide much information about cancer survivors with the proper methods. Moreover, a matched cohort design was shown in the Appendix table in our study. These results about cancer survivors compared with the general populations could provide the information by comparing the results of general populations. This various design could provide more accurate and delicate information to cancer survivors. Furthermore, this could help policy makers to provide accurate guidances to cancer survivors.

Because such few studies investigated the factor associated with health behavior changes, and examine the effects of health behavior changes on mortality among South Korean cancer survivors, our analysis provide the information about cancer survivors' health behaviors, which showed meaningful findings. However, some results should be interpreted carefully as several limiations emerged. First, the stage or severity of cancer

could not be included in this study because of a lack of data as the NHIS could not provide those data. However, as we included only cancer survivors who had survived for 5 years, the influence of this limitation has been decreased and could ensure homogeneity. Similarly, our data found that many lung cancer patients who continuously smoking could not survived for the 5 years after their diagnosis of cancer. Moreover, this study only use the 5-year cutoff for the definition of cancer survivors. However, a 5-year cutoff may be appropriate as majority of cancer patients survived more than 5 years with improvements in early detection and treatment of cancer, and this study have the appropriate follow-up time to show the mortality risk after their survival.²³ Although breast cancer is often considered to have 10 year survivals, this study could not distinguish the breast cancer due to lack of information. The data for ICD-10 code C50-C58 and C60-C63 including breast cancer were impossible to distinguish exactly what cancer it was, as those were not provided in the NHIS-NSC data.⁸⁵ Still, further research is needed for each type of cancer.

As health examinations including health behavior in the NHIS data were not collected annually, there were some missing values of health behaviors such as smoking status and physical activity. As we calculated the health behavior before cancer diagnosis using the first examined health behavior before diagnosis of cancer, and the health behavior after cancer diagnosis was calculated using the last examined health behavior from their cancer diagnosis to 5-year survivals, we tried to minimize the missing values. However, we could not find those who had changed their health behaviors during the time before their cancer diagnosis or during the post-diagnosis. Although the results of our

data were similar with others, the missing data may potentially influence our findings. Also, the health behavior change after their 5-year survivals were not considered in this study owing to a lack of follow-up time. The AIDS/HIV were not included in the CCI score, as the data of AIDS/HIV were not provided in the sample cohort which was considered as sensitive information. Moreover, non-insurance benefits data and information for over-the-counter drugs have not been included as NHIS is claim data.⁷² Since this data is claim data, there might be parts that have not been considered, but since this study analysis about cancer survivors, the impact of this part is likely to be less. Additionally, for the nomogram, external validation should be performed using different data with different timing and place of collection to evaluate generalization, but in this study, only internal validation was performed due to data limitations, and external validation was not performed, for more accurate analysis, external validation is necessary.

Despite these limitations, this study was able to demonstrate that factors associated with health behavior changes, and increased risk of all-cause mortality, as well as cancer-related mortality among cancer survivors with unhealthy behaviors. As the NHIS-NSC database contains nationally representative population-based data on more than one million participants with the decade-long follow up, these results could provide the necessary evidence to ensure the timely and proper care and higher value-added policies for the cancer survivors for health researchers and policy makers.

2. Discussion of the Results

Our findings indicate that cancer survivors who had unhealthy behaviors such as smoking or being physically inactive tend to have combined unhealthy behaviors. Compared to those who were physically active, those who were physically inactive had higher odds of smoking. With regard to mortality, we found that unhealthy behavior is associated with increased risk of all-cause mortality as well as cancer-related mortality. Compared to those who were nonsmoking, those who started, continued, or quit smoking had a higher risk of all-cause mortality. Those who were physically inactive after their diagnosis had a higher risk of all-cause mortality than those who were continuously active.

Cancer survivors tend to make positive changes in their lifestyles in response to their increased risk of subsequent health problems such as recurrence as well as many other diseases, and mortality.¹⁴ Some research even announce that cancer diagnosis has been described as a teachable moment for survivors to engage in health promoting behavior.⁸⁶ Cancer survivors' health behaviors have important implications for their morbidity and mortality as cancer diagnosis often serves as an impetus for making health behavior changes.¹⁴ Previous studies show that young adult survivors had higher levels of life stress which related to higher levels of health behavior changes.⁸⁷ Sometimes, cancer survivors even tried to quit smoking as they felt obliged or pressured by health care providers, not because they felt ready to quit.³⁹ Therefore, healthy lifestyle changes, such as increasing physical activity, and smoking cessation are indirectly influenced by

physical, emotional, and social adjustment following diagnosis and treatment that cancer survivors faced.⁸⁶

Based on our results, compared to those who continuously physically active, those who were physically inactive had higher odds of smoking among cancer survivors. Those who drank alcohol also had higher odds of smoking after their cancer diagnosis than those who never drank alcohol. Moreover, compared to those who never smoked, those who smoked had higher odds of physical inactivity. Therefore, those who had unhealthy behaviors, might have combined unhealthy behaviors. A previous study also shows that cancer survivors limit or discontinue unhealthy behaviors, such as smoking and heavy consumption of alcohol after their cancer diagnosis, which could be influenced by their general characteristics.⁸⁸ Considering that 88% of survivors reported one or more positive behavior change since cancer diagnosis, the mean number of positive changes was 3.9 behaviors, having unhealthy behavior could also combine, which lead to increased risk of health outcomes.⁸⁸ Individuals' lifestyle behaviors show an interaction between other lifestyle behaviors that could potentially modify their association with mortality.⁸⁹

However, those who have only unhealthy behavior is also highly associated with mortality. Our study shows that among nonsmokers, those who were physically inactive after their cancer diagnosis had a higher risk of all-cause mortality than those who were continuously active. Also, among individuals who were continuously active, those who had quit smoking had a higher risk of all-cause mortality than nonsmokers. A previous

study showed that compared to those who were in the high-risk unhealthy behavior group (over- or underweight and current or former smokers), those who were in the moderately high-risk group (at least 2 of the 3 risk factors) had an increased median of 2.1 years, the moderate- to low-risk group (only 1 of the 3 risk factors) had an increased median of 3.6 years, and the low-risk group (no risk factors) had an increased median of 5.4 years for their survival.⁹⁰ Although modifying one to two behaviors could still lead to a lower risk of mortality, this implicate that not participating in any unhealthy behavior is important for their positive health outcomes.

Despite of increasing new opportunities such as the development of new treatment strategies, consideration of what lifestyle factors they had, and how it changes may influence their survival.⁹¹ As is well known, tobacco use is an established risk factors for the development of several cancers, which also affect their overall survivals and disease-specific mortality.⁹² However, our study found that those who continued smoking was not statisitcally significant with the risk of all-cause mortality, as well as cancer-related mortality, than nonsmokers. Instead, those who started or quit smoking had a higher risk of all-cause mortality than nonsmokers. Considering that current and past smokers were more likely to die from lung cancer than never smokers, they might not survive until 5 years from their cancer diagnosis.⁹³ A previous study shows that a significantly increased mortality rate was observed among prediagnosis smokers regardless of post-diagnosis smoking status.⁹⁴ Also, in our results (Appendix 1), the risk of cancer-related mortality was significantly higher in those who continued smoking than

nonsmokers among cancer patients who did not survive for 5 years.

Physically inactive lifestyles were associated with persisting physical fatigue among cancer survivors for months or even years.⁹⁵ One study shows that cancer survivors scored lower on measures of physical performance, suggesting that participation in regular physical activity is not sufficient to overcome underlying physiologic changes imposed by intensified therapies and prolonged hospitalizations.⁹⁶ Our study also found that those who were physically inactive after their diagnosis, especially those whose physical activity decreased, had a higher risk of all-cause mortality than those who were continuously active. Although physical activity is highly associated with cancer survivors' improved quality of life and positive health outcomes, being physically active after their cancer diagnosis is difficult for the cancer survivors. Moreover, some cancer survivors whose severity of cancer was high led to physical inactivity for the post-diagnosis period and increased their mortality risk.

