Ph.D. Dissertation of Sports Science

ASSOCIATIONS BETWEEN PHYSICAL ACTIVITY AND MENTAL HEALTH IN KOREAN MILITARY PERSONNEL

한국 군인의 신체활동과 정신건강 간의 관련성

February 2023

Graduate School of Physical Education

Seoul National University

Sports Science

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Sports Science

February 2023

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ABSTRACT

Objectives: To examine the association between physical activity (PA) and mental health in Korean military personnel, this study (1) conducted a systematic review to investigate the comprehensive evidence between PA and mental health in military personnel; (2) examined the dose-response association between PA and the mental health of Korean military personnel; (3) analyzed the joint association between aerobic PA, muscle-strengthening activity (MSA), and mental health in Korean military personnel.

Methods: In the first study, for the systematic review, six electronic databases (PubMed, EMBASE, CINAHL, PsycINFO, SPORTDiscus, and Web of Science) were searched from all publication years till March 7, 2022. Search terms were selected by combining PA, mental health, and military personnel. Subsequently, studies were selected through the process of title and abstract and full-text screening.

In the second study, data from the 2014-2015 Military Health Survey were used to examine the dose-response relationship between PA and mental health in Korean military personnel. This study included 14,001 Korean military personnel. Multiple imputations were conducted on missing PA variables and covariates. A multiple logistic regression analysis was performed to analyze the association between the amount of PA and psychological distress, and suicidal ideation. A restricted cubic spline model was derived to evaluate the nonlinear relationship. In addition, military unit (Army, Navy/Marine corps, or Air force) and rank-stratified (enlisted or officer) analyses were conducted to examine the difference in relevance.

The third study also used data from the 2014-2015 Military Health Survey and had the same participants. Missing PA variables and covariates were imputed using 20 sets of multiple imputations. A multiple logistic regression analysis was performed to analyze the independent association between the amount of aerobic PA, frequency of MSA, psychological distress, and suicidal ideation. Finally, joint analyses were conducted to examine the combined association between the four variables.

Results: The systematic review included ten studies. Of these, seven were observational studies (six cross-sectional and one cohort) and three were interventional studies (two randomized control trials (RCTs) and one non-RCT). In total, nine mental health outcomes, which included depression, anxiety disorders, post-traumatic stress disorder (PTSD), mental health-related quality of life,

psychological distress, and suicidal ideation, were investigated. Anxiety disorders and PTSD were investigated in 4 and 3 studies, respectively. The others were investigated in less than two studies. The literature review confirmed that PA reduced soldiers' anxiety disorders and prevented PTSD, a new finding. However, due to evidence from cross-sectional studies, an insufficient number of studies, the heterogeneity of the mental health and PA variables, and a high risk of bias, there were limitations in dealing with a comprehensive discussion on the association with PA.

Second, of the 14,001 Korean military personnel, 6.66% had psychological distress, and 3.09% experienced suicidal ideation. After adjusting for all the potential confounders, there was a significant dose-response association between the amount of PA and psychological distress, up to approximately 1,600 MET-min/wk. However, there was no significant association with suicidal ideation. These associations were similar between military ranks; however, differed by military units.

Third, after adjusting for all the potential confounding variables, the amount of aerobic PA and frequency of MSA were significantly related to psychological distress; however, not to suicidal ideation. Based on the joint analysis of aerobic PA and MSA frequency, the odds ratio of psychological distress was low in the group with a high MSA frequency, regardless of the amount of aerobic PA. In addition, compared to the group with the lowest MSA frequency and amount of aerobic PA, there was no significant association between the amount of aerobic PA and suicidal ideation at the MSA frequency of two days or less. However, in the MSA frequency of three days or more, 2,000-6,000 MET-min/wk of aerobic PA was associated with a lower prevalence.

Conclusion: There was a significant association between the amount of PA and the mental health of Korean military personnel, especially with psychological distress. In addition, MSA could be a significant moderator. However, evidence on PA and the mental health of military personnel is still insufficient. In addition, this was a cross-sectional study. Hence, additional longitudinal and RCT studies are required to confirm the clear relationship between PA and mental health among military personnel.

Keywords : physical activity, exercise, mental disorders, depression, anxiety, suicide, soldiers

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CHAPTER 1. INTRODUCTION

1.1. Study Background

The global prevalence of depression in military personnel is 23%, which is higher than in the general population. In addition, military personnel also showed a high prevalence of anxiety and panic disorders, post-traumatic stress disorder (PTSD), and suicidal ideation than the general population (Kessler et al., 2014; Rusu, Zamorski, Boulos, & Garber, 2016). Furthermore, the prevalence of suicidal ideation and attempts among military personnel was 11% and 11%, respectively (Moradi, Dowran, & Sepandi, 2021). The suicide rate in the U.S. military has been increasing continuously, and suicide is also the most common cause of death in the Korean military (Department of Defense, 2021; Ministry of National Defense, 2020). Therefore, the high risk of mental disorders poses a significant threat to individuals and the military. Hence, efforts are required to improve it.

Physical activity (PA) may play an essential role in the management of mental health. The World Health Organization (WHO) reported that 150-300 min/wk of moderate-to-vigorous PA was significantly associated with lower depression and anxiety symptoms and a higher quality of life (World Health Organization, 2020). Consistent with this finding, recent meta-analysis studies reported a significant association between PA and depression (Pearce et al., 2022; Schuch et al., 2018), anxiety (Schuch et al., 2019), suicidal ideation (Vancampfort et al., 2018).

PA may also be a critical factor in mental health management among military personnel. However, there is insufficient evidence on the association between PA and

mental health among military personnel. Some studies reported significant associations between PA and mental disorders among military personnel (Hruby, Lieberman, & Smith, 2021; LeardMann et al., 2011; Martins & Lopes, 2013; Perez, Dong, Beckman, & Meadows, 2022; Stoller, Greuel, Cimini, Fowler, & Koomar, 2012). However, no studies have attempted to synthesize the overall evidence. To our best knowledge, although some studies conducted systematic reviews on PA and depression and PTSD among military veterans, no study included active-duty military personnel (Caddick & Smith, 2014; Walker, Smith, Limbert, & Colclough, 2020).

In addition, most studies were conducted in Western countries. However, the characteristics of the military's mission and culture and the prevalence of each mental disorder differs from country to country (Moradi et al., 2021). Thus, the association between PA and mental health in Korean military personnel may show different results from previous studies. However, no study has been conducted on this association.

Therefore, this study aimed to identify the overall evidence between PA and the mental health of military personnel through a systematic review and examine the association between PA and mental health among Korean military personnel.

1.2. Objectives

1) To identify comprehensive evidence from studies that examined the association between PA and mental health in active-duty military personnel.

2) To examine the dose-response association between the amount of PA and psychological distress in Korean military personnel and identify the differences in the association based on military-related factors.

3) To examine the independent and joint association between aerobic PA, muscle-strengthening activity (MSA), psychological distress and suicidal ideation in Korean military personnel.

1.3. Definitions

Physical activity

PA comprehensively refers to all body movements of skeletal muscles that require higher energy consumption. Exercise means planned, structured, and repetitive PA to improve physical strength and health (Caspersen, 1989).

Mental health

Mental health was defined as the absence of a mental disorder or the presence of biological, psychological, or social factors that contributed to an individual's mental state and social competence (Manwell et al., 2015).

Military personnel

In this study, military personnel were defined as active-duty service members, which consisted of soldiers enlisted through conscription or volunteering and active soldiers that included commissioned, non-commissioned, and warrant officers, and military office candidates based on the Military Service Act (Military Manpower Administration, 2022).

CHAPTER 2. LITERATURE REVIEW

2.1. Mental health among military personnel

Military personnel undergo intense training and various missions for the safety of their country and its citizens. Due to occupational characteristics, they are frequently exposed to high stress. Experiences of threatened death, serious injuries, or witnessing death cause unbearable stress. This stress can cause various mental disorders, such as post-traumatic stress disorder (PTSD), depression, anxiety disorders, and panic disorder (Gadermann et al., 2012; Sareen et al., 2007; Xue et al., 2015), in military personnel.

In addition, the work environment, such as strict hierarchical structure, stress regarding promotion, collectivism, frequent job transfer, and separation from family, is also a cause of high stress (Adler & Castro, 2013; Park, Kim, & Ko, 2013). In particular, in Korea, healthy adult males are obliged to serve in the military based on the Military Service Act. For those serving in the military as a duty rather than a choice, group life under strict discipline and control and the arduous training process can cause high stress (Koo, 2005, 2013).

Therefore, the global prevalence of mental disorders among military personnel is higher than that in the general population. The WHO reported that approximately 23% of military personnel had depression, which was higher than the prevalence in the general population (15-20%) (Moradi et al., 2021). In a study that compared the prevalence of mental disorders between U.S. service members and the general population, U.S. service members had a significantly higher prevalence of

depression, anxiety and panic disorders, and PTSD than the general population (Kessler et al., 2014). Canadian military personnel also reported a higher prevalence of mental disorders than the general population (Rusu et al., 2016), which indicated that military personnel had mental difficulties compared to the general population.

In Korea, a survey with 1,937 Korean military personnel in 2016 reported that approximately 8.4% were depressed (Shim et al., 2020). In addition, a survey with 441 Korean military personnel in 2018 showed a prevalence of 7.1% and 3.5% for depression and anxiety disorder, respectively (Yeom et al., 2020). This was a high prevalence compared to the 2021 Korean Mental Health Survey results, in which the average 1-year prevalence of depression and anxiety disorder in Koreans was 1.7%, and 3.1%, respectively (National Center for Mental Health, 2021). According to the 2020 Korean National Defense Statistical Yearbook, a high proportion of counseling during military service life was for mental problems, such as maladjustment to military service, mental illness, and suicidal impulses (Ministry of National Defense, 2020). Furthermore, the prevalence of stress among military personnel was high at 31.6% (Woo et al., 2021). Hence, mental disorders were frequent even among Korean military personnel.

The high suicide rate is an important indicator of military personnel' low mental health. Approximately 11% of worldwide military personnel reported suicidal ideation and attempts (Moradi et al., 2021). In the U.S. military, compared to 18.7 suicides per 100,000 military personnel in 2011, the rate increased to 28.6 suicides in 2020. Furthermore, it has been increasing continuously (Department of Defense, 2021).

The suicide rate among Korean military personnel is lower than that of the

general population. However, although it has shown a gradual decrease, it ranks highest among the causes of death in the military and its proportion is gradually increasing (Ministry of National Defense, 2022). In addition, the suicide rate per 100,000 enlisted soldiers in Korea showed a gradual decrease from 11.1 in 2012 to 6.4 per 100,000 people in 2016. In contrast, the suicide rate of officers decreased from 17.0 in 2012 to 14.7 per 100,000 people in 2016; however, there was no linear trend. Furthermore, the suicide rate among officers was twice as high as that of among enlisted soldiers (Korea Institute for Defense Analyses, 2021).

The above-mentioned data shows that suicide is still a major mental disorder in the Korean military. In a recent survey with 3,162 Korean military officers, 10.5%, 3.2%, and 0.2% reported that they had suicidal thoughts in the past month, seriously contemplated suicide, and attempted suicide, respectively (Choi, Byeon, Yim, Jo, & Park, 2021).

Mental disorders in military personnel can cause various problems. Military personnel with high levels of stress had a higher prevalence of mental disorders and lower job productivity than those with low levels of stress (Hourani, Williams, & Kress, 2006). Mental disorder was also associated with a higher risk of suicide (Ursano et al., 2018). In a study on Korean military personnel, mental disorders caused maladaptation in military life and were associated with a risk of suicide (An, Bae, Cho, & Kim, 2016; An, Kwon, & Kim, 2010).

2.2. PA and mental health

Many studies have identified PA as an effective way of improving mental health. Regular PA has positive effects on mental health, such as reducing the risk of depression and symptoms of depression and anxiety and improving sleep quality and quality of life (Physical Activity Guidelines Advisory Committee, 2018).

The WHO PA guidelines recommend participation in at least 150 minutes of moderate-intensity aerobic PA or 75 minutes of vigorous aerobic PA per week for health benefits (World Health Organization, 2020). According to several meta-analysis studies, when these recommended levels were met, the risk of depression and anxiety disorders were reduced by approximately 22% (Schuch et al., 2018) and 29% (Schuch et al., 2019), respectively. In addition, suicidal thought was reduced by approximately 9% (Vancampfort et al., 2018). Some studies also reported a dose-response association between PA and mental health (Bernard et al., 2018; Hamer, Stamatakis, & Steptoe, 2009).

However, PA of less than 150 minutes per week was also significantly associated with a lower risk of depression (Mammen & Faulkner, 2013). In addition, acute PA of less than 10 minutes was also effective in reducing this risk (Lucas et al., 2011). Acute PA of approximately 10 minutes reduced stress and depressive symptoms and improved self-esteem in adults (Barr-Anderson, AuYoung, Whitt-Glover, Glenn, & Yancey, 2011). Thus, evidence suggests that acute PA of less than 10 minutes also has a positive effect on mental health.

Regarding aerobic PA recommendations, the WHO PA guidelines recommended MSA on two or more days per week (World Health Organization, 2020). The type of PA, aerobic PA or MSA, more effective in improving mental

health is unclear. Previous studies examined the effect of aerobic PA and MSA on improving depression and found no difference between the two (Gordon et al., 2018; Schuch et al., 2016). However, when both PA recommendation criteria were met, the prevalence of depression was lower than when only one criterion was met (Bennie, Teychenne, De Cocker, & Biddle, 2019).

PA has a positive effect on mental health through various biological and psychosocial pathways. Regular PA improves tolerance for acute stress and also lowers the stress response. In addition, it may also improve sensitivity to other stresses, such as illness or psychological stress (Silverman & Deuster, 2014; Tsatsoulis & Fountoulakis, 2006).

PA stimulates the release of neurotrophic factors, such as brain-derived neurotrophic factor, and causes structural changes in the hippocampus, cortex, and white matter areas (Gujral, Aizenstein, Reynolds III, Butters, & Erickson, 2017). In addition, it also has a positive effect on depressive symptoms by stimulating neuroplasticity-related pathways (Kandola, Ashdown-Franks, Hendrikse, Sabiston, & Stubbs, 2019), such as increasing the circulation of the vascular endothelial growth factor (Morland et al., 2017).