Our finding showed the smoking was more common among male survivors and those under the age of 50. A previous study shows that the male, middle-aged group, the lowest income, and living with smoking family member were independently associated with persistent smoking among Korean cancer survivors.⁴⁹ However, the physically active was more common among male survivors and those under the age of 50. One study shows female cancer survivors were less likely to meet resistance exercise guideline than male cancer survivors. Although adherence to exercise recommendations is important, in both sexes, the prevalence of meeting exercise guidelines is low in Korean cancer

survivors.⁹⁷ Moreover, there are difference in the tendency to show health behavior change according to their general characteristics, the health behavior change is less likely to be undertaken and maintained by men, over age 65, and who are less educated.⁸⁸ Therefore, to optimize the effects of promoting cancer survivors to have healthy behaviors, more specified and targeted guidelines are necessary.³⁸

This study indicates that compared to those who were in the high-income group, those with low income had higher odds of smoking and physically inactive. Moreover, in the low-income group, those who quit smoking had a higher risk of all-cause mortality than nonsmokers. One study shows that persons from high poverty areas had substantially higher rates of cancer diagnosis and lower rates of cancer survival than those in low poverty areas.⁹⁸ A previous study shows that easy access to a gym, and the cost of healthy foods could be the barrier to the engagement in health behavior change among cancer survivors.⁸⁶ Barriers to health in low-income groups were reported to be inadequate access and availability of health care, lack of knowledge of illness, inaccurate beliefs about health, and a lack of health care providers.⁹⁸

Not only income, but also other socioeconomic factors are highly associated with health behavior changes and their mortality. Our study shows that those who live in rural areas had higher odds of physically inactivity than those who live in the metropolitan. Similary, a previous study showed that rural cancer survivors were more inactive than urban cancer survivors, which were highly associated with environmental factors.⁹⁹ Our finding shows that among those who live in rural areas, compared to those

who were nonsmokers, those who smoked before cancer diagnosis had a higher risk of all-cause mortality. Previous studies show that the cancer incidence and mortality rates in rural area were more likely among those who live in poverty, and smoke.¹⁰⁰ Rural survivors were less likely to meet physical activity recommendations than urban survivors and the prevalence of smoking among rural survivors was higher than among urban survivors.¹⁰¹

Advances in cancer therapy have dramatically improved survival for cancer patients, which increased cancer survivors and their risk of longer-term mortality.¹⁰² Cancer survivors have a greater risk of all-cause mortality, as well as disease-specific mortality, owing to both cancer and non-cancer causes than general populations.^{102,103} One study shows that a relative risk of later mortality among childhood and adolescent cancer survivors ranges between 10 and 20 times higher than that expected in the general populations.¹⁰² Although cancer survivors are often considered as someone who had been free of any sign of disease for a minimum five years, cancer survivors still need to pay more attention to manage their health.²⁷ Based on our results in the Appendix, cancer survivors had a higher risk of both all-cause mortality and cancer-related mortality than general populations. However, this study found that cancer survivors tend to embrace healthy behavior such as nonsmoking and being physically active compared with general populations. Cancer survivors are not only aware of their lifestyle factor but also voluntarily change their lifestyle in a positive way.¹⁰⁴ Considering that those who have healthy behavior had a lower risk of mortality among cancer survivors, ongoing

monitoring of late mortality is essential to reduce other health problems including mortality risk.

3. Policy Implications

To reduce the health risk among cancer survivors, interventions must be developed for both prevention and management, especially according to their healthy behaviors. Engagement in unhealthy behavior exacerbates the vulnerabilities and places cancer survivors at even further risk of experiencing adverse health outcomes later in life.⁴⁶ Therefore, to prevent them from longer-term adverse outcomes such as risk of late mortality, establishing the prevalence and risk factors for unhealthy behavior, aggressive health educations and effective campaign is necessary, with the targeted population considering their characteristics.

Survivors may encounter a range of potential effects resulting from the cancer itself or cancer treatments.¹⁰⁵ Monitoring systems of cancer survivors for their post-cancer processes such as changes in quality of life after survival other than cancer diagnosis and treatment are insufficient.⁶³ Understandably, as the focus of cancer care has been on cure, there are significant barriers to ideal post-treatment care.¹⁰⁵ In many circumstances there is a lack of evidence to provide the guidance regarding the aftercare of cancer survivors owing to important questions such as how often should people be reviewed, in what way, or who are the right people to be involved in post-treatment care are to be addressed.^{105,106}

Therefore, it is essential to provide the evidence for the aftercare of cancer survivors, which enables better outcomes for survivors, while using health care resources efficiently.¹⁰⁵

However, only cancer statistic information such as incidence, mortality and survival rate is provided as national indicators that can measure the cancer burden, so there is a limit to identifying the demand and having difficulty with providing the evidence for the cancer survivor policy.⁶³ Moreover, as cancer survivors increase, and interest about cancer survivors is increasing, there is still lack of studies on their health behaviors, and medical use of other instead of cancer tends to be underestimated.¹⁰⁷ Therefore, attention is required for the cancer survivors in various ways.

Cancer survivors themselves should pay attention to manage their health behaviors. Showing healthy behaviors is the easiest way to reduce the risk of adverse health outcomes, and the first step to use the resources effectively. However, changing their health behavior may not be easy. Previous studies show that more than 25% of cancer patients continued to smoke, which makes them to feel guilty and experience conflicts with their families.¹⁰⁸ More importantly, cancer survivors should continue to pay attention to manage long-term care and health risk.

Patients' need a will to have healthy behaviors, but healthcare professionals should also help patients not to do it in the wrong way. Among cancer survivors, excessive dietary control may lead to nutritional imbalances, and appropriate risk factor evaluation is required before managing the health behaviors of cancer survivors.

Therefore, healthcare professionals' help is needed to manage them correctly.¹⁰⁸ Beyond understanding which behaviors change and the direction in which they change, it is important to understand the correlates of these changes to make and advance guideline for the cancer survivors.⁸⁸ There might be stable and non-changeable characteristics which is hard to change, such as sex, however, focusing on which is the more modifiable characteristic, such as a certain belief or perceptions, could maximize the effects.⁸⁸ Moreover, more specific guidelines are needed for each targeted group and health professional should pay attention to manage their health behaviors.

With the cost burden that cancer survivors experience, especially after acute treatments, many cancer survivors demand for a cost burden from long-term treatment, support for returning to their work, or social return programs as a positive step toward an improved quality of life, as well as rehabilitation after treatment.^{109,110} Considering that only about 50% of cancer survivors return to work, even after three years of diagnosis, their economic burden will increase further.¹¹⁰ There are many supports to reduce the economic burden on cancer patients, but there are no well-equipped programs to help cancer survivors after their treatment with returning to work that they have not been able to do for their cancer treatment.¹⁰⁹

To design effective health behavior interventions for cancer survivors, it is important to know the timing, mediating factors, and the target group that would optimize the effects of the program to promote their healthy behaviors.³⁸ For the comprehensive approach to cancer survivorship, the "Shared care model" has been suggested. This model

is used by primary care providers and oncologists to care cancer survivors together with the regular communication for effective care since they diagnosis cancer.¹⁰⁸ According to previous studies, 88% of oncologists considered overlapping treatment with primary care providers when treating cancer survivors.¹¹¹ Although 70% of cancer survivors have accompanying diseases, most oncologists focus only on cancer screening and cancer-related treatments, and furthermore, even though they know the importance of lifestyle of cancer survivors, they do not manage their health behaviors.¹¹¹ Considering that, this could be solved with continuous communication with primary care providers and oncologists, the supporting system is urgently necessary.

Therefore, future efforts should be directed toward health promotion programs among cancer survivors, not only in those who are well beyond their diagnosis, but also in those who are more newly diagnosed and perhaps more motivated to participants in lifestyle change.³⁷ Healthcare professional' enhanced awareness and clinical skills to guide and support a patient is necessary. Monitoring should be accompanied with proper medical advice, providing more knowledge about their health conditions, and more likely to reduce psychological distress.¹¹² More importantly, this should be accompanied by accurate guidance regarding the aftercare of cancer survivors focusing on “for whom, in what way, and how?”^{105,106} Targeted guidance is needed by identifying their characteristics and psychosocial predictors which could be highly associated with increased follow-up care informational needs.¹¹² A validated nomogram could help both cancer survivors and policy makers to show the importance of controlling health

conditions through visualized graphs. Cancer survivors themselves should follow the recommendations of healthcare professionals with trust and try to show healthy behaviors which could reduce the burden of their adverse health outcomes. Policymaker should also be aware that survivorship care plans and evidence-based educational strategies that are well-targeted were necessary to prepare engaging roles in managing long-term care and health risk for both survivors and healthcare providers and encourage them to participate correctly.¹¹²

VI. Conclusion

The current study investigate the factor associated with health behavior changes, and identified a significant relationship between health behavior change and the mortality among cancer survivors in South Korea. Based on our results, cancer survivors with unhealthy behavior tend to have combined unhealthy behaviors. Our findings also indicate that individuals who changed their health behavior negatively had the higher risk of both all-cause mortality and cancer-related mortality. As our study also found out that cancer survivors had a higher risk of mortality than to general populations, this may emphasize that cancer survivor's healthy behaviors is more important than the general populations to reduce their late adverse outcomes. Therefore, this highlights the importance of managing their health behavior among cancer survivors.

We believe this study can have meaningful impact not only physically, and economically, but also socially, and politically by raising awareness about importance of managing health behaviors among cancer survivors to reduce the risk of adverse health outcomes. Hence, it is crucial to direct attention toward to the mortality risk in cancer survivors with unhealthy behaviors. Further research is needed with more diverse health behaviors screening tools as cancer survivors continue to increase and the need for the researches and guidelines for their post-treatment managements is emphasized, which is still underestimated.¹⁰⁷

Considering that by showing the results of unhealthy behaviors such as being physically inactivity and smoking are usually combines and the results of unhealthy behaviors is highly associated with risk of mortality among cancer survivors, clinicians and policymakers should make sure to have acute and rapid recognitions that is essential for cancer survivors to assist them to have healthy behaviors and also assist for the resource-planning, social policies, and interventions to alleviate the risk of adverse health outcomes in the South Korean cancer survivors.

Consequently, managing health behavior is important to prevent premature death. Our finding implies that care should be showed for cancer survivors, especially those with unhealthy behaviors. Future interventions to reduce the risk of mortality among cancer survivors, along with encouragement to have healthy behaviors including not smoking and being physically active, are necessary. Moreover, the development of a validated nomogram may, thus, provide useful insight into both official policy and existing practice in health care systems, which would benefit further research for the cancer survivors.