Regular PA affects mental health through biological factors and psychosocial benefits. Although low self-esteem exacerbates depressive symptoms, regular PA improves depressive symptoms by increasing the self-esteem of patients with depression (Sonstroem & Morgan, 1989). In addition, PA also has a positive effect by strengthening social support from opportunities for interactions and increasing self-efficacy (Hallgren, Lundin, Tee, Burström, & Forsell, 2017; Rodgers, Markland, Selzler, Murray, & Wilson, 2014).

2.3. PA level of military personnel

Military personnel are required to maintain physical readiness to execute their national defense duties at any time. Therefore, continuous efforts are made to maintain physical fitness through repetitive training. Hence, military personnel engage in higher amounts of PA than the general population.

According to the 2015 U.S. Department of Defense Health-related Behaviors Survey, 64.1% and 25% of U.S. military personnel participated in at least 150 and more than 300 minutes of moderate PA per week, respectively. In addition, 50% and 41.3% participated in vigorous PA for at least 75 and 150 or more minutes per week, respectively. These results showed that at least 50% of military personnel met the recommended amount of PA, which was higher than in the general population as approximately only 20% of Americans met the PA recommendations (Meadows et al., 2018). In addition, approximately 46.5% of U.S. military personnel participated in MSA three or more times per week, which was a high percentage. Meanwhile, only 35.7% of the American population participated in MSA twice a week (Centers for Disease Control and Prevention, 2019).

Most studies on PA on military personnel were conducted in the United States. However, some studies were also conducted in other countries. Brazilian military police officers participated in 123 minutes of moderate-vigorous PA, and 52.7% met the PA recommendation (Ferraz et al., 2020). Among Belgian military personnel, approximately 80% of military personnel met the PA recommendations, and 57% participated in higher levels of PA (Mullie & Clarys, 2015).

In Korea, several studies reported a higher level of PA in military personnel compared to the Korean general population. A survey of 196 Korean female military

personnel found that approximately 80% met the PA recommendation, and the average amount of PA was 2,900 MET-min per week (Kwon, Park, Kim, & Lee, 2021). Moreover, approximately 61% of male and female Navy personnel met the PA recommendation and participated in an average of 2,848 MET-min per week of PA (Roh, Lee, Lee, & Kim, 2012).

However, some studies reported the PA level of Korean military personnel was similar to or less than that of the Korean general population. In an analysis of 763 male officers, only 38.1% participated in moderate or vigorous PA for at least 30 minutes for 5 days or 20 minutes for 3 days per week, respectively (Kim & Lee, 2009). A study investigated the amount of PA in 20 Korean Air force pilots, who wore a pedometer for a week, and found that their daily average number of steps was approximately 6,900 steps, which was slightly higher than that of sedentary people (Lim, 2013).

These results indicated that military personnel participated in a higher level of PA on average than the general population. However, the amount of PA varied according to factors, such as military unit and rank and age (Meadows et al., 2018; Sung, Park, & Jung, 2018).

2.4. PA and mental health in military personnel

Studies on the relationship between PA and the mental health of military personnel have been conducted mainly on veterans. Results reported that PA significantly affected the improvement of veterans' mental health (Caddick & Smith, 2014, 2018; Walker et al., 2020). Studies have also been conducted on active-duty military personnel, and some reported significant associations.

There was an inverse correlation between participation in exercise and sports activities and depression and stress in U.S. military personnel (Morgan, Hourani, & Tueller, 2017). In addition, in a study that analyzed the association between PA and PTSD in 39,883 U.S. military personnel, PA was associated with a lower prevalence of PTSD symptoms, especially vigorous PA (LeardMann et al., 2011). Military personnel who participated in at least 20 minutes of vigorous PA twice a week or more had a lower prevalence of PTSD than inactive military personnel. However, the frequency of MSA was not associated with the prevalence of PTSD.

In a survey conducted with 13,000 U.S. military personnel, high amounts of vigorous and moderate PA were associated with a lower prevalence of anxiety disorders and PTSD, respectively. Conversely, the prevalence of depression, anxiety, and PTSD was associated with a lower amount of PA (Hruby et al., 2021).

In addition, U.S. Army service members who participated in high-intensity interval training were mentally healthier than those who did not participate (Kegel, Kazman, Scott, & Deuster, 2020). Furthermore, Hatha yoga lowered state and trait anxiety and improved the quality of life among U.S. military personnel (Stoller et al., 2012).

A study identified the association between PA, job stress, and psychological

distress in 500 Brazilian Army service members and reported different associations according to the domain of PA. The total amount of PA was not associated with job stress and psychological distress. However, occupational PA was significantly related to high job stress and psychological distress. In addition, leisure time PA was significantly associated with low job stress and psychological distress (Martins & Lopes, 2013).

CHAPTER 3. STUDY 1
A systematic review of the relationship between PA and mental health in active-duty military personnel

3.1. Introduction

Mental disorders are one of the leading causes of global burden of disease (GBD Mental Disorders Collaborators, 2022), and account for approximately 11% of the total global burden. Mental disorders, such as depression and anxiety, make it difficult to perform daily life and cause various disease and deaths (Whiteford et al., 2013). Therefore, it is essential to understand the importance of mental health and make an active effort to promote it.

Many studies reported a significant association between PA and mental health, such as stress reduction, prevention of depression and anxiety, self-esteem improvement, prevention of suicide, and improvement of quality of life (Gill et al., 2013; Gujral, Aizenstein, Reynolds III, Butters, & Erickson, 2017; Hamer, Endrighi, & Poole, 2012; Hamer, Stamatakis, & Steptoe, 2009; Kandola, Ashdown-Franks, Hendrikse, Sabiston, & Stubbs, 2019; Sonstroem & Morgan, 1989). Furthermore, meta-analysis studies have also reported a comprehensive relationship (Mammen & Faulkner, 2013; Rodriguez-Ayllon et al., 2019; Vancampfort et al., 2018; Wang & Boros, 2021).

Mental health is important for the general population and also active-military personnel. In particular, for military personnel frequently exposed to high stress situations, mental health management is crucial. Mental disorders in military

personnel makes it difficult for them to adapt to military life, attenuates duty performance, and increases the risk of suicide (An et al., 2016; An, Kwon, & Kim, 2010; Hourani, Williams, & Kress, 2006). The mental health management of military personnel could be an important factor in strengthening national defense capabilities.

Previous studies reported that high PA in the active-military personnel was associated with a low prevalence of mental disorders. However, till date, no studies have attempted to identify a comprehensive relationship. Although, some studies reported that regular PA had a positive association with mental health of veterans through a systematic review (Caddick & Smith, 2014; Walker, Smith, Limbert, & Colclough, 2020), to our best knowledge, no studies examined active-duty military personnel.

Therefore, this study intended to draw a comprehensive conclusion on the relationship between PA and mental health in active-duty military personnel via a systematic review.

3.2. Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Appendix 1) (Page et al., 2021).

Search strategy

In total, six electronic databases (PubMed, EMBASE, CINAHL, PsycINFO, SPORTDiscus, and Web of Science) were searched from all publication years till March 7, 2022. Key terms were selected by combining three major topics: “physical activity,” “mental health,” and “military personnel” and searched in the title and

abstract fields. All search terms used in each database are shown in Appendix 2.

Eligibility criteria

Inclusion criteria were studies that (1) were from any geographical location or setting, (2) included active-duty military personnel, (3) directly examined an association between PA and any health outcome, (4) had designs included primary research studies (cross-sectional or longitudinal designs, interventions or natural experiments with pre-post measures and an inactive comparison), and (5) were published in a peer reviewed journal in the English language.

Exclusion criteria were (1) studied with the full-text unavailable; (2) gray literature that included unpublished and ongoing trials, annual reports, dissertations, and conference proceedings, (3) editorials, opinion pieces, magazine and newspaper articles, case reports, and papers with no primary data, and (4) studies that used multiple health-related behaviors (dietary, sleep, education) as main exposures or interventions.

Selection process

The retrieved titles and abstract were screened by two independent reviewers (G. Kim & H. Sung) after removing duplicates. The same reviewers (G. Kim & H. Sung) screened the full texts of the articles included through title and abstract screening. A third reviewer (Y. Kim) resolved any disagreements. The selection process was conducted using the Covidence software (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia, available at www.covidence.org) a web-based systematic review platform. Inter-rater agreement

was calculated using Cohen's kappa coefficient (κ).

Data extraction

Data from the included studies were extracted and coded by two reviewers (G. Kim & H. Sung) using the Covidence software. For each study, general information (authors, publication year, title, and study location), sample characteristics (sample size, age, and sex), study design, mental health indicators and instruments, PA intervention characteristics for an experimental study (frequency, intensity, time, and type), PA parameters and instruments for an observational study, and the main findings were collected.

Risk of bias assessment

Risk of bias for the included studies was assessed by two reviewers (G. Kim & H. Sung). Based on the study design, different tools were used. First, the revised Cochrane risk of bias tool (RoB 2) was used to assess the risk of bias of randomized controlled trials (Sterne et al., 2019). This tool was structured into five domains: (1) bias that arose from the randomization process; (2) bias due to deviations from intended interventions; (3) bias due to missing outcome data; (4) bias in the measurement of the outcome; and (5) bias in the selection of the reported result. Each domain consisted of three to five questions and risk of bias for each domain was evaluated based on the responses. The overall risk of bias for each study was evaluated as "low risk of bias," "some concerns," or "a high risk of bias" based on the risk assessment results for each domain.

Second, the ROBINS-I tool was used to assess non-randomized experimental

studies (Sterne et al., 2016). The ROBINS-I was structured into seven domains: (1) bias due to confounding; (2) bias in the selection of the participants; (3) bias in the classification of interventions; (4) bias due to deviations from intended interventions; (5) bias due to missing data; (6) bias in the measurement of the outcomes; and (7) bias in the selection of the reported result. Each domain consisted of three to eight questions. Based on the responses, the overall risk of bias of each study was assessed as “low risk of bias,” “moderate risk of bias,” “serious risk of bias,” “critical risk of bias,” and “no information.”

Third, the Newcastle-Ottawa Scale was used to assess the risk of bias of observational studies (Wells et al., 2000). It has been frequently used to assess the risk of bias in systematic review for non-randomized studies (Farrah, Young, Tunis, & Zhao, 2019). This scale consisted of seven items in three domains (selection, comparability, and exposure). For each item, if the quality was high, it was evaluated and marked with a “star.” In total, one or two stars were given to each item and ranged from 0 to 8 total stars (for cross-sectional study) or 0 to 9 (for cohort study). We assigned scores of 0–3, 4–6 and 7–9 for the low, moderate, and high risk of bias, respectively (Schuch et al., 2018). We used the modified version of the Newcastle-Ottawa Scale for cross-sectional studies used by Moskalewicz et al. (2020) and Wells et al. (2000) for longitudinal studies (Wells et al., 2000). These scales were modified with language specific to our study (Moskalewicz & Oremus, 2020) (Appendix 3-4).

3.3. Results

Study selection

A PRISMA flow chart of the study selection process is shown in Figure 1. In total, 20,636 studies were identified from six electronic databases after duplicates were removed. Of the 10,543 studies, 10,390 studies were excluded after the title and abstract screening. The inter-rater agreement for the title and abstract screening was κ=0.60. After the full-text of 153 studies was screening, 143 were excluded for following reasons: (1) no full-text (n=13); (2) wrong population (n=21); (3) wrong study design (n=38); wrong intervention (n=25); wrong exposure (n=25); wrong outcome (n=12); not written in English (n=9). The inter-rater agreement for the full-text screening was κ=0.87. Finally, ten studies were included in this systematic review.

Study characteristics

The characteristics of all the included studies are shown in Table 1. Most were observational studies, with six cross-sectional studies (Barreto, Carvalho, & Lins-Kusterer, 2021; do Nascimento et al., 2020; Hruby, Lieberman, & Smith, 2021; Magerøy, Riise, Johnsen, & Moen, 2007; Oakey-Frost et al., 2022; Perez, Dong, Beckman, & Meadows, 2022) and one longitudinal study (LeardMann et al., 2011). In addition, three were experimental studies, two RCTs (Stoller, Greuel, Cimini, Fowler, & Koomar, 2012; Telles, Bhardwaj, Kumar, Kumar, & Balkrishna, 2012) and one non-RCT (Pavett, Butler, Marcinik, & Hodgdon, 1987).

Of the seven observational studies, five used PA volume as the main exposure (do Nascimento et al., 2020; Hruby et al., 2021; LeardMann et al., 2011; Magerøy et

al., 2007; Perez et al., 2022), two used frequency of PA (Barreto et al., 2021; Oakey-Frost et al., 2022). Of the three experimental studies, the two RCTs used a yoga program as the intervention (Stoller et al., 2012; Telles et al., 2012) and the non-RCT study used circuit weight training (Pavett et al., 1987).