Abbreviations

NCCS — National Coalition for Cancer Survivorship
ACS — American Cancer Society
NCCN — National Comprehensive Cancer Network
NHIS-NSC — National Health Insurance Service National Sample Cohort
ICD-10 — International Classification of Disease, 10th revision
CCI — Charlson Comorbidity Index
NHIS — National Health Insurance Service
OR — Odds Ratio
CI — Confidence Interval
HR — Hazard Ratio

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Appendix

Appendix 1. Results of association between Health Behaviors and Mortality among Cancer patients before 5 year from diagnosis

Appendix 2. Subgroup analysis of the association between Risk of All-cause Mortality and covariates, according to Smoking status

Appendix 3. Subgroup analysis of the association between Risk of Cancer-related Mortality and covariates, according to Smoking status

Appendix 4. Subgroup analysis of the association between Risk of All-cause Mortality and covariates, according to Physical activity

Appendix 5. Subgroup analysis of the association between Risk of Cancer-related Mortality and covariates, according to Physical activity

Appendix 6. General characteristics of the Study population of Cancer survivors and General population

Appendix 7. Results of Multinomial logistic regressions about association between Cancer survivors and Smoking status

Appendix 8. Results of Multinomial logistic regressions about association between Cancer survivors and Physical activity

Appendix 9. Incidence rates of All-cause Mortality in the Matched cohort

Appendix 10. Results of association between Cancer survivors and the Mortality

Appendix 11. Subgroup analysis of the association between Risk of Mortality and covariates, according to Cancer survivors

Appendix 12. Results of association between Cancer survivors stratified with Health Behaviors and the Mortality compared with General population

Appendix 1. Results of association between Health Behaviors and Mortality among Cancer patients before 5 year from diagnosis ^{a,b}

Variables	All-cause Mortality		Cancer-related Mortality	
	Adjusted HR	95% CI	Adjusted HR	95% CI
Smoking status				
Started smoking	1.03	(0.59 - 1.81)	0.46	(0.17 - 1.27)
Continued smoking	1.22	(0.87 - 1.72)	1.58	(1.05 - 2.37)
Quit smoking	1.36	(1.03 - 1.80)	1.65	(1.18 - 2.31)
Nonsmoking	1.00		1.00	
Physical activity				
Continuously active	1.00		1.00	
Increase	1.12	(0.77 - 1.62)	1.08	(0.70 - 1.64)
Decrease	1.53	(1.09 - 2.16)	1.28	(0.86 - 1.92)
Inactive	1.58	(1.15 - 2.16)	1.36	(0.95 - 1.96)

^a Adjusted for sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cancer diagnosis.

^b Data were analyzed for the cancer diagnosed to mortality within follow up period or before their 5 year survivals from diagnosis.

Appendix 2. Subgroup analysis of the association between Risk of All-cause Mortality and covariates, according to Smoking status ^a

Variables	All-cause Mortality							
	Started smoking		Continued smoking		Quit smoking		Non smoking	
	Adjusted HR	95% CI Lower Upper	Adjusted HR	95% CI Lower Upper	Adjusted HR	95% CI Lower Upper	Adjusted HR	
Physical activity								
Continuously active	2.07	(0.47-9.01)	1.26	(0.46-3.43)	3.03	(1.46-6.31)	1.00	
Increase	2.16	(0.72-6.43)	0.87	(0.32-2.34)	1.19	(0.53-2.69)	1.00	
Decrease	2.32	(0.88-6.16)	1.36	(0.64-2.87)	1.18	(0.60-2.34)	1.00	
Inactive	1.79	(0.90-3.54)	0.95	(0.53-1.68)	1.30	(0.80-2.12)	1.00	
Sex								
Male	2.08	(1.30-3.32)	1.09	(0.75-1.61)	1.44	(1.04-2.01)	1.00	
Female	-		0.70	(0.09-5.39)	1.49	(0.45-4.88)	1.00	
Age								
< 50	3.77	(0.68-20.81)	0.44	(0.05-4.03)	4.90	(1.33-18.08)	1.00	
50-59	2.17	(0.59-7.94)	1.78	(0.75-4.23)	0.81	(0.29-2.24)	1.00	
60-69	2.19	(1.03-4.64)	1.17	(0.65-2.09)	2.02	(1.28-3.19)	1.00	
≥70	1.56	(0.74-3.31)	0.82	(0.42-1.60)	0.87	(0.48-1.57)	1.00	
Income								
Low	0.90	(0.21-3.92)	1.31	(0.58-2.96)	1.93	(1.02-3.64)	1.00	
Middle	2.63	(1.30-5.32)	1.31	(0.71-2.42)	0.91	(0.49-1.70)	1.00	
High	1.86	(0.92-3.78)	0.85	(0.46-1.56)	1.78	(1.12-2.83)	1.00	
Region								
Metropolitan	2.40	(1.01-5.74)	0.83	(0.37-1.90)	1.78	(0.96-3.32)	1.00	
City	0.98	(0.23-4.22)	1.71	(0.86-3.43)	1.14	(0.57-2.30)	1.00	
Rural	2.20	(1.20-4.03)	0.92	(0.53-1.59)	1.56	(1.01-2.42)	1.00	
Disability								
Yes	1.81	(0.45-7.25)	2.00	(0.61-6.56)	0.40	(0.09-1.87)	1.00	
No	2.06	(1.25-3.40)	1.05	(0.70-1.57)	1.57	(1.14-2.17)	1.00	
Alcohol Consumption								
0 time	1.86	(1.01-3.40)	1.27	(0.79-2.03)	1.42	(0.98-2.06)	1.00	
1-2 times a week	2.44	(0.79-7.52)	0.77	(0.26-2.33)	1.67	(0.68-4.12)	1.00	
≥3 times a week	2.37	(0.79-7.15)	1.05	(0.45-2.45)	2.56	(1.04-6.28)	1.00	

Appendix 2. Subgroup analysis of the association between Risk of All-cause Mortality and covariates, according to Smoking status (Continued) ^a

Variables	All-cause Mortality							
	Started smoking		Continued smoking		Quit smoking		Non smoking	
	Adjusted HR	95% CI Lower Upper	Adjusted HR	95% CI Lower Upper	Adjusted HR	95% CI Lower Upper	Adjusted HR	
BMI								
Underweight	6.19	(0.26-146.59)	2.44	(0.45-13.33)	2.82	(0.72-11.07)	1.00	
Normal	2.18	(1.07-4.44)	1.00	(0.58-1.72)	1.63	(1.00-2.66)	1.00	
Overweight	3.58	(1.67-7.68)	1.01	(0.41-2.52)	1.07	(0.52-2.20)	1.00	
Obesity	0.62	(0.15-2.58)	1.23	(0.53-2.85)	1.37	(0.77-2.47)	1.00	
Cancer type								
Stomach cancer	5.40	(1.81-16.10)	1.55	(0.61-3.93)	1.75	(0.82-3.73)	1.00	
Colorectal cancer	-		1.62	(0.51-5.15)	1.18	(0.38-3.68)	1.00	
Lung cancer	-		0.30	(0.04-2.63)	0.68	(0.20-2.37)	1.00	
Liver cancer	3.04	(0.75-12.35)	2.47	(0.91-6.69)	2.46	(0.92-6.55)	1.00	
Other cancer	2.23	(1.23-4.04)	0.87	(0.50-1.51)	1.41	(0.91-2.19)	1.00	
Charlson Comorbidity Index (CCI)								
0	15.58	(1.66-146.66)	1.89	(0.25-14.51)	1.07	(0.09-12.46)	1.00	
1	2.14	(0.47-9.68)	0.55	(0.18-1.63)	2.40	(1.07-5.35)	1.00	
2	3.17	(1.17-8.59)	1.07	(0.42-2.71)	1.63	(0.80-3.32)	1.00	
≥3	1.64	(0.87-3.09)	1.30	(0.82-2.07)	1.36	(0.90-2.05)	1.00	
Diabetes before cancer								
Yes	1.31	(0.55-3.13)	1.02	(0.53-1.96)	0.87	(0.42-1.79)	1.00	
No	2.46	(1.42-4.28)	1.12	(0.71-1.78)	1.69	(1.19-2.42)	1.00	
Hypertension before cancer								
Yes	1.77	(0.93-3.36)	1.00	(0.57-1.75)	1.28	(0.82-2.02)	1.00	
No	2.18	(1.10-4.31)	1.27	(0.76-2.11)	1.60	(1.02-2.51)	1.00	

^a Adjusted for physical activity, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cancer diagnosis.