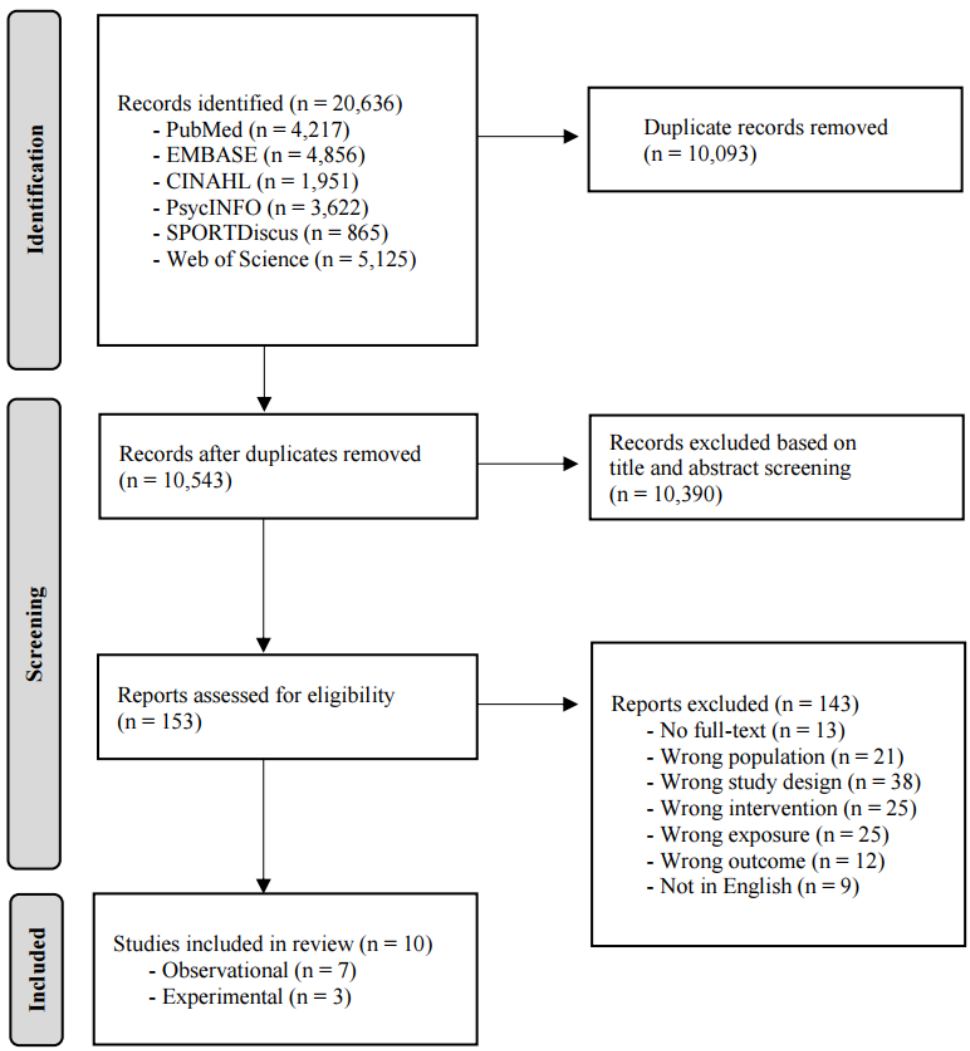

Figure 1. PRISMA flow chart of study selection

Table 1. Characteristics of included studies (n=10)

Author (year)	Study design	Country / Participants	Sample size	Sex (% female)	Age		PA exposure/intervention	Mental health indicators	Major findings
					Mean	Range			
Barreto et al. (2021)	Cross-sectional	Brazil / Military police officer	329	Only males		24-54	· Vigorous PA frequency	· Mental health-related quality of life	· The mental component summary was not associated with vigorous PA (P=0.639).
Hruby et al. (2021)	Cross-sectional	United States / US military personnel	12,708	Both (14.7%)		≥ 17	· Moderate PA volume · Vigorous PA volume · Strength training frequency	· GAD · Depression · PTSD	· Higher levels of vigorous PA were associated with lower odds of GAD · Higher levels of moderate PA were associated with lower odds of PTSD
LeardMann et al. (2011)	Longitudinal	United States / US military personnel	38,883	Both (22.3%)		≥ 17	· Light/Moderate PA volume · Vigorous PA volume · Strength training volume	· PTSD	· Engagement in PA, especially vigorous PA is associated with decreased odds of PTSD
Magerøy et al. (2007)	Cross-sectional	Norway / Navy officers	1,316	Only males	38.0	25-62	· Total PA volume	· Mental health-related quality of life	· PA volume was positively associated with mental health-related quality of life scores
Oakey-Frost et al. (2021)	Cross-sectional	United States / Army	1,019	Both (17.8%)		18-29	· Vigorous PA frequency · Strength training frequency	· GAD · Depression · Suicidal ideation	· The frequency of vigorous PA and strength training were not correlated with GAD, depression and, suicidal ideation
Pavett et al. (1987)	Non-RCT	United States / Navy and Marine corps	245	Only males	23.5		· 12-weeks of circuit weight training on alternate days, 60 % 1RM of intensity	· Job stress · Self-esteem	· Circuit weight training reduced job stress (P=0.000), but not self-esteem (P=0.080)
Perez et al. (2022)	Cross-sectional	United States / US military personnel	17,166	Both (31.2%)		≥ 18	· PA guideline adherence · Screen time (2 hours/day)	· PTSD · Suicidal ideation · Psychological distress	· Meeting PA recommendation was associated with lower odds of serious psychological distress only in males (OR: 0.76, 95% CI: 0.58-1.00) · Low screen time was associated with lower odds of suicide ideation only in females (OR: 0.66, 95% CI: 0.45-0.95)
do Nascimento et al. (2020)	Cross-sectional	Brazil / Military police officer	254	Both (16.5%)		21-55	· PA level (active vs inactive)	· Deep sadness · Anxiety · Burnout syndrome	· The inactive group had higher odds of burnout syndrome (OR: 2.49, 95% CI: 1.42-4.43), and deep sadness (OR: 1.85, 95% CI: 1.03-3.33) compared to the active group
Stoller et al. (2012)	RCT	United States / Army and Air force	70	Both (31.4%)	31.8		· 3-weeks of Hatha yoga, 7 times/wk, 75min/session	· Trait anxiety · State anxiety	· Hatha yoga was effective in reducing state and trait anxiety (P<0.0001)
Telles et al. (2012)	RCT	India / Army	140	Only males	30.3	20-48	· 45-min of a single yoga session	· State anxiety	· State anxiety decreased after a single yoga session (P<0.0001), no decrease in the control group (breath awareness group)

PA, physical activity; GAD, general anxiety disorder; PTSD, post-traumatic stress disorder; RM; repetition maximum; OR, odds ratio; CI, confidence interval; RCT, randomized controlled trial.

In total, three studies considered PTSD as mental health outcome (Hruby et al., 2021; LeardMann et al., 2011; Perez et al., 2022), two considered depression (Hruby et al., 2021; Oakey-Frost et al., 2022), four considered anxiety: general anxiety disorder (GAD), state anxiety, and trait anxiety (Hruby et al., 2021; Oakey-Frost et al., 2022; Stoller et al., 2012; Telles et al., 2012), two considered mental-health related quality of life (Barreto et al., 2021; Magerøy et al., 2007), and two considered suicidal ideation (Oakey-Frost et al., 2022; Perez et al., 2022). In addition, job stress (Pavett et al., 1987), self-esteem (Pavett et al., 1987), psychological distress (Perez et al., 2022), deep sadness (do Nascimento et al., 2020), and burn syndrome (do Nascimento et al., 2020) each were used in one study.

Furthermore, six studies were conducted in United States (Hruby et al., 2021; LeardMann et al., 2011; Oakey-Frost et al., 2022; Pavett et al., 1987; Perez et al., 2022; Stoller et al., 2012), and the remaining four in another countries (Barreto et al., 2021; do Nascimento et al., 2020; Magerøy et al., 2007; Telles et al., 2012).

In addition, four studies included both sexes (do Nascimento et al., 2020; Hruby et al., 2021; LeardMann et al., 2011; Oakey-Frost et al., 2022; Perez et al., 2022; Stoller et al., 2012), while six included only males (Barreto et al., 2021; Magerøy et al., 2007; Pavett et al., 1987; Telles et al., 2012).

Risk of bias assessment

The results of risk of bias assessment for each study are shown in Tables 2-4. The risk of bias assessment using RoB 2 for the two RCT studies are shown in Table 2. Of these, one study was scored as high risk of bias, and the other as low risk. In Table 3, the one non-RCT study was scored as a critical risk of bias.

Table 2. Risk of bias assessment using the RoB 2 for RCT studies

Study	Randomisation process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall bias
Stoller et al. (2012)	Some concerns	Some concerns	Low	High	Some concerns	High
Telles et al. (2012)	Low	Low	Low	Low	Low	Low

Table 3. Risk of bias assessment using the ROBINS-I for Non-RCT studies

Study	Confounding	Selection of participants into the study	Classification of interventions	Deviations from intended interventions	Missing data	Measurement of outcomes	Selection of the reported result	Overall bias
Pavett et al. (2012)	Serious	Low	Low	Critical	Low	Moderate	Low	Critical

Table 4. Risk of bias assessment using Newcastle-Ottawa Scale for observational studies

Study	Study design	Selection	Comparability	Outcome	Total Score	Overall bias
Barreto et al. (2021)	Cross-sectional	1	2	2	5	High
Hruby et al. (2021)	Cross-sectional	4	2	2	8	Low
Magerøy et al. (2007)	Cross-sectional	2	2	2	6	Moderate
Oakey-Frost et al. (2021)	Cross-sectional	2	0	2	4	High
Perez et al. (2022)	Cross-sectional	3	2	2	7	Low
do Nascimento et al. (2020)	Cross-sectional	3	0	2	5	High
LeardMann et al. (2011)	Longitudinal	3	2	2	7	Low

Scores for risk of bias in observational studies are shown in Table 4. Of the six cross-sectional studies, two, one, and three studies were scored as low, moderate and high risk of bias, respectively. In addition, one longitudinal study was scored as a low risk of bias.

Depression

Of the studies, two cross-sectional studies examined the association between PA and depression (Hruby et al., 2021; Oakey-Frost et al., 2022) and found no significant association. Hruby et al. (2012) examined the association of moderate PA, vigorous PA, and strength training with odds of depression (Hruby et al., 2021). Depression was assessed using a self-reported questionnaire (Patient Health Questionnaire 9, PHQ-9). Compared to <150 min/wk of moderate PA and <75 min/wk of vigorous PA, a higher amount of moderate and vigorous PA was not associated with lower odds of depression, respectively. Oakey-Frost et al.'s study (2021) also showed similar results (Oakey-Frost et al., 2022). Weekly frequency of vigorous PA was not significantly correlated with PHQ-8 scores, which assessed depressive symptoms.

For muscle-strengthening exercise, exercise over 3 days/wk was not associated with lower odds of depression. However, exercise for 1 to 2 days/wk was significantly associated with lower odds of depression compared to no exercise (Hruby et al., 2021). Conversely, there was no significant correlation between frequency of muscle-strengthening exercise and major depressive disorder symptoms.

Anxiety

In total, four studies used anxiety as mental health outcome. Of these, two each were cross-sectional (Hruby et al., 2021; Oakey-Frost et al., 2022) and RCT studies (Stoller et al., 2012; Telles et al., 2012). Furthermore, two studies measured general anxiety disorders (GAD) using the 7-item GAD questionnaire (GAD-7). Hruby et al. (2021) reported that vigorous PA of 150 minutes or more per week was associated with lower odds of GAD. However, in Oakey-Frost et al.'s study (2021), vigorous PA frequency and muscle-strengthening exercise had no correlation with anxiety.

In addition, two RCT studies examined the effect of yoga intervention on state and trait anxiety. Telles et al. examined the acute effect of 45-min of single yoga session, and found a significant effect on state anxiety (Telles et al., 2012). Consistent with this study, a 3-week hatha yoga intervention was effective in reducing state and trait anxiety in military personnel deployed in Iraq (Stoller et al., 2012).

Psychological distress

Only one study examined the association between PA and psychological distress among United States military personnel (Perez et al., 2022). After adjusting for potential confounding factors, male soldiers who met PA recommendations had significantly lower odds of psychological distress; however, females did not. The study also examined the association between screen time, as sitting time, and psychological distress; however, there was no significant association.

PTSD

In total, three observational studies analyzed of the association between PTSD

and PA in military personnel in Unites States (Hruby et al., 2021; LeardMann et al., 2011; Perez et al., 2022), one study was a longitudinal design.

Meeting the moderate-vigorous PA recommendation was not associated with lower odds of PTSD (Perez et al., 2022). However, in a study that separately identified the association between moderate and vigorous PA, a higher amount of moderate PA, not in vigorous PA and muscle-strengthening exercise, was associated with lower odds of PTSD (Hruby et al., 2021).

Conversely, LeardMann et al. (2011) examined the prospective association between PA and new-onset and persistent PTSD symptoms, and identified that only vigorous PA, not moderate PA and muscle-strengthening exercise, was significantly associated with new-onset and persistent PTSD symptoms (LeardMann et al., 2011).

Mental health-related quality of life

The association of PA with mental health-related quality of life was investigated by two cross-sectional studies. Whereas participation in vigorous PA was not associated with mental health-related quality of life scores in military policemen (Barreto et al., 2021), the amount of PA was negatively associated with the scores among Norwegian Navy officers (Magerøy et al., 2007).

Suicidal ideation

No study reported a significant association between PA and suicidal ideation. There was no correlation in vigorous PA and muscle-strengthening exercise with suicidal ideation (Oakey-Frost et al., 2022). Furthermore, meeting the moderate-vigorous PA recommendation was not associated with the prevalence of suicidal ideation (Perez et al., 2022). However, female soldiers with less sedentary time had

lower odds for the prevalence of suicidal ideation.

Job stress

The effect of PA intervention on job stress was examined by one RCT (Pavett et al., 1987). Job stress was evaluated based on perceived quantity and frequency of job stress. Twelve weeks of circuit weight training decreased job stress in 245 United States Navy and Marine corps members.

Burnout syndrome

do Nascimento et al. (2020) used burnout syndrome as a study outcome (do Nascimento et al., 2020). They studied the association between PA and burnout syndrome in Brazilian military police officers. Compared to soldiers who were physically active, physically soldiers inactive had higher odds of burnout syndrome.

Self-esteem

Pavett et al. (1987) examined the effects of 12-weeks of circuit weight training on the self-esteem of Navy and Marine corps members (Pavett et al., 1987). There was no significant difference between the circuit weight training group and the control group.

3.4. Discussion

This study conducted a systematic review to identify the association between PA and mental health in military personnel. The review included 10 studies, most cross-sectional, with limited experimental and longitudinal studies. Regarding PA exposures, observational studies mainly examined the amount and frequency of moderate or vigorous PA and frequency of muscle-strengthening activity, while experimental studies mainly used yoga intervention. Regarding mental health-related outcomes, various mental health indicators, such as depression, anxiety, psychological pain, quality of life, PTSD, and suicidal ideation, were investigated. However, due to the insufficient number of studies, heterogeneous PA variables and outcomes, and evidence-based cross-sectional studies, it was not possible to determine the direction of the association between PA and mental health in military personnel in this study.

Among the 10 included studies, the most frequently examined mental health indicator was anxiety. In total, four studies examined the association between anxiety and PA. Of these, two experimental studies investigated the effect of yoga intervention, and both reported significant effects (Stoller et al., 2012; Telles et al., 2012). Consistent with these results, a recent meta-analysis reported that yoga was effective in reducing anxiety (Cramer et al., 2018). These results suggested that yoga interventions could be an effective way of reducing anxiety in military personnel. However, only two studies examined the effectiveness of yoga in military personnel. A cross-sectional study found a negative association between vigorous PA and anxiety (Hruby et al., 2021). Therefore, further research is required on the association between PA and anxiety in military personnel.

Only one longitudinal study included in this review examined the association between PA and PTSD in military personnel. In addition, two cross-sectional studies also examined the same association. Different results from each study were reported by three studies. One cross-sectional study reported that ≥ 150 min/wk of moderate-vigorous PA was not associated with the prevalence of PTSD (Perez et al., 2022). However, another reported that only the amount of moderate PA, not vigorous PA, was negatively associated with PTSD (Hruby et al., 2021). However, a longitudinal study reported a strong inverse association, where low amount of moderate PA and strength training were associated with the risk of PTSD (LeardMann et al., 2011). A meta-analysis study examined the effects of PA intervention on PTSD symptoms and reported a significant effect (Rosenbaum et al., 2015). Moreover, we found evidence that PA intervention reduced PTSD symptoms in a small number of veterans (Dustin, Bricker, Arave, Wall, & Wendt, 2011). The results of this longitudinal study that PA was associated with a lower risk of PTSD in military personnel were consistent with previous findings. However, additional experimental or longitudinal studies are required to confirm an apparent association.

This review has insufficient evidence to explain the association between PA and each mental health indicators. In addition, since most were cross-sectional studies, there are limitations in dealing with a comprehensive discussion on the association with PA. Mental health outcomes, such as depression, quality of life, and psychological distress, were examined in fewer than two studies and all were cross-sectional. Hence, the quantity and quality of evidence was insufficient. In addition, there was significant heterogeneity in the measures of PA and mental health, which were mostly investigated using self-report questionnaire. Furthermore, some studies did not provide validity and reliability of the tools used for PA and mental health

indicators. Therefore, more than half of the included studies had high risk of bias, which limited the synthesis of the study findings. More high-quality evidence is required to synthesize the association between PA and mental health in military personnel.

A strength of this study is that, to our best knowledge, it is the first literature review to systematically examine the relationship between PA and mental health among active-duty military personnel according to the PRISMA reporting guidelines.

Conversely, this study has some limitations. First, we were unable to conduct a meta-analysis due to the insufficient evidence and heterogeneity between the studies. To ascertain the direction of the apparent association between PA and mental health, it is necessary to determine the effect size of the association. Second, a systematic search strategy aimed to identify all the relevant studies. However, it might not have identified all mental health-related outcomes. It is possible that some studies were overlooked during the search and selection process. Additionally, a study on the physiological responses associated with mental health, such as hypothalamic-pituitary-adrenal responsiveness and secretion of cortisol (Rimmele et al., 2009), may have been overlooked. Third, this review included only studies written in English. Therefore, there could have been evidence in other languages that was not included in this review. Lastly, no exclusion criteria were established for the sample size in each study. It is recommended to ensure that the studies included in this review are sufficiently large and powerful to determine significant association.

In conclusion, due to limitations in the quality and quantity of evidence, this review was limited in deriving a comprehensive association between PA and each mental health outcome. However, this systematic review maps the available evidence and suggests that there is some evidence to link increased amount PA with poorer

mental health in active-duty military personnel.

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CHAPTER 4. STUDY 2
Dose-response association between PA and mental health in Korean military personnel

4.1. Introduction

Military personnel are frequently exposed to high stress due to their duties and job characteristics, such as combat, intense training, hierarchical organizational culture, and frequent moving (Adler & Castro, 2013; Park, Kim, & Ko, 2013; Sareen et al., 2007; Xue et al., 2015). In addition, high stress among military personnel is a major risk factor of mental disorders. The prevalence of mental disorders, such as depression, anxiety disorder, and PTSD, among military personnel is higher than in the general population (Gadermann et al., 2012; Meadows et al., 2018; Moradi, Dowran, & Sepandi, 2021; Rusu, Zamorski, Boulos, & Garber, 2016; Schilz & Sammito, 2021).

It is critical to improve the mental health of military personnel as mental disorders cause maladaptation in military life (An et al., 2016), decrease work productivity (Hourani, Williams, & Kress, 2006), and increase the suicide risk (Ursano et al., 2018). Furthermore, they also cause personal tragedy and loss of national defense capabilities. The incidence of suicide among military personnel in the U.S. is continuously increasing (Department of Defense, 2021). In addition, suicide is also a major factor of death in the Korean military (Ministry of National Defense, 2022), which makes it a persistent problem.

It is well known that regular PA is effective for mental health. Recent studies reported that PA positively correlated with various mental health outcomes, such as

reduced stress, depression, and anxiety and improved quality of life (Physical Activity Guidelines Advisory Committee, 2018). These associations were also seen in military personnel. Several studies reported that regular PA was associated with lower depression, psychological distress, job stress, and PTSD in military personnel (Hruby, Lieberman, & Smith, 2021; Kegel, Kazman, Scott, & Deuster, 2020; Martins & Lopes, 2013; Morgan, Hourani, & Tueller, 2017).

Regarding PA interventions for mental health management, it is essential to identify the extent to which PA is associated with lower mental health or a higher prevalence of mental disorders and provide a recommendation. An adequate amount of PA is beneficial for mental health; however, excessive PA may not. Several studies examined the dose-response relationship between the amount of PA and mental health and identified an appropriate amount for mental health (Bernard et al., 2018; Chekroud et al., 2018; Xu et al., 2022).

Military personnel participate in a higher amount of PA than the general population (Schilz & Sammito, 2021). However, mental disorders are also higher among miliary personnel. PA has a positive effect on mental health; however, when in limited amounts. Excessive PA may hardly have a positive effect or, conversely, may exacerbate mental disorders (Paluska & Schwenk, 2000; Pearce et al., 2022). Military personnel are exposed to a high amount of PA due to mission demands (Schilz & Sammito, 2021). High amounts of occupational PA in military personnel was associated with a high level of stress (Martins & Lopes, 2013). Hence, higher amounts of PA in military personnel may not improve their mental health. However, to our best knowledge, no studies have investigated the dose-response association between PA and mental health in Korean military personnel. Therefore, to effectively manage the mental health of military personnel, it is necessary to examine the dose-

response association between PA and mental health among them.

The amount of PA among military personnel varies depending on military-related characteristics, such as military unit and rank (Meadows et al., 2018; Sung, 2018). In addition, the prevalence of mental disorders also differs according to military units and branches (Moradi et al., 2021). Therefore, the association between PA and mental health may differ according to military-related characteristics. For example, there was a difference in the association between PA and mental health in the U.S. special forces group and another service group (Cooper et al., 2020).

Therefore, the primary aim of this study was to examine the cross-sectional dose-response association between the amount of PA and psychological distress in Korean military personnel and the association's shape. The secondary aim was to examine the military rank and unit-stratified association between the amount of PA and psychological distress and suicidal ideation.

4.2. Materials and methods

Study sample

This study was based on data from the 2014-2015 Military Health Survey (MHS) conducted by the Republic of Korea School of Military Medicine to identify Korean Military personnel's health-related behaviors and medical utilization. Study participants were randomly selected among active-duty military personnel in the Korean Army, Navy, Air force, and Marine corps, and considered their military rank, service type, and service area. In total, 14,291 active-duty military personnel participated in the survey. Among the 14,291 participants, 290 were excluded for the following reasons: sum of daily self-reported PA time over 16 hours a day (n=46)

and missing outcome data (n=244). Finally, 14,001 military personnel were included in this analysis. This study was approved by the Institutional Review Board of Korea Armed Forces Medical Command (IRB No: AFMC-14-IRB004 & AFMC-15060-IRB-15-049) and was conducted in accordance with the Declaration of Helsinki and its future amendments.

Measures of PA

The PA was evaluated using the short form of the International Physical Activity Questionnaire (IPAQ). The IPAQ short form enquired regarding the frequency and duration of vigorous-intensity and moderate-intensity PA and walking activities in the past week. Each PA amount was expressed as MET-minutes/week and calculated using the following equation: frequency of PA (day) × duration of PA (minutes) × intensity of PA (3.3, 4.0, and 8.0 MET for walking, moderate PA, and vigorous PA, respectively) (IPAQ Research Committee, 2005). The total amount of weekly PA was calculated through the summation of three PA amounts and categorized into five groups according to the amount (0-999, 1,000-1,999, 2,000-3,999, 4,000-5,999, and ≥6,000 MET-min/week).

Outcomes

Psychological distress was evaluated using the Kessler psychological distress scale (K10), a 10-item questionnaire developed to assess non-specific psychological distress (Kessler et al., 2002). There was a strong association between the K10 score and Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) diagnosis for depressive and anxiety disorder and other mental disorders (Andrews & Slade, 2001; Cornelius, Groothoff, Van Der Klink, & Brouwer, 2013;

Fassaert et al., 2009; Toshi A Furukawa et al., 2008; Toshiaki A Furukawa, Kessler, Slade, & Andrews, 2003). Participants were asked to rate how often they felt negative feelings on a scale from 1-5: “all of the time,” “most of the time,” “some of the time,” “a little of the time,” or “none of the time.” The total score ranged from 10-50. We used the cut-off score of 13 to define the presence of significant psychological distress (National Center for Mental Health, 2020). The Korean version of the K10 questionnaire was used in the MHS (Kim, 2011).

Suicidal ideation was indicated as “yes” or “no” based on the reported response to the question, “During the past 12 months, have you ever seriously considered attempting suicide?”

Covariates

Sex (male or female), age group (19-24, 25-29, 30-39, or ≥40 years), body mass index (underweight, normal weight, overweight, or obese), education level (≤high school graduate, university or college, or ≥graduate school), marital status (unmarried, divorced/separated/widowed, or married), smoking status (non-smoker, former, or current smoker), military unit (Army, Navy/Marine corps, or Air force), military rank (enlisted or officer), and military branch (combat-related, technical service, administrative support, or special) were included as covariates.

Body mass index was calculated as self-reported weight (kg) divided by self-reported height squared (m^2) and classified as underweight, normal weight, overweight, and obese based on the WHO’s cut-points for the Asian population (World Health Organization, 2000).

Military branch was classified into the following four groups: combat-related (infantry, armor, artillery, air defense, intelligence, engineering,

information/communication, aviation, and aviation control), technical service (ordnance, quartermaster, transportation, chemical, weather, facilities, ship handling, management, and air weapon maintenance), administrative support (adjutant, military police, finance, troop information, instruction, and personnel administration), and special (medical service, judicial affairs, chaplain, and martial music).

Statistical analysis

Multiple imputations with chained equations for missing values of primary exposure and covariates were conducted with 20 imputed data sets. PA, sex, age, body mass index, education level, marital and smoking status, and military unit, rank, and branch were included in the imputed model. Participants' characteristics were expressed as counts or percentages across observed dataset, imputed datasets, and complete dataset.

A multivariable logistic regression was conducted using the imputed datasets to estimate the odds ratios (ORs) and 95% confidence intervals (CIs) of psychological distress and suicidal ideation according to the amount of PA. The lowest amount of PA (0-999 MET-min/week) was used as the reference group. We estimated the ORs and 95% Cis, adjusted for sex and age, in Model 1. Furthermore, we further adjusted for body mass index, education level, marital status, and smoking status in Model 2. Military unit, rank, and branch were additionally adjusted in Model 3.

A sensitivity analyses using complete-case analysis were performed to assess the robustness of our results. Furthermore, stratified analyses were performed to identify the association of PA and mental health outcomes based on military rank and units.

To identify the shape of association between the amount of PA and psychological distress and suicidal ideation, we generated a non-linear curve using a restricted cubic spline transformation of PA, with 6 knots at the 5, 23, 41, 59, 77, and 95th percentiles. All statistical analyses were performed using Stata SE version 17.0 and *P* value < 0.05 were considered statistically significant.

4.3. Results

The distributions of participants' characteristics in the observed, imputed (n=14,001), and complete datasets (n=8,331) are shown in Table 5. Among the 14,001 participants, missing data were <3% in all variables, except for PA (34%). Participants' characteristics showed similar distributions between datasets. There were 932 (6.8%) and 433 cases of psychological distress (total K10 score ≥13) and suicidal ideation. Most participants were males (97%), aged <25 years (73%), in the Army (59%), and in combat-related military branches (63%). Participants' characteristics across the amounts of PA groups are shown in Appendix 5.

Tables 6 and 7 show the ORs (95%CIs) of the prevalence of psychological distress and suicidal ideation across the amount of PA after adjusting for covariates. Compared to the lowest amount of PA group (0-999 MET-min/wk), a higher amount of PA was associated with significantly lower odds of psychological distress, except for in the highest PA group (≥6,000 MET-min/wk). These associations were consistent, even after adjusting for covariates. However, there were no significant associations between the amount of PA and suicidal ideation in all the analysis models.

Table 5. Characteristics of sample in this study.