Appendix 3. Subgroup analysis of the association between Risk of Cancer-related Mortality and covariates, according to Smoking status ^a

Variables	Cancer-related Mortality							
	Started smoking		Continued smoking		Quit smoking		Non smoking	
	Adjusted HR	95% CI Lower Upper	Adjusted HR	95% CI Lower Upper	Adjusted HR	95% CI Lower Upper	Adjusted HR	
Physical activity								
Continuously active	2.87	(0.63-13.14)	0.85	(0.18-3.94)	3.42	(1.42-8.26)	1.00	
Increase	1.03	(0.13-8.07)	1.39	(0.44-4.44)	0.68	(0.15-3.09)	1.00	
Decrease	2.72	(0.76-9.69)	1.09	(0.35-3.42)	1.76	(0.81-3.85)	1.00	
Inactive	0.93	(0.28-3.13)	0.34	(0.10-1.14)	1.28	(0.64-2.57)	1.00	
Sex								
Male	1.61	(0.80-3.26)	0.69	(0.37-1.29)	1.50	(0.97-2.31)	1.00	
Female	-		2.48	(0.31-19.77)	3.37	(0.77-14.69)	1.00	
Age								
< 50	4.88	(0.39-61.74)	-		9.56	(1.62-56.55)	1.00	
50-59	2.70	(0.53-13.61)	1.04	(0.28-3.86)	0.80	(0.25-2.51)	1.00	
60-69	0.54	(0.07-3.95)	1.10	(0.50-2.44)	2.37	(1.31-4.30)	1.00	
≥70	1.75	(0.64-4.75)	0.35	(0.08-1.50)	0.65	(0.25-1.69)	1.00	
Income								
Low	2.69	(0.55-13.24)	2.63	(0.93-7.44)	2.91	(1.19-7.16)	1.00	
Middle	0.98	(0.29-3.34)	0.39	(0.12-1.32)	0.68	(0.28-1.67)	1.00	
High	1.54	(0.54-4.37)	0.50	(0.18-1.40)	1.97	(1.11-3.48)	1.00	
Region								
Metropolitan	2.13	(0.63-7.18)	0.62	(0.18-2.13)	1.51	(0.66-3.44)	1.00	
City	0.69	(0.09-5.36)	1.33	(0.50-3.50)	1.11	(0.46-2.70)	1.00	
Rural	1.50	(0.58-3.90)	0.44	(0.16-1.26)	1.75	(0.98-3.13)	1.00	
Disability								
Yes	2.12	(0.15-29.81)	0.73	(0.07-7.48)	0.53	(0.05-5.63)	1.00	
No	1.57	(0.75-3.28)	0.73	(0.39-1.36)	1.62	(1.06-2.48)	1.00	
Alcohol Consumption								
0 time	1.13	(0.41-3.13)	1.02	(0.52-2.02)	1.51	(0.93-2.46)	1.00	
1-2 times a week	2.22	(0.44-11.08)	-		0.70	(0.15-3.37)	1.00	
≥3 times a week	3.57	(0.77-16.47)	0.68	(0.16-2.90)	4.46	(1.43-13.92)	1.00	

Appendix 3. Subgroup analysis of the association between Risk of Cancer-related Mortality and covariates, according to Smoking status (Continued) ^a

Variables	Cancer-related Mortality						
	Started smoking		Continued smoking		Quit smoking		Non smoking
	Adjusted HR	95% CI Lower Upper	Adjusted HR	95% CI Lower Upper	Adjusted HR	95% CI Lower Upper	Adjusted HR
BMI							
Underweight	-		-		-		1.00
Normal	2.67	(1.01-7.04)	0.69	(0.29-1.67)	1.92	(0.99-3.72)	1.00
Overweight	1.25	(0.28-5.54)	0.75	(0.21-2.71)	0.61	(0.20-1.82)	1.00
Obesity	0.48	(0.06-3.57)	0.51	(0.12-2.25)	1.78	(0.90-3.52)	1.00
Cancer type							
Stomach cancer	7.42	(1.89-29.07)	0.48	(0.06-3.99)	1.30	(0.43-3.91)	1.00
Colorectal cancer	-		0.62	(0.06-6.15)	1.24	(0.29-5.25)	1.00
Lung cancer	-		0.27	(0.03-2.72)	0.60	(0.14-2.49)	1.00
Liver cancer	2.96	(0.24-36.00)	8.49	(1.62-44.45)	6.52	(1.31-32.51)	1.00
Other cancer	1.27	(0.45-3.61)	0.65	(0.27-1.55)	1.66	(0.93-2.96)	1.00
Charlson Comorbidity Index (CCI)							
0	-		0.45	(0.02-8.38)	-		1.00
1	1.84	(0.22-15.28)	0.72	(0.20-2.60)	3.57	(1.41-9.03)	1.00
2	1.03	(0.13-8.06)	0.57	(0.12-2.61)	1.48	(0.59-3.71)	1.00
≥3	1.21	(0.43-3.41)	0.79	(0.35-1.79)	1.45	(0.82-2.57)	1.00
Diabetes before cancer							
Yes	0.72	(0.15-3.34)	0.76	(0.28-2.07)	0.83	(0.30-2.26)	1.00
No	1.87	(0.84-4.14)	0.67	(0.32-1.43)	1.77	(1.12-2.81)	1.00
Hypertension before cancer							
Yes	1.46	(0.52-4.15)	0.73	(0.28-1.86)	1.50	(0.83-2.71)	1.00
No	1.66	(0.64-4.31)	0.84	(0.39-1.84)	1.59	(0.89-2.87)	1.00

^a Adjusted for physical activity, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cancer diagnosis.

Appendix 4. Subgroup analysis of the association between Risk of All-cause Mortality and covariates, according to Physical activity ^a

All-cause Mortality										
Variables	Continuously active	Increase		Decrease			Inactive			
	Adjusted HR	Adjusted HR	95% CI		Adjusted HR	95% CI		Adjusted HR	95% CI	
			Lower	Upper		Lower	Upper		Lower	Upper
Smoking status										
Started smoking	1.00	1.96	(0.21-18.59)		3.66	(0.45-29.60)		3.00	(0.40-22.67)	
Continued smoking	1.00	1.08	(0.29-4.01)		1.99	(0.64-6.24)		1.25	(0.41-3.84)	
Quit smoking	1.00	0.57	(0.21-1.51)		0.81	(0.34-1.92)		1.18	(0.55-2.52)	
Nonsmoking	1.00	1.36	(0.86-2.17)		1.56	(1.01-2.40)		1.68	(1.12-2.53)	
Sex										
Male	1.00	1.15	(0.75-1.76)		1.45	(0.98-2.14)		1.40	(0.97-2.03)	
Female	1.00	1.40	(0.61-3.21)		1.48	(0.66-3.31)		1.62	(0.78-3.36)	
Age										
< 50	1.00	1.45	(0.43-4.92)		0.75	(0.17-3.25)		0.46	(0.11-1.98)	
50-59	1.00	1.04	(0.38-2.86)		2.40	(1.05-5.49)		1.50	(0.64-3.56)	
60-69	1.00	1.24	(0.67-2.29)		1.48	(0.84-2.61)		1.48	(0.87-2.52)	
≥70	1.00	1.10	(0.58-2.07)		1.26	(0.69-2.29)		1.57	(0.91-2.70)	
Income										
Low	1.00	1.68	(0.65-4.36)		2.39	(0.97-5.86)		2.27	(0.97-5.30)	
Middle	1.00	1.25	(0.65-2.41)		1.46	(0.75-2.82)		1.48	(0.83-2.65)	
High	1.00	0.99	(0.57-1.72)		1.28	(0.79-2.05)		1.24	(0.79-1.96)	
Region										
Metropolitan	1.00	0.40	(0.17-0.94)		1.27	(0.74-2.17)		1.21	(0.70-2.08)	
City	1.00	2.64	(1.16-5.98)		3.33	(1.54-7.21)		2.38	(1.11-5.11)	
Rural	1.00	1.27	(0.71-2.27)		1.08	(0.59-1.96)		1.29	(0.77-2.18)	
Disability										
Yes	1.00	1.48	(0.33-6.58)		1.84	(0.45-7.43)		1.18	(0.30-4.65)	
No	1.00	1.17	(0.79-1.73)		1.41	(0.98-2.03)		1.46	(1.04-2.05)	
Alcohol Consumption										
0 time	1.00	1.14	(0.74-1.77)		1.28	(0.85-1.92)		1.35	(0.93-1.96)	
1-2 times a week	1.00	0.72	(0.24-2.13)		1.25	(0.48-3.26)		1.68	(0.71-4.00)	
≥3 times a week	1.00	2.80	(0.69-11.34)		5.16	(1.40-19.00)		2.94	(0.81-10.62)	

Appendix 4. Subgroup analysis of the association between Risk of All-cause Mortality and covariates, according to Physical activity (Continued) ^a

All-cause Mortality										
Variables	Continuously active	Increase			Decrease			Inactive		
	Adjusted HR	Adjusted HR	95% CI		Adjusted HR	95% CI		Adjusted HR	95% CI	
			Lower	Upper		Lower	Upper		Lower	Upper
BMI										
Underweight	1.00	-			-			-		
Normal	1.00	1.14	(0.63-2.05)		1.49	(0.88-2.52)		1.20	(0.73-1.99)	
Overweight	1.00	1.06	(0.47-2.37)		1.60	(0.77-3.33)		1.65	(0.82-3.31)	
Obesity	1.00	1.34	(0.67-2.66)		1.07	(0.55-2.07)		1.54	(0.85-2.80)	
Cancer type										
Stomach cancer	1.00	0.59	(0.19-1.84)		1.39	(0.58-3.33)		1.29	(0.58-2.90)	
Colorectal cancer	1.00	2.55	(0.73-8.95)		2.72	(0.84-8.79)		1.87	(0.57-6.08)	
Lung cancer	1.00	0.74	(0.18-2.96)		0.97	(0.25-3.81)		0.71	(0.19-2.63)	
Liver cancer	1.00	1.36	(0.50-3.70)		1.13	(0.42-3.01)		0.99	(0.38-2.55)	
Other cancer	1.00	1.20	(0.70-2.04)		1.58	(0.97-2.58)		1.69	(1.08-2.66)	
Charlson Comorbidity Index (CCI)										
0	1.00	0.80	(0.07-8.66)		5.35	(0.92-31.28)		1.29	(0.16-10.31)	
1	1.00	1.29	(0.52-3.18)		1.98	(0.86-4.54)		0.82	(0.34-1.97)	
2	1.00	1.53	(0.67-3.49)		0.72	(0.27-1.93)		1.66	(0.79-3.53)	
≥3	1.00	1.01	(0.61-1.68)		1.40	(0.89-2.19)		1.49	(0.98-2.26)	
Diabetes before cancer										
Yes	1.00	1.16	(0.56-2.43)		1.29	(0.68-2.46)		1.93	(1.07-3.48)	
No	1.00	1.23	(0.79-1.93)		1.62	(1.07-2.46)		1.32	(0.89-1.97)	
Hypertension before cancer										
Yes	1.00	1.17	(0.68-2.01)		1.36	(0.82-2.23)		1.52	(0.96-2.42)	
No	1.00	1.19	(0.70-2.05)		1.60	(0.97-2.61)		1.35	(0.84-2.15)	

^a Adjusted for smoking status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cancer diagnosis.

Appendix 5. Subgroup analysis of the association between Risk of Cancer-related Mortality and covariates, according to Physical activity ^a

Variables	Cancer-related mortality									
	Continuously active	Increase			Decrease			Inactive		
		Adjusted HR	Adjusted HR	95% CI	Adjusted HR	95% CI	Adjusted HR	95% CI		
				Lower Upper		Lower Upper		Lower Upper		
Smoking status										
Started smoking	1.00	-		-		-				
Continued smoking	1.00	2.36	(0.28-19.96)	1.50	(0.18-12.77)	0.68	(0.08-6.14)			
Quit smoking	1.00	0.21	(0.04-1.08)	1.05	(0.40-2.75)	0.52	(0.20-1.38)			
Nonsmoking	1.00	1.47	(0.82-2.65)	-		1.37	(0.80-2.34)			
Sex										
Male	1.00	0.88	(0.49-1.56)	1.28	(0.78-2.10)	1.03	(0.63-1.68)			
Female	1.00	2.12	(0.74-6.02)	1.60	(0.55-4.67)	1.39	(0.52-3.76)			
Age										
< 50	1.00	1.47	(0.28-7.66)	0.88	(0.16-5.00)	0.14	(0.01-1.70)			
50-59	1.00	1.33	(0.40-4.46)	2.68	(0.98-7.36)	1.60	(0.55-4.71)			
60-69	1.00	0.97	(0.43-2.18)	1.20	(0.59-2.45)	1.19	(0.61-2.32)			
≥70	1.00	1.00	(0.43-2.35)	0.96	(0.42-2.21)	0.84	(0.39-1.81)			
Income										
Low	1.00	1.10	(0.33-3.70)	2.06	(0.69-6.20)	1.43	(0.48-4.21)			
Middle	1.00	1.24	(0.49-3.16)	1.75	(0.72-4.26)	1.39	(0.61-3.18)			
High	1.00	1.07	(0.55-2.06)	1.03	(0.57-1.89)	0.86	(0.48-1.56)			
Region										
Metropolitan	1.00	0.28	(0.08-0.97)	1.16	(0.59-2.29)	0.66	(0.31-1.40)			
City	1.00	3.78	(1.32-10.82)	4.68	(1.72-12.79)	2.05	(0.71-5.92)			
Rural	1.00	1.01	(0.47-2.14)	0.64	(0.28-1.47)	0.94	(0.48-1.84)			
Disability										
Yes	1.00	2.21	(0.16-30.79)	3.92	(0.33-46.00)	1.24	(0.10-15.67)			
No	1.00	1.12	(0.68-1.85)	1.28	(0.81-2.02)	1.07	(0.69-1.67)			
Alcohol Consumption										
0 time	1.00	1.01	(0.58-1.77)	1.18	(0.71-1.97)	1.00	(0.61-1.62)			
1-2 times a week	1.00	0.67	(0.14-3.14)	1.45	(0.37-5.58)	1.37	(0.35-5.36)			
≥3 times a week	1.00	4.21	(0.69-25.65)	5.10	(0.97-26.85)	2.71	(0.51-14.36)			

Appendix 5. Subgroup analysis of the association between Risk of Cancer-related Mortality and covariates, according to Physical activity (Continued) ^a

Cancer-related mortality									
Variables	Continuously active	Increase		Decrease			Inactive		
	Adjusted HR	Adjusted HR	95% CI	Adjusted HR	95% CI	Adjusted HR	95% CI		
			Lower Upper		Lower Upper		Lower Upper		
BMI									
Underweight	1.00	-		-		-			
Normal	1.00	1.22	(0.57-2.61)	1.15	(0.56-2.34)	0.92	(0.47-1.81)		
Overweight	1.00	0.96	(0.35-2.63)	1.32	(0.54-3.22)	1.02	(0.42-2.46)		
Obesity	1.00	1.58	(0.66-3.79)	1.58	(0.70-3.56)	1.39	(0.62-3.08)		
Cancer type									
Stomach cancer	1.00	0.17	(0.02-1.89)	1.90	(0.58-6.22)	1.13	(0.35-3.62)		
Colorectal cancer	1.00	5.37	(0.98-29.39)	2.34	(0.41-13.33)	1.77	(0.32-9.90)		
Lung cancer	1.00	0.30	(0.05-1.76)	0.88	(0.20-3.97)	0.81	(0.20-3.33)		
Liver cancer	1.00	1.73	(0.34-8.70)	2.35	(0.51-10.87)	2.50	(0.58-10.83)		
Other cancer	1.00	1.19	(0.63-2.26)	1.30	(0.71-2.39)	0.92	(0.51-1.65)		
Charlson Comorbidity Index (CCI)									
0	1.00	1.93	(0.18-20.80)	3.25	(0.39-27.09)	0.77	(0.06-9.55)		
1	1.00	1.28	(0.44-3.70)	2.00	(0.78-5.13)	0.72	(0.26-2.00)		
2	1.00	1.43	(0.54-3.76)	0.82	(0.28-2.43)	0.98	(0.39-2.46)		
≥3	1.00	0.87	(0.42-1.81)	1.16	(0.61-2.20)	1.14	(0.63-2.08)		
Diabetes before cancer									
Yes	1.00	1.59	(0.60-4.18)	1.24	(0.49-3.15)	1.60	(0.68-3.72)		
No	1.00	1.06	(0.60-1.87)	1.54	(0.92-2.56)	1.03	(0.62-1.72)		
Hypertension before cancer									
Yes	1.00	1.22	(0.62-2.41)	1.02	(0.53-1.99)	0.91	(0.49-1.72)		
No	1.00	0.99	(0.49-2.01)	1.69	(0.92-3.10)	1.22	(0.67-2.20)		

^a Adjusted for smoking status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, cancer type, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cancer diagnosis.

Appendix 6. General characteristics of the Study population of Cancer survivors and General population ^a

Variables	Total		Cancer survivor		General population		P-value	Standardized Difference
Total	27,537	(100.0)	9,179	(33.3)	18,358	(66.7)		
Smoking status							<0.0001	0.1386
Started smoking	848	(3.1)	228	(2.5)	620	(3.4)		
Continued smoking	3,197	(11.6)	867	(9.4)	2,330	(12.7)		
Quit smoking	2,397	(8.7)	948	(10.3)	1,449	(7.9)		
Nonsmoking	21,095	(76.6)	7,136	(77.7)	13,959	(76.0)		
Physical activity							0.0145	0.0415
Continuously active	6,258	(22.7)	2,174	(23.7)	4,084	(22.2)		
Increase	5,624	(20.4)	1,896	(20.7)	3,728	(20.3)		
Decrease	5,499	(20.0)	1,825	(19.9)	3,674	(20.0)		
Inactive	10,156	(36.9)	3,284	(35.8)	6,872	(37.4)		
Sex							0.4581	0.0095
Male	13,239	(48.1)	4,442	(48.4)	8,797	(47.9)		
Female	14,298	(51.9)	4,737	(51.6)	9,561	(52.1)		
Age							0.9999	0.0010
< 50	8,064	(29.3)	2,688	(29.3)	5,376	(29.3)		
50-59	7,979	(29.0)	2,659	(29.0)	5,320	(29.0)		
60-69	7,462	(27.1)	2,486	(27.1)	4,976	(27.1)		
≥70	4,032	(14.6)	1,346	(14.7)	2,686	(14.6)		
Income							0.9267	0.0050
Low	5,494	(20.0)	1,830	(19.9)	3,664	(20.0)		
Middle	9,432	(34.3)	3,158	(34.4)	6,274	(34.2)		
High	12,611	(45.8)	4,191	(45.7)	8,420	(45.9)		
Region							<0.0001	0.0956
Metropolitan	10,221	(37.1)	3,194	(34.8)	7,027	(38.3)		
City	7,017	(25.5)	2,275	(24.8)	4,742	(25.8)		
Rural	10,299	(37.4)	3,710	(40.4)	6,589	(35.9)		
Medical Insurance							0.0341	0.0320
Insurance (Corporate)	19,317	(70.1)	6,441	(70.2)	12,876	(70.1)		
Insurance (Regional)	8,093	(29.4)	2,682	(29.2)	5,411	(29.5)		
Medical aid	127	(0.5)	56	(0.6)	71	(0.4)		
Disability							0.0176	0.0301
Yes	1,838	(6.7)	659	(7.2)	1,179	(6.4)		
No	25,699	(93.3)	8,520	(92.8)	17,179	(93.6)		