	Observed data		Imputed data (n=14,001)	Complete data (n=8,331)
Characteristics	**N available**	**%**	**%**	**%**
Physical activity (MET-min/wk)	9,216			
0-999	1,538	16.69	17.12	16.25
1000-1999	1,460	15.84	16.00	15.98
2000-3999	2,500	27.13	27.07	27.07
4000-5999	1,587	17.22	16.95	17.52
≥6000	2,131	23.12	22.85	23.18
Psychological distress	14,001			
No	13,069	93.34	93.34	93.83
Yes	932	6.66	6.66	6.17
Suicidal ideation	14,001			
No	13,568	96.91	96.64	97.05
Yes	433	3.09	3.36	2.95
Sex	13,987			
Male	13,518	96.65	96.64	97.44
Female	469	3.35	3.36	2.56
Age group (year)	13,695			
19-24	9,941	72.59	72.58	75.73
25-29	1,670	12.19	12.17	11.63
30-39	1,398	10.21	10.24	8.44
≥40	686	5.01	5.00	4.20
BMI category (kg/m^2)	13,686			
Underweight (≤18.5)	209	1.53	1.54	1.51
Normal weight (18.5-23)	6,809	49.75	50.83	50.75
Overweight (23-24.9)	3,341	24.41	23.86	23.89
Obese (≥25)	3,327	24.31	23.76	23.85
Education level	13,845			
≤High school graduate	2,527	18.25	18.25	18.45
University or college	10,930	78.95	78.98	79.10
≥Graduate school	388	2.80	2.77	2.45
Marital status	13,738			
Unmarried	11,635	54.69	84.09	86.46
Divorced/separated/widowed	387	2.82	3.66	2.35
Married	1,716	12.49	12.26	11.19
Smoking status	13,770			
Non-smoker	7,025	51.02	50.98	50.26
Former smoker	1,053	7.65	8.37	7.79
Current smoker	5,692	41.34	40.65	41.95
Military unit	13,992			
Army	8,223	58.77	58.77	58.84
Navy/Marine corps	2,666	14.77	19.07	18.33
Air force	3,103	22.18	22.16	22.83
Military rank	13,849			
Enlisted	7,709	55.66	55.62	60.00
Officer	6,140	44.34	44.38	40.00
Military branch	13,639			
Combat	8,554	62.72	62.70	63.16
Technical service	3,525	25.85	26.16	25.83
Administrative support	971	7.12	6.94	7.07
Special	589	4.32	4.21	3.94

Table 6. Logistic regression between the amount of physical activity and psychological distress with multiple imputation.

Amount of physical activity (MET-min/wk)	ORs (95% CIs) of psychological distress		
	Model 1	Model 2	Model 3
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	**0.64 (0.50-0.83)**	**0.64 (0.50-0.83)**	**0.63 (0.48-0.81)**
2000-3999	**0.69 (0.54-0.87)**	**0.69 (0.54-0.87)**	**0.67 (0.52-0.85)**
4000-5999	**0.66 (0.51-0.85)**	**0.66 (0.51-0.85)**	**0.63 (0.49-0.81)**
≥ 6000	0.90 (0.73-1.13)	0.90 (0.72-1.13)	0.85 (0.69-1.07)
P for trend	0.798	0.781	0.458

Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status.
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

Table 7. Logistic regression between the amount of physical activity and suicidal ideation with multiple imputation.

Amount of physical activity (MET-min/wk)	ORs (95% CIs) of suicidal ideation		
	Model 1	Model 2	Model 3
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	0.82 (0.54-1.24)	0.82 (0.54-1.24)	0.80 (0.53-1.21)
2000-3999	0.87 (0.61-1.24)	0.88 (0.61-1.26)	0.84 (0.59-1.21)
4000-5999	0.80 (0.52-1.24)	0.81 (0.53-1.25)	0.77 (0.49-1.19)
≥ 6000	0.97 (0.69-1.35)	0.96 (0.69-1.35)	0.89 (0.63-1.26)
P for trend	0.982	0.933	0.616

Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status.
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

In the sensitivity analyses, the associations between the amount of PA and psychological distress and suicidal ideation were similar to those from the primary model with multiple imputations, although the ORs were decreased overall (Appendix 6 and 7). Compared to the lowest amount of PA group, higher PA was

associated with a lower prevalence of psychological distress, except for the highest amount of PA group.

Figures 1 and 2 present the restricted cubic spline model of psychological distress and suicidal ideation as a function of the amount of PA group. These models showed the dose-response association between the amount of PA and odds of psychological distress (Figure 1) and suicidal ideation (Figure 2). Both models were adjusted for sex, age, body mass index, education level, marital and smoking status, and military unit, rank, and branch. The solid black lines indicate the ORs, and the shaded area indicate the 95%CIs.

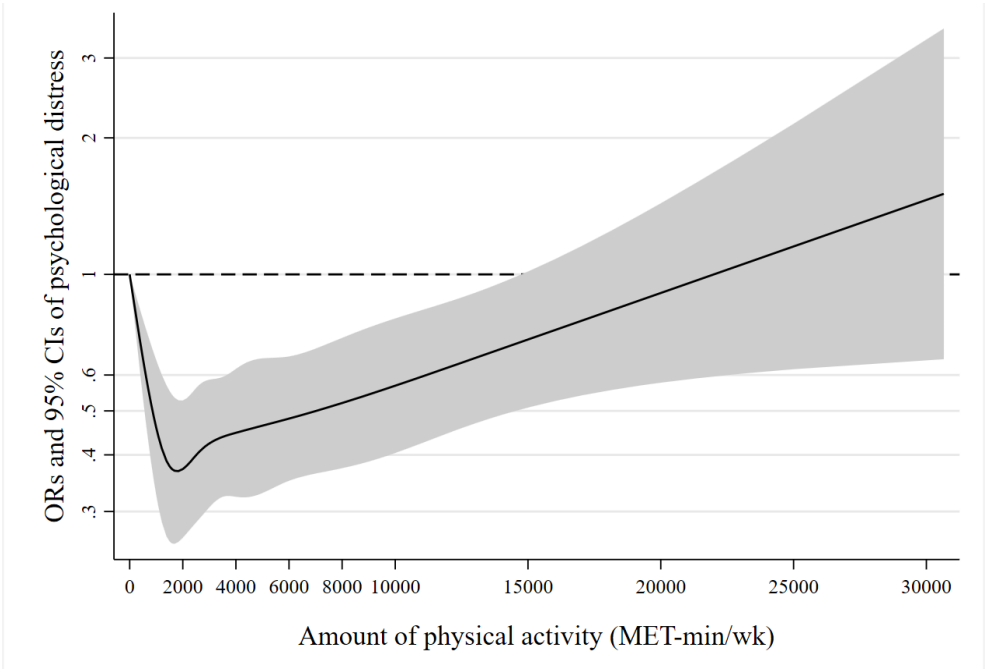

Figure 2. Restricted cubic spline models estimating ORs and 95% CIs of psychological distress

Figure 2 shows a non-linear association between the amount of PA and psychological distress in the spline model with significant chi-squared tests of non-

linearity ($p < 0.001$). The dose-response analysis showed a J-curve association between the amount of PA and psychological distress. A higher PA dose was associated with a lower OR of psychological distress, with an upper limit of approximately 1,600 MET-min/wk.

In Figure 3, there was no curvilinear association between the amount of PA and suicidal ideation ($p = 0.479$). Although the amount of PA, up to approximately 1,500 MET-min/wk, was likely to have a negative association with suicidal ideation, it was not statistically significant. PA doses above 1,500 MET-min/wk had no association with suicidal ideation.

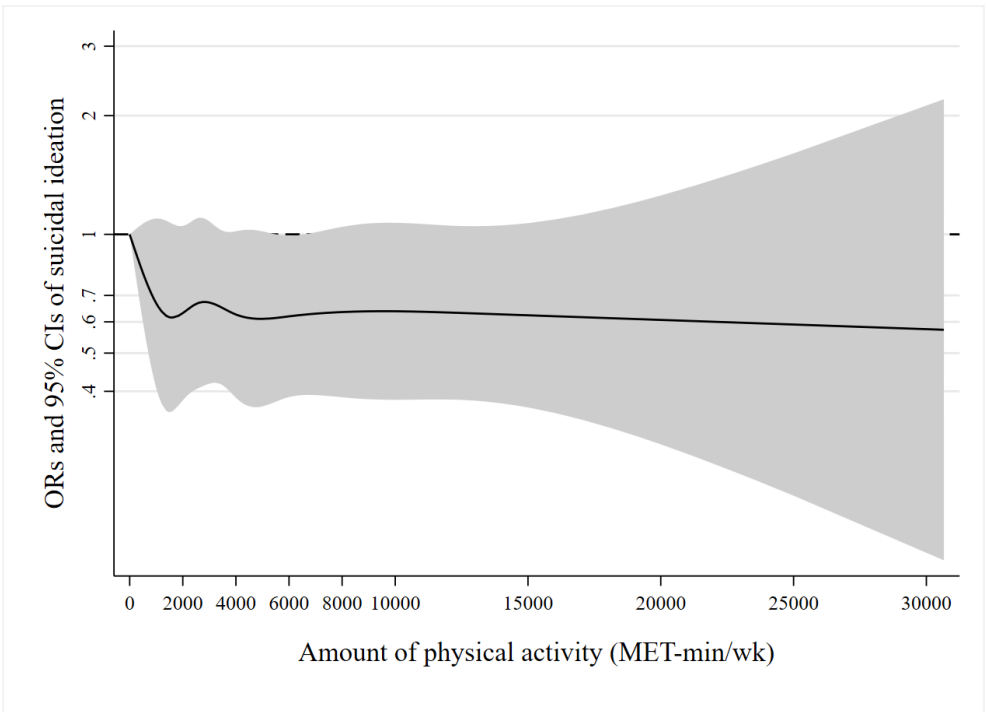

Figure 3. Restricted cubic spline models estimating ORs and 95% CIs of suicidal ideation

Figures 4-7 show the odds ratios of psychological distress and suicidal ideation across the amount of PA stratified by military rank and unit, respectively. In Figure 4, the association between PA and psychological distress differed by military rank. Compared with the lowest amount of PA group, enlisted soldiers had significantly lower odds of psychological distress in PA amount below 6,000 MET-min/wk. In contrast, officers had significantly lower odds only in the 2,000-3,999 MET-min/wk group. However, there was no significant association between PA and suicidal ideation in the enlisted and officers (Figure 5).

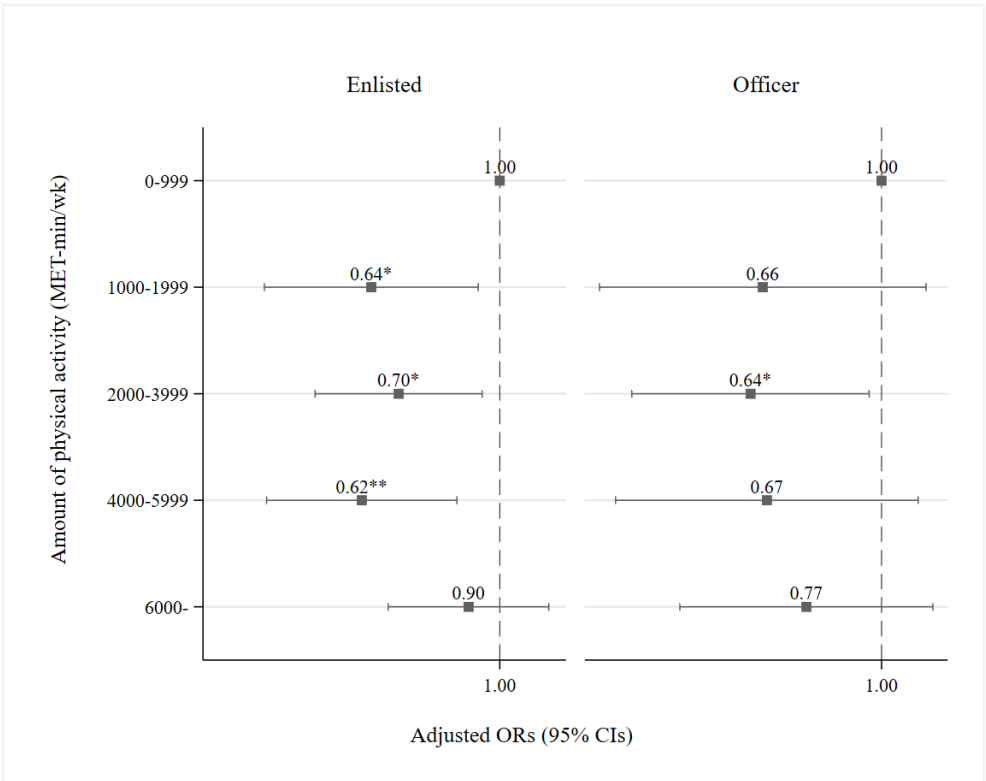

Figure 4. Odds ratios of psychological distress by the amount of physical activity in military rank-stratified analysis

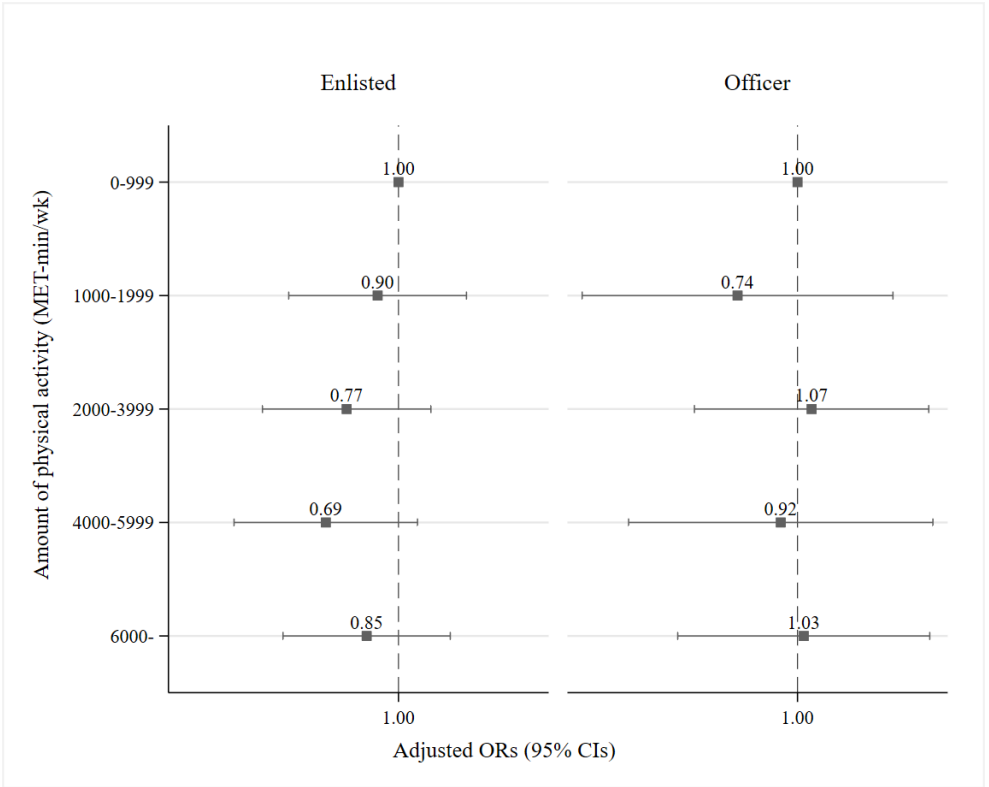

Figure 5. Odds ratios of suicidal ideation by the amount of physical activity in military unit-stratified analysis

Figures 6 and 7 show the different associations by military unit. In Figure 6, Army personnel reported significantly lower odds of psychological distress only in 1,000-1,999 and 2,000-3,999 PA groups. Moreover, Air force personnel reported decreased odds only in the 2,000-3,999 PA group. There was no significant association in Navy/Marine corps personnel. Regarding suicidal ideation, a significant association was found only in the Navy/Marine corps group (Figure 7). Furthermore, the OR for suicidal ideation was significantly lower at PA amount of 2,000-3,999 MET-min/wk.