Appendix 6. General characteristics of the Study population of Cancer survivors and General population (Continued) ^a

Variables	Total	Cancer survivor	General population	P-value	Standardized Difference
Alcohol Consumption				<0.0001	0.1648
0 time	18,009 (65.4)	6,466 (70.4)	11,543 (62.9)		
1-2 times a week	6,296 (22.9)	1,849 (20.1)	4,447 (24.2)		
≥3 times a week	3,232 (11.7)	864 (9.4)	2,368 (12.9)		
BMI				0.015	0.0413
Underweight	860 (3.1)	294 (3.2)	566 (3.1)		
Normal	10,002 (36.3)	3,446 (37.5)	6,556 (35.7)		
Overweight	7,247 (26.3)	2,389 (26.0)	4,858 (26.5)		
Obesity	9,428 (34.2)	3,050 (33.2)	6,378 (34.7)		
Charlson Comorbidity Index (CCI)				0.9842	0.0051
0	3,346 (12.2)	1,116 (12.2)	2,230 (12.1)		
1	6,666 (24.2)	2,222 (24.2)	4,444 (24.2)		
2	6,904 (25.1)	2,289 (24.9)	4,615 (25.1)		
≥3	10,621 (38.6)	3,552 (38.7)	7,069 (38.5)		
Diabetes before cancer				0.3703	0.0114
Yes	5,153 (18.7)	1,745 (19.0)	3,408 (18.6)		
No	22,384 (81.3)	7,434 (81.0)	14,950 (81.4)		
Hypertension before cancer				0.606	0.0066
Yes	10,693 (38.8)	3,584 (39.0)	7,109 (38.7)		
No	16,844 (61.2)	5,595 (61.0)	11,249 (61.3)		
Year of Cohort entry				1.0000	0.0007
2005	2,169 (7.9)	724 (7.9)	1,445 (7.9)		
2006	4,456 (16.2)	1,485 (16.2)	2,971 (16.2)		
2007	5,108 (18.5)	1,702 (18.5)	3,406 (18.6)		
2008	5,547 (20.1)	1,849 (20.1)	3,698 (20.1)		
2009	5,400 (19.6)	1,800 (19.6)	3,600 (19.6)		
2010	4,857 (17.6)	1,619 (17.6)	3,238 (17.6)		

^aThe matching variables was sex, age, income, Charlson Comorbidity Index score, and year of cohort entry.

Appendix 7. Results of Multinomial logistic regressions about association between Cancer survivors and Smoking status ^{a,b}

Variables	Smoking status					
	Started smoking		Continued smoking		Quit smoking	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Cancer survivor						
Yes	0.73	(0.63 - 0.86)	0.75	(0.68 - 0.82)	1.26	(1.15 - 1.39)
No (General population)	1.00		1.00		1.00	
Physical activity						
Continuously active	1.00		1.00		1.00	
Increase	1.90	(1.53 - 2.37)	1.13	(1.00 - 1.28)	1.16	(1.01 - 1.32)
Decrease	1.72	(1.37 - 2.15)	1.26	(1.12 - 1.43)	1.20	(1.05 - 1.37)
Inactive	2.05	(1.67 - 2.52)	1.54	(1.38 - 1.73)	1.39	(1.23 - 1.57)
Sex						
Male	1.00		1.00		1.00	
Female	0.06	(0.05 - 0.08)	0.03	(0.02 - 0.03)	0.05	(0.04 - 0.06)
Age						
< 50	1.00		1.00		1.00	
50-59	0.49	(0.41 - 0.60)	0.61	(0.55 - 0.68)	0.87	(0.77 - 0.99)
60-69	0.36	(0.30 - 0.45)	0.40	(0.35 - 0.45)	0.69	(0.61 - 0.79)
≥70	0.32	(0.24 - 0.42)	0.28	(0.24 - 0.33)	0.54	(0.45 - 0.64)
Income						
Low	1.81	(1.48 - 2.21)	1.99	(1.77 - 2.25)	1.33	(1.17 - 1.51)
Middle	1.51	(1.28 - 1.77)	1.64	(1.49 - 1.81)	1.22	(1.10 - 1.35)
High	1.00		1.00		1.00	
Region						
Metropolitan	1.00		1.00		1.00	
City	1.02	(0.85 - 1.23)	1.14	(1.03 - 1.27)	1.13	(1.01 - 1.27)
Rural	1.16	(0.99 - 1.38)	1.10	(1.00 - 1.22)	1.01	(0.90 - 1.12)
Medical Insurance						
Insurance (Corporate)	1.00		1.00		1.00	
Insurance (Regional)	1.33	(1.13 - 1.56)	1.33	(1.20 - 1.47)	1.03	(0.93 - 1.15)
Medical aid	2.87	(1.23 - 6.72)	1.57	(0.80 - 3.09)	1.95	(1.05 - 3.62)
Disability						
Yes	0.85	(0.63 - 1.13)	0.91	(0.77 - 1.08)	0.97	(0.82 - 1.15)
No	1.00		1.00		1.00	

Appendix 7. Results of Multinomial logistic regressions about association between Cancer survivors and Smoking status (Continued) ^{a,b}

Variables	Smoking status					
	Started smoking		Continued smoking		Quit smoking	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Alcohol Consumption						
0 time	1.00		1.00		1.00	
1-2 times a week	1.90	(1.59 - 2.27)	2.06	(1.86 - 2.29)	1.28	(1.15 - 1.42)
≥3 times a week	3.01	(2.50 - 3.63)	3.03	(2.70 - 3.39)	1.43	(1.25 - 1.62)
BMI						
Underweight	1.50	(1.01 - 2.21)	1.62	(1.27 - 2.07)	1.18	(0.89 - 1.58)
Normal	1.00		1.00		1.00	
Overweight	0.78	(0.65 - 0.94)	0.78	(0.70 - 0.87)	1.09	(0.97 - 1.23)
Obesity	0.78	(0.66 - 0.93)	0.75	(0.68 - 0.83)	1.00	(0.89 - 1.11)
Charlson Comorbidity Index (CCI)						
0	1.00		1.00		1.00	
1	1.00	(0.79 - 1.27)	0.99	(0.85 - 1.14)	1.10	(0.94 - 1.29)
2	1.06	(0.83 - 1.36)	1.02	(0.88 - 1.18)	1.19	(1.01 - 1.40)
≥3	1.08	(0.84 - 1.38)	1.09	(0.94 - 1.26)	1.22	(1.04 - 1.44)
Diabetes before cancer						
Yes	1.37	(1.12 - 1.66)	1.16	(1.03 - 1.30)	0.98	(0.87 - 1.11)
No	1.00		1.00		1.00	
Hypertension before cancer						
Yes	0.81	(0.68 - 0.96)	0.69	(0.62 - 0.76)	0.83	(0.75 - 0.93)
No	1.00		1.00		1.00	
Year of Cohort entry						
2005	1.00		1.00		1.00	
2006	1.14	(0.86 - 1.52)	1.07	(0.90 - 1.28)	1.16	(0.94 - 1.42)
2007	1.23	(0.93 - 1.62)	1.22	(1.03 - 1.45)	1.19	(0.97 - 1.45)
2008	1.03	(0.78 - 1.37)	1.16	(0.98 - 1.38)	1.38	(1.13 - 1.68)
2009	0.79	(0.59 - 1.06)	1.12	(0.94 - 1.33)	1.48	(1.21 - 1.80)
2010	0.82	(0.61 - 1.11)	1.08	(0.90 - 1.28)	1.62	(1.33 - 1.97)

^a Reference group is Nonsmoking.

^b Adjusted for cancer survivor, physical activity status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cohort entry.

Appendix 8. Results of Multinomial logistic regressions about association between Cancer survivors and Physical activity ^{a,b}

Variables	Physical activity					
	Increase		Decrease		Inactive	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Cancer survivor						
Yes	0.94	(0.87 - 1.01)	0.90	(0.84 - 0.98)	0.85	(0.80 - 0.91)
No (General population)	1.00		1.00		1.00	
Smoking status						
Started smoking	1.91	(1.53 - 2.37)	1.73	(1.39 - 2.17)	2.08	(1.69 - 2.55)
Continued smoking	1.13	(1.00 - 1.28)	1.28	(1.13 - 1.45)	1.57	(1.40 - 1.75)
Quit smoking	1.17	(1.03 - 1.34)	1.22	(1.07 - 1.39)	1.40	(1.24 - 1.59)
Nonsmoking	1.00		1.00		1.00	
Sex						
Male	1.00		1.00		1.00	
Female	2.00	(1.83 - 2.20)	1.60	(1.46 - 1.75)	2.66	(2.45 - 2.89)
Age						
< 50	1.00		1.00		1.00	
50-59	0.80	(0.72 - 0.88)	1.18	(1.07 - 1.30)	0.97	(0.89 - 1.07)
60-69	0.93	(0.83 - 1.03)	1.35	(1.21 - 1.51)	1.36	(1.23 - 1.50)
≥70	1.33	(1.15 - 1.54)	2.17	(1.87 - 2.50)	2.90	(2.55 - 3.30)
Income						
Low	1.37	(1.23 - 1.51)	1.23	(1.11 - 1.36)	1.60	(1.46 - 1.75)
Middle	1.36	(1.25 - 1.48)	1.14	(1.05 - 1.24)	1.50	(1.39 - 1.62)
High	1.00		1.00		1.00	
Region						
Metropolitan	1.00		1.00		1.00	
City	1.00	(0.91 - 1.10)	1.02	(0.94 - 1.12)	0.94	(0.87 - 1.02)
Rural	1.40	(1.28 - 1.53)	1.25	(1.15 - 1.37)	1.82	(1.68 - 1.97)
Medical Insurance						
Insurance (Corporate)	1.00		1.00		1.00	
Insurance (Regional)	1.16	(1.06 - 1.26)	1.27	(1.17 - 1.38)	1.41	(1.30 - 1.52)
Medical aid	1.87	(0.93 - 3.78)	1.78	(0.89 - 3.59)	2.16	(1.15 - 4.09)