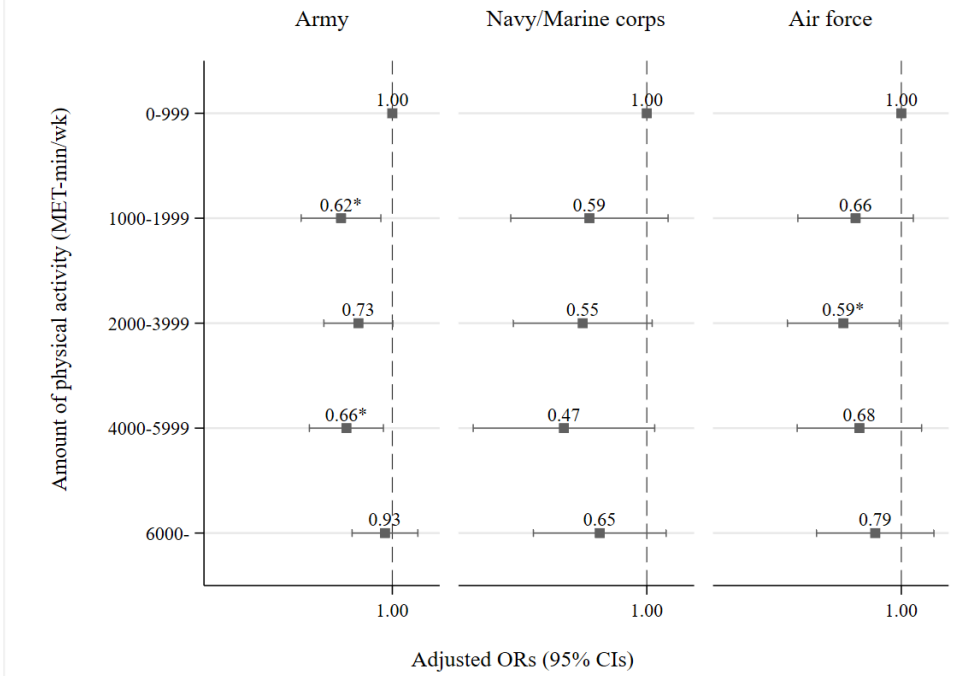

Figure 6. Odds ratios of psychological distress by the amount of physical activity in military unit-stratified analysis

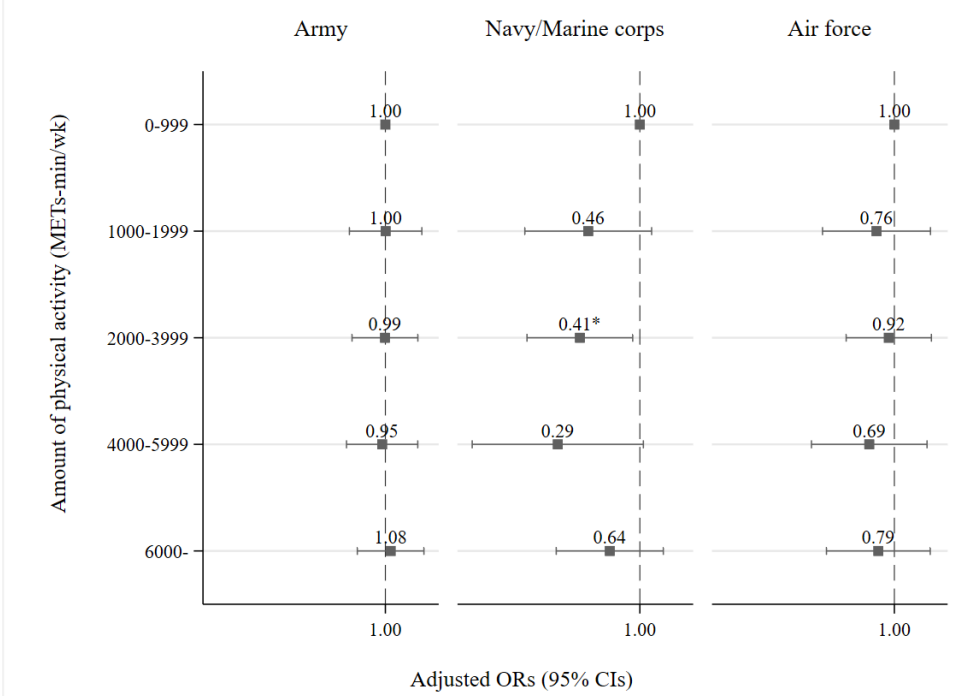

Figure 7. Odds ratios of suicidal ideation by the amount of physical activity in military unit-stratified analysis

4.4. Discussion

This study aimed to examine the dose-response association between the amount of PA and psychological distress and suicidal ideation in Korean military personnel and the military rank and unit-stratified association. Although there was no association between the amount of PA and suicidal ideation, there was a significant non-linear association with psychological distress. Furthermore, this association was different according to the military unit.

A dose-response analysis showed a J-curve association between the amount of PA and psychological distress. A higher amount of PA was associated with a lower prevalence of psychological distress, with an upper limit of approximately 1,600 MET-min/wk. From the PA over 1,600 MET-min/wk, there was a positive association between PA and psychological distress. Only one study examined this association in military personnel (Perez, Dong, Beckman, & Meadows, 2022). Similar to our findings, this study reported that higher amounts of PA were associated with a lower prevalence of psychological distress. However, the limitation of the dose-response was not reported. A study examined the dose-response association between PA and psychological distress in the general population and found that the prevalence of psychological distress was lowest at 2.5-7.5 hrs/wk of moderate-vigorous PA (Kim et al., 2012). These results were similar to our findings as 2.5-7.5 hrs/wk of moderate-vigorous PA corresponded to approximately 500-1,500 MET-min/wk.

Psychological distress was defined as an unpleasant feelings or emotions characterized by symptoms of depression and anxiety (Mirowsky & Ross, 2017). Thus, psychological distress was highly related to depression and anxiety. In fact,

our study used the K10 questionnaire to define psychological distress, which can also be used to screen depression or anxiety disorders (Donker et al., 2010; Vasiliadis, Chudzinski, Gontijo-Guerra, & Préville, 2015). One study examined the association between moderate and vigorous PA and depression and anxiety in military personnel. It was reported that vigorous PA of ≥75 min/wk was associated with a low prevalence of anxiety disorder; however, not depression, after adjusting for all potential confounding variables. However, in this study, the association between depression, anxiety disorder, and PA was significantly weakened after adjusting for the presence of other mental disorders, which was a strong moderator of analysis model. Without adjusting other mental disorders, moderate and vigorous PA had a significant association with depression and anxiety. However, a dose-response association was not examined.

In a study on Korean general adults, those with PA of 1,200-,800 MET-min/wk and 1,800-3,000 MET-min/wk had a lowest prevalence of depression (Kim et al., 2018), and anxiety (Kim et al., 2020), respectively. A greater amount of PA was associated with a higher prevalence of depression and anxiety. Although there were some differences in the amount of PA, these results were similar to our finding, which showed the lowest prevalence of PA, approximately 1,600 MET-min/wk, supported our findings.

Moderate-vigorous PA of 1,600 MET-min/wk corresponded to approximately 500 minutes per week, two to three times the recommended amount of PA (Physical Activity Guidelines Advisory Committee, 2018). Although PA of approximately 1,600 MET-min/wk or more was positively associated with psychological distress, the prevalence was still significantly low compared to the lowest amount of PA. In Figure 1, the prevalence was still low until approximately 15,000 MET-min/wk of

PA. Even when the amount of PA was relatively high, its prevalence was still low compared to a low amount of PA.

Our results did not reveal a significant association between the amount of PA and prevalence of suicidal ideation. Previous studies examined the relationship between PA and suicidal ideation in military personnel and reported a significant relationship in female soldiers; however, not in male soldiers (Perez et al., 2022). Our sample was mostly male. In addition, we conducted a sex-stratified analysis and found no difference in the association (Appendix 8, 9). Conversely, the frequency of high-intensity PA in the U.S. military was not significantly associated with suicidal ideation (Oakey-Frost et al., 2022). A study on veterans also found no association between PA and suicidal ideation (Gutierrez, Davidson, Friese, & Forster, 2016). However, a meta-analysis study on the relationship between PA and suicide in the general population reported that meeting PA guidelines was associated with low suicidal ideation, which indicated evidence different from our study results (Vancampfort et al., 2018).

We conducted a subgroup analysis to examine whether the association between PA, psychological distress, and suicidal ideation differed based on military rank and unit. We divided the participants into officers and enlisted soldiers, and found a difference in the amount of PA associated with the significantly a lower prevalence of psychological distress; however, a similar trend was shown. Even when analyzed by military rank, there was no association between PA and suicidal ideation. However, there were some differences in the association when stratified by military unit. A certain amount of PA was associated with lower prevalence of psychological distress in the Army and Air force subgroups. However, it was not significant in the Navy and Marine corps subgroups.

Conversely, when the relationship between PA and suicidal ideation was divided by a military unit, only the Navy showed a significantly lower prevalence of suicidal ideation and PA. It is difficult to clearly explain the difference in these associations. As shown in the Appendix 11 and 13, the prevalence of psychological distress and suicidal ideation in the Navy/Marine corps was significantly lower than that in the Army and Air force. There may be different characteristics of PA among those in the Army and Air force, or there may be more important variables that ignore the effect of PA on association in the Navy. However, it is difficult to explain these differences with the current data and evidence.

PA stimulates several neuroplastic processes associated with depression, which reduce inflammation and increase resilience to oxidative stress. Additionally, PA improves depressive symptoms by promoting self-esteem and self-efficacy (Kandola, Ashdown-Franks, Hendrikse, Sabiston, & Stubbs, 2019). Therefore, a proper amount of PA has a positive effect on mental health. However, excessive PA may increase symptoms of mental disorders, such as depression and anxiety. Excessive PA can increase oxidative stress, which can result in a decrease in antioxidant capacity in the body (Maes, Galecki, Chang, & Berk, 2011), and increase the response of corticotropin and cortisol, which can cause abnormalities in the immune system, leading to depression (Zunszain, Anacker, Cattaneo, Carvalho, & Pariante, 2011). Furthermore, excessive PA can cause an increase in inflammatory cytokines, such as TNF-alpha, IL-1, and IL-6, which can negatively affect areas of the brain, such as the prefrontal cortex and the hippocampus that controls anxiety (Halson & Jeukendrup, 2004; Michopoulos, Powers, Gillespie, Ressler, & Jovanovic, 2017; Smith, 2000). Based on this evidence, excessive PA may be associated with a high prevalence of psychological distress.

A strength of our study is that, to our best knowledge, it is the first to examine the dose-response association between PA and mental health in Korean military personnel. However, the study has some limitations. First, this study was a cross-sectional study. Hence, it is not possible to draw a conclusion regarding the causal relationship between PA and prevalence of psychological distress. In addition, reverse causality is possible. Second, since this study investigated PA using a questionnaire, there may be a difference from the actual amount of PA. Third, study participants were asked regarding PA during the recent week. Therefore, there may be a difference in the amount of PA based on the period during which the survey was conducted. Afterward, it is necessary to conduct research using PA collected through an objective measurement. Lastly, mental strength was always emphasized in military personnel. Hence, results of a psychological distress assessment might be underestimated.

In conclusion, this study found a J-shape dose-response association between PA and psychological distress in Korean military personnel. Furthermore, these associations differed by military unit. Longitudinal studies are required to examine the causal association between PA and psychological distress in Korean military personnel.

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CHAPTER 5. STUDY 3
Independent and joint associations between aerobic and muscle-strengthening activity with mental health in Korean military personnel

5.1. Introduction

Mental disorders, such as depression, anxiety disorders, and PTSD, are more common in military personnel than in the general population. The global prevalence of depression in military personnel is approximately 23%, which is approximately four times higher than that in the general population (Lim et al., 2018; Moradi, Dowran, & Sepandi, 2021). Furthermore, military personnel also reported higher anxiety disorders and suicidal ideation than in the general population (Rusu, Zamorski, Boulos, & Garber, 2016). Therefore, mental health management is an important issue that should be addressed more seriously in the military personnel.

Several studies reported on the mental health benefits of PA. Regular PA had a positively effect on mental health, such as reduced risk of depression and anxiety and improved sleep and quality of life (Piercy et al., 2018). The recent WHO PA guidelines recommended engaging in at least 150-300 minutes or 75-150 minutes per week of moderate aerobic or vigorous aerobic PA, respectively (Bull et al., 2020).

When these recommendations are met, various health benefits can be gained, including improved mental health, such as preventing depression and reduced anxiety. Consistent with this, meta-analyses of prospective studies reported that when the recommended levels of PA were met, the risk of depression, anxiety disorders, and suicidal ideation was reduced by approximately 22%, 29%, and 9%,

respectively (Schuch et al., 2019; Schuch et al., 2018; Vancampfort et al., 2018).

However, these recommendations were inclusive of overall health outcomes and not optimized for specific mental health outcomes. In addition, several studies showed conflicting results in the association between PA and mental health based on the intensity, amount, and type of PA (Asztalos, De Bourdeaudhuij, & Cardon, 2010; Gerber et al., 2014; Pavey, Peeters, Bauman, & Brown, 2013).

With aerobic PA recommendations, engaging in muscle-strengthening activities (MSA) at least twice per week for additional health benefits was also recommended (Bull et al., 2020). However, it is unclear which type of PA, MSA or aerobic PA, is more effective for mental health. Previous studies reported the effects of MSA and aerobic PA on improving depression (Gordon et al., 2018; Schuch et al., 2016), and there was no significant difference between the results. However, people who met both the MSA and aerobic PA criteria had a lower prevalence of depressive symptoms than those who met only one PA criterion (Bennie, De Cocker, Biddle, & Teychenne, 2020).

Some studies examined the independent association between aerobic PA and MSA and mental health in military personnel. A study reported that only vigorous PA, not MSA, was associated with a new-onset of PTSD (LeardMann et al., 2011). Another study reported that a higher amount of aerobic PA, not MSA, was associated with a lower prevalence of anxiety disorders and PTSD (Hruby, Lieberman, & Smith, 2021). However, to our best knowledge, no study examined the joint association between aerobic PA and MSA in military personnel.

Evidence of the association between PA and mental health in the military is insufficient. Therefore, further research is required to identify the amount and type of PA related to the mental health of military personnel to establish the basis for

managing their mental health. Therefore, we examined the independent and joint association between the amount of aerobic PA and MSA with mental health in Korean military personnel.

5.2. Materials and methods

Study sample

Data were obtained from the 2014-2015 Military Health Survey conducted by the Republic of Korea School of Military Medicine to examine the health-related behaviors and medical utilization among military personnel in the Republic of Korea. A representative sample was selected and considered the distribution by military rank, branch, and region in the Army, Navy, Air force, and Marine corps. In total, 14,291 military personnel participated.

Of the 14,291 active-duty military personnel, 290 were excluded due to invalid PA time (>16 hours a day) and missing mental health outcomes. Therefore, 14,001 participants were included.

This study was approved by the Institutional Review Board of Korea Armed Forces Medical Command (IRB No: AFMC-14-IRB004 & AFMC-15060-IRB-15-049) and was conducted following the Declaration of Helsinki and its future amendments.

Measures of PA

Self-reported PA was assessed using the short form of the International Physical Activity Questionnaire (IPAQ). The short form of the IPAQ enquired the frequency and time of walking activity, moderate-intensity PA, and vigorous-intensity PA

during the last week. Each PA amount was expressed as MET-minutes/week and calculated using the following equation: frequency of PA (day) × duration of PA (minutes) × intensity of PA (3.3, 4.0, and 8.0 MET for walking, moderate PA, vigorous PA, respectively) (IPAQ Research Committee, 2005). The total amount of weekly PA was calculated through the summation of three PA amounts and categorized into five groups according to the amount of PA (0-999, 1,000-1,999, 2,000-3,999, 4,000-5,999, and ≥6,000 MET-min/week). MSA was categorized into five groups according to the frequency (none, 1, 2, 3, 4, and 5 or more days/wk), based on the reported response to the question: "How many days did you do muscle-strengthening activity, such as push-ups, sit-ups or training using dumbbell or barbell?"

A combined variable of both the variables was created to examine a joint association between the amount of aerobic PA and number of days of MSA. First, MSA was recategorized into "0-2 days/wk" and "3-7 days/wk." Subsequently, the five and two categories of aerobic PA and MSA, respectively, (0-2, 3-7 days/wk) were combined, and a variable with ten categories was created and used in the joint analysis.

Outcomes

Psychological distress and suicidal ideation were used as the main outcomes. The 10-item Kessler psychological distress scale (K10) was used to assess psychological distress (Kessler et al., 2002). This study used the Korean version of the K10 questionnaire (Kim, 2011). This scale was strongly related to the DSM-IV diagnosis for depression, anxiety disorder, and other mental disorders (Andrews & Slade, 2001; Cornelius, Groothoff, Van Der Klink, & Brouwer, 2013; Fassaert et al.,

2009; Toshi A Furukawa et al., 2008; Toshiaki A Furukawa, Kessler, Slade, & Andrews, 2003)

Participants were asked how often they felt negative emotions in the past four weeks. Response options for each question included “all of the time,” “most of the time,” “some of the time,” “a little of the time,” or “none of the time.” Each question was scored from 1-5, and the total score was calculated by adding the scores of all questions. The total score ranged from 10-50. The presence of psychological distress was defined by using the cut-off score of 13 (National Center for Mental Health, 2020).

Suicidal ideation was assessed using the following question: “During the past 12 months, have you ever seriously considered attempting suicide?”

Covariates

Sex, age group (19-24, 25-29, 30-39, or ≥40 years), body mass index (<18.5 kg/m^2, 18.5-22.9 kg/m^2, 23.0-24.9 kg/m^2, or ≥25.0 kg/m^2), education level (≤high school graduate, university or college, or ≥graduate school), marital status (unmarried, divorced/separated/widowed, or married), smoking status (non-smoker, former smoker, or current smoker), military unit (Army, Navy/Marine corps, or Air force), military rank (enlisted or officer), and military branch (combat-related, technical service, administrative support, or special) were included as covariates.

Body mass index was calculated as self-reported weight (kg) divided by self-reported height squared (m^2) and classified as underweight, normal weight, overweight, or obese based on the WHO’s cut-points for the Asian population (World Health Organization, 2000).

Military branch was classified into the following four groups: combat-related

(infantry, armor, artillery, air defense, intelligence, engineering, information/communication, aviation, and aviation control), technical service (ordnance, quartermaster, transportation, chemical, weather, facilities, ship handling, management, and air weapon maintenance), administrative support (adjutant, military police, finance, troop information, instruction, and personnel administration), and special (medical service, judicial affairs, chaplain, and martial music).

Statistical analysis

For PA and covariates with missing data, we conducted multiple imputations by chained equations for missing values with 20 imputed data sets. Furthermore, we presented the participants characteristics with observed datasets for each variable, the imputed datasets, and complete dataset.

We conducted a multivariable logistic regression to calculate the odds ratios and 95% confidence intervals of psychological distress and suicidal ideation based on the amount of aerobic PA and MSA, respectively. A multivariate analysis was conducted, adjusted for age and sex, for Model 1. In Model 2, we adjusted for Model 1 plus body mass index, education level, marital status, and smoking status. Military unit, military rank, and branch were further adjusted in Model 3.

Joint analyses of aerobic PA and MSA with psychological distress were conducted. The lowest amount of aerobic PA and 0-2 days/wk of MSA group was used as the reference group. In addition, age, sex, body mass index, education level, marital and smoking status, and military unit, rank, and branch were adjusted in the analysis model. All statistical analyses were performed using Stata SE version 17.0, and P value < 0.05 were considered statistically significant.

5.3. Results

Participants' characteristics are shown in Table 8. We presented the sample characteristics using the observed, imputed, and complete cases datasets. Of the 14,001 participants, 6.66% had psychological distress, and 3.09% had experienced suicidal ideation. Based on the observed dataset, most participants were male (96.65%), aged <25 years old (72.59%), of normal weight (49.75%), attended or had graduated from university or college (78.95%), unmarried (84.69%), non-smoker (51.02%), in the Army (58.77%), enlisted (55.66%), and in the combat-related branch (62.72%). Participants' characteristics across the amount of aerobic PA is shown in Appendix 14.

Table 8. Characteristics of sample in this study (continued)

	Observed data		**Imputed data (n=14,001)**	**Complete data (n=8,309)**
Characteristics	**N available**	**%**	**%**	**%**
Physical activity (MET-min/wk)	9,216			
0-999	1,538	16.69	17.12	16.22
1000-1999	1,460	15.84	16.07	15.96
2000-3999	2,500	27.13	27.16	27.06
4000-5999	1,587	17.22	16.99	17.55
≥ 6000	2,131	23.12	22.67	23.22
Muscle-strengthening activity (days/wk)	13,551			
0	2,838	20.94	20.95	20.98
1	1,718	12.68	12.68	11.51
2	2,142	15.81	15.79	15.92
3	2,483	18.32	18.33	18.11
4	1,219	9.00	9.00	9.35
≥ 5	3,151	23.25	23.25	24.13
Psychological distress	14,001			
No	13,069	93.34	93.34	93.83
Yes	932	6.66	6.66	6.17
Suicidal ideation	14,001			
No	13,568	96.91	96.91	97.04
Yes	433	3.09	3.09	2.96

Table 8. Characteristics of sample in this study

Characteristics	Observed data		Imputed data (n=14,001)	Complete data (n=8,309)
	N available	%	%	%
Sex	13,987			
Male	13,518	96.65	96.64	97.45
Female	469	3.35	3.36	2.55
Age group (year)	13,695			
19-24	9,941	72.59	72.56	75.74
25-29	1,670	12.19	12.19	11.61
30-39	1,398	10.21	10.24	8.44
≥40	686	5.01	5.01	4.21
BMI category (kg/m^2)	13,686			
Underweight (≤18.5)	209	1.53	1.54	1.52
Normal weight (18.5-23)	6,809	49.75	49.71	50.76
Overweight (23-24.9)	3,341	24.41	24.38	23.89
Obese (≥25)	3,327	24.31	24.37	23.83
Education level	13,845			
≤High school graduate	2,527	18.25	18.25	18.46
University or college	10,930	78.95	78.95	79.08
≥Graduate school	388	2.80	2.80	2.46
Marital status	13,738			
Unmarried	11,635	84.69	84.08	86.44
Divorced/separated/widowed	387	2.82	3.66	2.36
Married	1,716	12.49	12.26	11.20
Smoking status	13,770			
Non-smoker	7,025	51.02	51.00	50.25
Former smoker	1,053	7.65	8.35	7.80
Current smoker	5,692	41.34	40.65	41.95
Military unit	13,992			
Army	8,223	58.77	58.77	58.85
Navy/Marine corps	2,666	19.05	19.68	18.31
Air force	3,103	22.18	22.16	22.84
Military rank	13,849			
Enlisted	7,709	55.66	55.64	60.02
Officer	6,140	44.34	44.36	39.98
Military branch	13,639			
Combat	8,554	62.72	62.71	63.14
Technical service	3,525	25.85	26.15	25.84
Administrative support	971	7.12	6.94	7.09
Special	589	4.32	4.21	3.94

Table 9 shows the ORs (95%CIs) of the prevalence of psychological distress across the amount of aerobic PA and frequency of MSA. The multivariable logistic regression revealed that all amount of aerobic PA was associated with lower odds of psychological distress compared to 0-999 MET-min/wk of aerobic PA, after adjusting for potential confounders. However, there was no linear trend (*p* for trend

= 0.075). In addition, more frequent MSA was also associated with lower odds of psychological distress. There was a slightly higher OR at five or more days per week of MSA; however, there was a significant linear association (p for trend <0.001). Results of the sensitivity analysis using complete cases dataset is shown in Appendix 15. It was similar with the main findings.

Table 9. Logistic regression between the amount of aerobic PA and frequency of MSA and psychological distress with multiple imputations.

	ORs (95% CIs) of psychological distress		
Physical activity	**Model 1**	**Model 2**	**Model 3**
Aerobic PA (MET-min/wk)			
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	**0.62 (0.48-0.80)**	**0.62 (0.48-0.80)**	**0.60 (0.46-0.77)**
2000-3999	**0.65 (0.51-0.82)**	**0.65 (0.51-0.82)**	**0.63 (0.50-0.80)**
4000-5999	**0.59 (0.46-0.77)**	**0.59 (0.46-0.77)**	**0.57 (0.43-0.74)**
≥ 6000	0.82 (0.65-1.03)	0.81 (0.64-1.03)	**0.76 (0.60-0.97)**
P for trend	0.193	0.183	0.075
MSA (days/wk)			
0	1.00 (reference)	1.00 (reference)	1.00 (reference)
1	**0.60 (0.48-0.76)**	**0.60 (0.48-0.76)**	**0.62 (0.49-0.78)**
2	**0.51 (0.42-0.64)**	**0.51 (0.41-0.64)**	**0.53 (0.42-0.66)**
3	**0.46 (0.37-0.57)**	**0.46 (0.37-0.57)**	**0.45 (0.36-0.56)**
4	**0.38 (0.28-0.51)**	**0.38 (0.28-0.52)**	**0.37 (0.27-0.50)**
≥ 5	**0.49 (0.40-0.59)**	**0.49 (0.41-0.60)**	**0.45 (0.37-0.55)**
P for trend	<0.001	<0.001	<0.001

PA, physical activity; MSA, muscle-strengthening activity; OR, odds ratio; CI, confidence interval.
Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

Table 10 shows the ORs (95%CIs) of the prevalence of suicidal ideation across the amount of aerobic PA and frequency of MSA. As a result of the multivariate logistic regression analysis, there was no association between aerobic PA and suicidal ideation, even after adjusting for confounding variables. A significant linear relationship was found between MSA and suicidal ideation (P for trend <0.001); however, it was irregular. A sensitivity analysis using the complete cases is shown in Appendix 16.

Table 10. Logistic regression between the amount of aerobic PA and frequency of MSA and suicidal ideation with multiple imputations.