Appendix 8. Results of Multinomial logistic regressions about association between Cancer survivors and Physical activity (Continued) ^{a,b}

Variables	Physical activity					
	Increase		Decrease		Inactive	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Disability						
Yes	1.19	(1.01 - 1.40)	1.29	(1.11 - 1.51)	1.38	(1.20 - 1.59)
No	1.00		1.00		1.00	
Alcohol Consumption						
0 time	1.00		1.00		1.00	
1-2 times a week	0.87	(0.79 - 0.95)	0.68	(0.61 - 0.74)	0.66	(0.61 - 0.72)
≥3 times a week	1.05	(0.93 - 1.19)	0.84	(0.74 - 0.95)	0.82	(0.74 - 0.92)
BMI						
Underweight	1.38	(1.08 - 1.77)	1.48	(1.16 - 1.91)	1.69	(1.35 - 2.10)
Normal	1.00		1.00		1.00	
Overweight	0.92	(0.84 - 1.01)	0.99	(0.90 - 1.08)	0.82	(0.75 - 0.89)
Obesity	0.89	(0.82 - 0.98)	1.07	(0.98 - 1.17)	0.88	(0.81 - 0.95)
Charlson Comorbidity Index (CCI)						
0	1.00		1.00		1.00	
1	0.93	(0.83 - 1.06)	0.99	(0.87 - 1.13)	1.00	(0.89 - 1.12)
2	0.93	(0.82 - 1.06)	0.92	(0.81 - 1.05)	0.95	(0.85 - 1.07)
≥3	0.95	(0.84 - 1.08)	0.99	(0.87 - 1.13)	1.04	(0.92 - 1.17)
Diabetes before cancer						
Yes	0.81	(0.73 - 0.91)	1.08	(0.98 - 1.19)	0.83	(0.76 - 0.91)
No	1.00		1.00		1.00	
Hypertension before cancer						
Yes	0.98	(0.90 - 1.07)	1.05	(0.96 - 1.14)	1.01	(0.94 - 1.09)
No	1.00		1.00		1.00	
Year of Cohort entry						
2005	1.00		1.00		1.00	
2006	1.00	(0.85 - 1.17)	0.91	(0.78 - 1.07)	1.07	(0.93 - 1.24)
2007	1.02	(0.87 - 1.19)	0.90	(0.77 - 1.05)	1.02	(0.89 - 1.18)
2008	1.03	(0.88 - 1.20)	0.89	(0.76 - 1.03)	1.02	(0.89 - 1.17)
2009	1.09	(0.94 - 1.28)	0.88	(0.75 - 1.02)	0.98	(0.86 - 1.13)
2010	1.07	(0.91 - 1.24)	0.83	(0.71 - 0.97)	0.95	(0.82 - 1.09)

^a Reference group is Continuously active.

^b Adjusted for cancer survivor, smoking status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cohort entry.

Appendix 9. Incidence rates of All-cause Mortality in the Matched cohort

Exposure	Number of Subjects	Number of Death	Person years	Incidence rate (95% CI) per 100,000 person years	
Total	27,537	830	732572.2		
Cancer survivor					
Yes	9,179	324	242930.6	103.3	(94.6 - 112.9)
No (General population)	18,358	506	489641.5	133.4	(119.4 - 149.0)

Appendix 10. Results of association between Cancer survivors and the Mortality ^a

Variables	All-cause Mortality		Cancer-related Mortality	
	Adjusted HR	95% CI	Adjusted HR	95% CI
Cancer survivor				
Yes	1.25	(1.09 - 1.44)	1.77	(1.44 - 2.18)
No (General population)	1.00		1.00	
Smoking status				
Started smoking	1.63	(1.17 - 2.26)	1.76	(1.07 - 2.90)
Continued smoking	1.89	(1.55 - 2.32)	2.01	(1.48 - 2.72)
Quit smoking	1.51	(1.21 - 1.89)	1.77	(1.28 - 2.44)
Nonsmoking	1.00		1.00	
Physical activity				
Continuously active	1.00		1.00	
Increase	1.30	(1.01 - 1.68)	1.04	(0.73 - 1.49)
Decrease	1.52	(1.20 - 1.93)	1.26	(0.90 - 1.75)
Inactive	1.63	(1.31 - 2.03)	1.23	(0.90 - 1.67)
Sex				
Male	1.00		1.00	
Female	0.50	(0.42 - 0.60)	0.51	(0.39 - 0.67)
Age				
< 50	1.00		1.00	
50-59	2.98	(2.03 - 4.38)	3.98	(2.32 - 6.83)
60-69	7.05	(4.91 - 10.12)	8.74	(5.20 - 14.69)
≥70	16.98	(11.77 - 24.50)	15.32	(8.96 - 26.20)
Income				
Low	1.09	(0.91 - 1.31)	1.01	(0.77 - 1.34)
Middle	1.04	(0.89 - 1.22)	1.00	(0.79 - 1.27)
High	1.00		1.00	
Region				
Metropolitan	1.00		1.00	
City	1.03	(0.84 - 1.25)	0.96	(0.72 - 1.28)
Rural	1.17	(0.99 - 1.38)	1.11	(0.87 - 1.42)
Medical Insurance				
Insurance (Corporate)	1.00		1.00	
Insurance (Regional)	1.18	(1.02 - 1.36)	1.03	(0.83 - 1.28)
Medical aid	0.73	(0.27 - 1.98)	0.92	(0.22 - 3.77)

Appendix 10. Results of association between Cancer survivors and the Mortality
(Continued)^a

Variables	All-cause Mortality		Cancer-related Mortality	
	Adjusted HR	95% CI	Adjusted HR	95% CI
Disability				
Yes	1.14	(0.92 - 1.41)	0.88	(0.61 - 1.27)
No	1.00		1.00	
Alcohol Consumption				
0 time	1.00		1.00	
1-2 times a week	0.84	(0.69 - 1.03)	0.76	(0.56 - 1.03)
≥3 times a week	0.86	(0.70 - 1.06)	0.92	(0.68 - 1.25)
BMI				
Underweight	2.51	(1.97 - 3.21)	1.84	(1.17 - 2.87)
Normal	1.00		1.00	
Overweight	0.75	(0.62 - 0.90)	0.89	(0.68 - 1.18)
Obesity	0.79	(0.66 - 0.93)	1.07	(0.83 - 1.38)
Charlson Comorbidity Index (CCI)				
0	1.00		1.00	
1	1.29	(0.88 - 1.90)	1.25	(0.76 - 2.05)
2	1.54	(1.06 - 2.23)	1.18	(0.73 - 1.93)
≥3	2.15	(1.50 - 3.08)	1.53	(0.96 - 2.44)
Diabetes before cancer				
Yes	1.34	(1.15 - 1.57)	1.15	(0.90 - 1.48)
No	1.00		1.00	
Hypertension before cancer				
Yes	1.02	(0.88 - 1.19)	0.93	(0.74 - 1.16)
No	1.00		1.00	
Year of Cohort entry				
2005	1.00		1.00	
2006	1.04	(0.80 - 1.35)	1.02	(0.68 - 1.51)
2007	0.72	(0.55 - 0.94)	0.85	(0.57 - 1.26)
2008	0.61	(0.47 - 0.79)	0.67	(0.45 - 1.01)
2009	0.32	(0.24 - 0.43)	0.38	(0.24 - 0.59)
2010	0.10	(0.06 - 0.15)	0.14	(0.07 - 0.26)

^a Adjusted for cancer survivor, smoking status, physical activity status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cohort entry.

Appendix 11. Subgroup analysis of the association between Risk of Mortality and covariates, according to Cancer survivors ^a

Variables	All-cause Mortality			Cancer-related Mortality		
	Cancer survivor		General population	Cancer survivor		General population
	Adjusted HR	95% CI Lower Upper	Adjusted HR	Adjusted HR	95% CI Lower Upper	Adjusted HR
Smoking status						
Started smoking	1.83	(0.92-3.63)	1.00	1.73	(0.60-5.01)	1.00
Continued smoking	0.70	(0.48-1.04)	1.00	0.64	(0.35-1.18)	1.00
Quit smoking	1.59	(1.07-2.37)	1.00	2.32	(1.32-4.07)	1.00
Nonsmoking	1.36	(1.14-1.61)	1.00	2.19	(1.68-2.85)	1.00
Physical activity						
Continuously active	1.76	(1.20-2.59)	1.00	2.29	(1.38-3.80)	1.00
Increase	1.24	(0.87-1.77)	1.00	2.32	(1.37-3.92)	1.00
Decrease	1.42	(1.05-1.91)	1.00	2.18	(1.41-3.38)	1.00
Inactive	1.07	(0.87-1.32)	1.00	1.32	(0.95-1.82)	1.00
Sex						
Male	1.30	(1.10-1.54)	1.00	1.78	(1.39-2.29)	1.00
Female	1.17	(0.91-1.51)	1.00	1.75	(1.20-2.56)	1.00
Age						
< 50	2.08	(1.05-4.10)	1.00	4.48	(1.52-13.20)	1.00
50-59	1.64	(1.12-2.40)	1.00	2.04	(1.25-3.34)	1.00
60-69	1.26	(0.99-1.59)	1.00	1.59	(1.14-2.20)	1.00
≥70	1.10	(0.90-1.36)	1.00	1.63	(1.15-2.31)	1.00
Income						
Low	1.16	(0.85-1.59)	1.00	1.61	(1.01-2.57)	1.00
Middle	1.29	(1.01-1.64)	1.00	1.64	(1.14-2.35)	1.00
High	1.27	(1.03-1.56)	1.00	1.98	(1.45-2.70)	1.00
Region						
Metropolitan	1.22	(0.93-1.59)	1.00	1.63	(1.12-2.37)	1.00
City	1.82	(1.34-2.47)	1.00	3.30	(2.07-5.24)	1.00
Rural	1.09	(0.89-1.33)	1.00	1.45	(1.07-1.96)	1.00
Disability						
Yes	0.85	(0.55-1.30)	1.00	0.90	(0.42-1.90)	1.00
No	1.31	(1.13-1.52)	1.00	1.88	(1.51-2.33)	1.00

Appendix 11. Subgroup analysis of the association between Risk of Mortality and covariates, according to Cancer survivors (Continued) ^a

Variables	All-cause Mortality			Cancer-related Mortality		
	Cancer survivor		General population	Cancer survivor		General population
	Adjusted HR	95% CI Lower Upper	Adjusted HR	Adjusted HR	95% CI Lower Upper	Adjusted HR
Alcohol Consumption						
0 time	1.36	(1.15-1.61)	1.00	2.10	(1.63-2.70)	1.00
1-2 times a week	0.99	(0.67-1.44)	1.00	1.01	(0.57-1.79)	1.00
≥3 times a week	1.10	(0.75-1.61)	1.00	1.28	(0.75-2.20)	1.00
BMI						
Underweight	0.80	(0.49-1.31)	1.00	1.04	(0.42-2.60)	1.00
Normal	1.26	(1.01-1.57)	1.00	2.12	(1.50-3.00)	1.00
Overweight	1.41	(1.04-1.91)	1.00	1.85	(1.20-2.85)	1.00
Obesity	1.33	(1.02-1.73)	1.00	1.59	(1.11-2.29)	1.00
Charlson Comorbidity Index (CCI)						
0	1.49	(0.74-3.03)	1.00	2.35	(0.95-5.85)	1.00
1	1.60	(1.10-2.31)	1.00	2.52	(1.55-4.11)	1.00
2	1.08	(0.79-1.47)	1.00	1.92	(1.23-3.00)	1.00
≥3	1.23	(1.03-1.47)	1.00	1.47	(1.10-1.95)	1.00
Diabetes before cancer						
Yes	1.12	(0.87-1.45)	1.00	1.39	(0.93-2.07)	1.00
No	1.33	(1.12-1.57)	1.00	1.94	(1.51-2.47)	1.00
Hypertension before cancer						
Yes	1.13	(0.93-1.37)	1.00	1.51	(1.13-2.03)	1.00
No	1.43	(1.16-1.77)	1.00	2.09	(1.55-2.81)	1.00

^a Adjusted for smoking status, physical activity status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cohort entry.

Appendix 12. Results of association between Cancer survivors stratified with Health Behaviors and the Mortality compared with General population ^{a,b}

Variables	All-cause Mortality		Cancer-related Mortality	
	Adjusted HR	95% CI	Adjusted HR	95% CI
Smoking status ^a				
Started smoking	1.98	(1.22 - 3.23)	2.51	(1.23 - 5.11)
Continued smoking	1.16	(0.81 - 1.66)	1.22	(0.69 - 2.15)
Quit smoking	1.75	(1.31 - 2.34)	2.69	(1.83 - 3.96)
Nonsmoking	1.13	(0.97 - 1.33)	1.64	(1.30 - 2.07)
General population	1.00		1.00	
Physical activity ^b				
Continuously active	1.08	(0.80 - 1.44)	1.77	(1.23 - 2.56)
Increase	1.13	(0.86 - 1.50)	1.79	(1.23 - 2.61)
Decrease	1.45	(1.14 - 1.84)	2.12	(1.52 - 2.95)
Inactive	1.27	(1.05 - 1.54)	1.57	(1.17 - 2.10)
General population	1.00		1.00	

^a Adjusted for physical activity status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cohort entry.

^b Adjusted for smoking status, sex, age, income, region, medical insurance, disability, alcohol consumption, BMI, Charlson Comorbidity Index, diabetes before cancer, hypertension before cancer, and the year of cohort entry.

국문요약

암 생존자들의 건강 행동 변화와 사망에 대한 연구

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서론: 암 조기진단과 치료 기술 향상으로 인해 암 환자들의 생존율은 높아지고 있다. 암 생존자들이 증가함에 따라, 그들의 건강 행동을 잘 관리하여 사망률을 낮추는 것의 중요성은 강조되고 있다. 따라서 이 연구는 암 생존자들의 건강 행동과 관련 있는 요인들을 파악하고, 이러한 암 생존자들의 건강 행동 변화가 사망에 미치는 영향을 분석하여 이를 노모그램으로 만들고자 한다. 이를 통해 암 생존자들의 건강 행동을 사전에 관리하여 사망 위험을 낮추고 개발된 노모그램을 이용하여 이와 관련된 정책 수립의 근거를 제공할 수 있다.

연구방법: 이 연구는 2002 년 ~ 2015 년 국민건강보험공단 표본 코호트 자료를 이용하여, 총 9,300 명의 암 생존자를 대상으로 하였다. 암 진단 후 5 년 이상 생존하였을 때 암 생존자라고 정의하였다. 첫째, 이 연구에서는 암 생존자들의 건강 행동 변화와 관련 있는 요인에 대한 분석을 실시했다. 건강 행동 (흡연, 신체활동)은 암 진단 전과 진단부터 5 년 생존까지의 변화를 측정하였다. 분석에는 다항 로지스틱 회귀분석(Multinomial logistic regression)을 사용하였다. 둘째, 암 생존자들의 건강 행동 변화에 따른 사망 위험을 분석하였으며, 이때 사망 위험은 모든 원인으로 인한 사망과 암으로 인한 사망으로 구분하였다. 분석에는 콕스 비례위험 회귀분석(Cox proportional hazard regression)을 사용하였다. 노모그램은 3:1 의 비율로 Training data 와

Testing data 를 나누었으며, Training data 를 이용해 노모그램을 구축하고, Testing data 를 이용해서 타당도 검증을 시행하였다. 노모그램 타당성 검증에는 Discrimination (Harrell' s C-Index)과 Calibration (Hosmer-Lemeshow test)을 사용하였다.

연구결과: 총 9,300 명의 암 생존자 중, 235 명 (2.5%)이 흡연을 시작하고, 880 명 (9.5%)이 계속해서 흡연을 했으며, 964 명 (10.4%)이 진단 후 금연을 하였다. 아울러, 2,197 명 (23.6%)은 꾸준히 신체활동을 하였으며, 1,915 명 (20.6%)은 신체활동을 시작하고, 1,857 명 (20.0%)은 신체활동을 그만두었다. 건강 행동을 하지 않는 사람이 다른 건강 행동도 하지 않을 오즈가 높았다. 뿐만 아니라, 비흡연자에 비해 흡연을 시작하거나 그만둔 경우 사망 위험이 더 높았다 (흡연 시작: HR=1.98, 95% CI=1.25-3.15, 금연: HR=1.44, 95% CI=1.05-1.97). 신체 활동을 꾸준히 하는 군에 비해, 신체 활동을 하지 않는 군이 사망할 위험이 더 높았다 (HR=1.45, 95% CI=1.05-2.02). 노모그램에서의 Training data 와 Testing data 에서 측정된 노모그램의 판별력(Discrimination ability)은 각각 0.79 와 0.81 이었으며, Hosmer-Lemeshow test 결과 P-value 가 0.05 이상으로 노모그램이 적합하다는 것을 알 수 있다.

결론: 이 연구를 통해 암 생존자들의 건강 행동 변화와 관련 있는 요인들을 파악하였으며, 건강하지 않은 행동을 하는 암 생존자의 사망 위험이 건강한 행동을 하는 군에 비해 높음을 알 수 있다. 암 생존자들의 사망 위험을 줄이기 위해서는 그들의 건강 행동에 대한 적절한 관리가 필요함을 알 수 있으며, 그에 따른 정책적 대안을 수립해야 한다. 개발된 노모그램은 암 생존자에 대한 정책 및 가이드라인에 근거를 제공하고 그 중요성을 강조할 수 있다.