	ORs (95% CIs) of psychological distress		
Physical activity	**Model 1**	**Model 2**	**Model 3**
Aerobic PA (MET-min/wk)			
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	0.81 (0.55-1.20)	0.81 (0.55-1.21)	0.79 (0.53-1.17)
2000-3999	0.80 (0.58-1.12)	0.81 (0.57-1.13)	0.77 (0.55-1.09)
4000-5999	0.71 (0.48-1.06)	0.72 (0.49-1.07)	0.68 (0.46-1.01)
≥ 6000	0.84 (0.59-1.20)	0.84 (0.58-1.20)	0.78 (0.54-1.12)
P for trend	0.315	0.316	0.160
MSA (days/wk)			
0	1.00 (reference)	1.00 (reference)	1.00 (reference)
1	**0.68 (0.49-0.94)**	**0.68 (0.49-0.95)**	**0.71 (0.51-0.99)**
2	**0.73 (0.54-0.98)**	**0.73 (0.54-0.99)**	0.77 (0.57-1.04)
3	**0.55 (0.40-0.75)**	**0.55 (0.41-0.75)**	**0.56 (0.51-0.76)**
4	0.71 (0.50-1.03)	0.72 (0.50-1.03)	0.71 (0.49-1.02)
≥ 5	**0.48 (0.36-0.64)**	**0.48 (0.36-0.65)**	**0.45 (0.33-0.60)**
P for trend	<0.001	<0.001	<0.001

PA, physical activity; MSA, muscle-strengthening activity; OR, odds ratio; CI, confidence interval.
Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

Figure 8 shows the odds ratios (95%CIs) for a joint association between aerobic PA, MSA, and psychological distress. Compared to the lowest amount of aerobic PA and 0-2 days/wk of MSA, all groups showed significantly lower odds of psychological distress, except for 4,000 or more MET-min/wk of aerobic PA and low frequency of MSA.

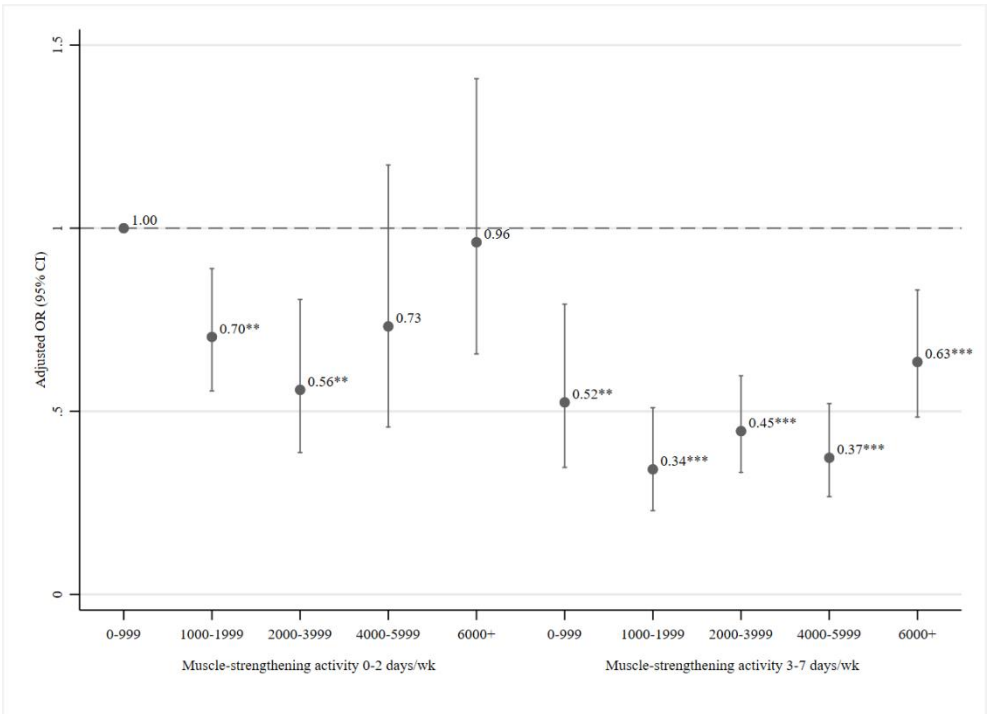

Figure 8. Joint associations between aerobic PA, MSA and psychological distress

Figure 9 shows the odds ratios (95%CIs) for a joint association between aerobic PA, MSA, and suicidal ideation. Compared to the lowest amount of aerobic PA and 0-2 days/wk of MSA, there was no relationship between aerobic PA and suicidal ideation in the MSA of 2 days or less. In contrast, in the MSA of 3 or more days, aerobic PA of 2,000-4,000 MET-min/wk was significantly associated with a lower prevalence of suicidal ideation.

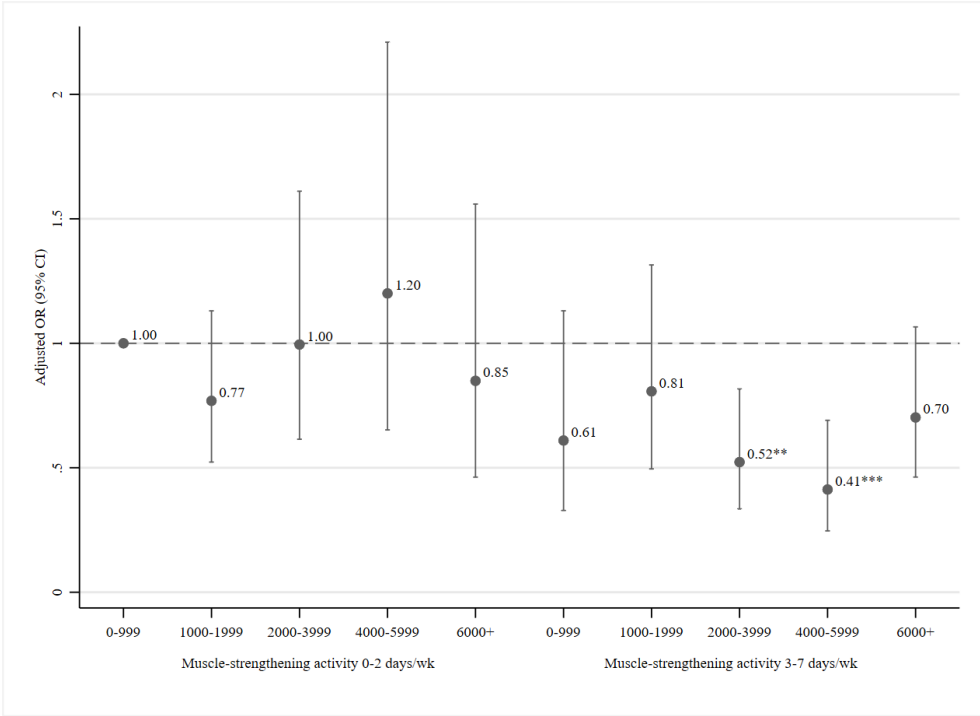

Figure 9. Joint associations between aerobic PA, MSA and suicidal ideation

5.4. Discussion

We examined the independent and joint associations between aerobic PA and MSA with psychological distress and suicidal ideation in Korean military personnel. We examined the independent association between aerobic PA and psychological distress and found that compared to the lowest amount of aerobic PA, more aerobic PA was associated with a lower prevalence of psychological distress. However, it was not significantly lower in the highest amount. There was a dose-response association between frequency of MSA and psychological distress up to the frequency of 4 days or less per week. Furthermore, the prevalence slightly increased at the frequency of 5 days/wk or more; however, it was still significantly low.

Consistent with our findings, a study that examined the association between aerobic PA and psychological distress in military personnel found a significant association (Perez, Dong, Beckman, & Meadows, 2022) between meeting the aerobic PA recommendation and reduced odds of psychological distress in U.S. military personnel. Similarly, previous studies conducted on the general population reported a significant association between regular aerobic PA and reduced odds of psychological distress (Kim et al., 2012; Perales, Pozo-Cruz, & Pozo-Cruz, 2014; Sheikh, Vancampfort, & Stubbs, 2018; Sloan et al., 2013). However, in our study, excessive amounts of aerobic PA were not associated with reduced odds of psychological distress. These results were consistent with the results of previous studies that examined the dose-response curve between aerobic PA and psychological distress (Kim et al., 2012), depression (Kim et al., 2018), and anxiety symptoms (Kim et al., 2020).

To our best knowledge, only one study investigated the association between

frequency of MSA and psychological distress in military personnel (Hruby et al., 2021). Compared to no MSA, this study reported a significantly lower prevalence of depression and anxiety disorder, only at a low frequency of 1-2 days/wk, and found no association at the frequency of ≥ 3 days/wk.

In our study, we examined how the association between aerobic PA and psychological distress varied based on the frequency of MSA. As a result of the analysis, in the < 2 days/wk of MSA group, there were significantly higher odds of psychological distress at the lowest or highest amount of aerobic PA compared to 2000-3999 MET-min/wk of aerobic PA. However, the group that participated in MSA for more than 3 days had overall lower odds of psychological pain compared to those who participated for less than 2 days. Similar to our findings, previous studies reported that MSA combined with aerobic PA was associated with lower psychological distress and depression than aerobic PA alone (Bennie et al., 2020; De Cocker, Teychenne, White, & Bennie, 2020).

Our study found no association between aerobic PA and MSA with suicidal ideation. These results were consistent with previous studies that reported that there was no significant relationship between aerobic PA (Gutierrez, Davidson, Friese, & Forster, 2016) and MSA (Oakey-Frost et al., 2022) and suicidal ideation in military personnel. However, a meta-analysis on the general population reported a significant relationship between PA and suicidal ideation (Vancampfort et al., 2018). A study found that soldiers who received exercise therapy more than 8 times had a lower risk of suicidal ideation, compared to soldiers who did not. This result contradicted our findings (Meerwijk, Sayko Adams, Larson, Highland, & Harris, 2022).

Although no independent association was found between aerobic PA and MSA and suicidal ideation, in a joint analysis, high frequency of MSA and a certain

amount of aerobic PA were associated with a lower prevalence of suicidal ideation. No study has examined the combined relationship between aerobic PA and MSA in military personnel, especially in Korean adults. The prevalence of suicidal ideation was lower in adults who participated in both aerobic and MSA than in adults who participated in only one activity (Kim et al., 2021).

In contrast to reported positive effects of leisure time PA on mental health, some studies report that occupational PA was not associated with mental health or positively associated with mental disorders (Teychenne et al., 2020; White et al., 2017). A study found that leisure time PA was strongly associated with lower prevalence of psychological distress; however, not with occupational PA (Mizrahi et al., 2022).

Due to the nature of military duties, military personnel are exposed to higher amounts of PA than the general population (Schilz & Sammito, 2021). A large amount of occupational PA is associated with high levels of stress (Martins & Lopes, 2013). Therefore, higher amounts of PA in soldiers may be detrimental to their mental health.

Although we did not investigate PA by classifying it into leisure time and occupational PA, most aerobic PA of military personnel could be occupational. However, since MSA is generally structured and planned, it tends to be performed mostly in leisure time (Bennie et al., 2020). Therefore, MSA may be considered as part of leisure time PA. A high frequency of MSA may mean a high percentage of leisure time PA in the total PA among military personnel. Hence, the group with high frequency of MSA may show a lower odd of psychological distress, despite excessive aerobic PA. However, to confirm an obvious association, further research is required to investigate the PA of military personnel by domain and analyze the

relationship between mental disorders.

This study has some limitations. First, self-reported PA was used. Self-reported PA can differ significantly from actual PA (Prince et al., 2008). Hence, it is necessary to analyze the PA evaluated using an objective tool. Second, given the study's cross-sectional nature, we were unable to draw conclusions regarding causality or direction. It is necessary to confirm the effect of PA on soldiers' mental health through a longitudinal study in the future.

In conclusion, this study investigated an independent and joint association between the amount of aerobic PA and frequency of MSA and psychological distress in Korean military personnel. Certain amounts of aerobic PA and MSA were associated with low psychological distress. In addition, aerobic PA with high frequency of MSA was associated with lower odds of psychological distress.

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CHAPTER 6. CONCLUSION

This study aimed to synthesize related evidence through a systematic literature review on military PA and mental health. Although the evidence was insufficient to draw an overall association between PA and mental health in military personnel, we mapped the evidence available in research area and identified new evidence on some mental health variables, such as anxiety and PTSD.

Second, the association between PA and mental health for the first time in Korean military personnel was examined. We conducted two cross-sectional studies to analyze the dose-response association between amount of PA and psychological distress and identify the joint association between them.

Our findings showed that (1) there was a j-shaped association between PA and psychological distress in Korean military personnel. (2) Approximately 1,500-2,000 MET-min/wk was the optimal amount of PA related with lowest prevalence of distress. (3) PA above optimal amount was still associated with less psychological distress than physical inactivity. (4) Aerobic PA with MSA was associated a lower odd of psychological distress compared to only aerobic PA.

Due to the nature of military personnel' duties, they carry out a lot of work-related physical activities compared to the general population. Mental health management plans should be prepared for military personnel who perform excessive PA. Conversely, while military personnel are, on average, physically active, based on our data, some military personnel with low levels of PA do not meet the WHO recommendations. It is necessary to increase the PA of military personnel who are less physically active, especially during leisure time.

However, there was little evidence regarding the association between PA and mental health in Korean military personnel. In the future, to draw a comprehensive conclusion on the relationship between PA and mental health in active-duty military personnel, additional evidence based on longitudinal and interventional studies should be accumulated. In addition, it is necessary to perform a meta-analysis using the accumulated evidence.

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APPENDIX

Appendix 1. PRISMA item checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	14
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	-
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	14
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	15
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	16
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	15-16
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	15-16
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	16-17
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	17
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	17
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	17

Section and Topic	Item #	Checklist item	Location where item is reported
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	17-18
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	-
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	-
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	-
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	-
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	-
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	-
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	-
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	17-18
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	-
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	19
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	20
Study characteristics	17	Cite each included study and present its characteristics.	21
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	23
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	24-27
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	22-23
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	-

Section and Topic	Item #	Checklist item	Location where item is reported
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	-
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	-
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	-
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	-
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	28
	23b	Discuss any limitations of the evidence included in the review.	30
	23c	Discuss any limitations of the review processes used.	30
	23d	Discuss implications of the results for practice, policy, and future research.	-
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	-
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	-
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	-
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	-
Competing interests	26	Declare any competing interests of review authors.	-
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	-

Appendix 2. Search Strategy

PubMed (~ March 7, 2022)

	Query	Results
1	((((((((((("physical activity"[Title/Abstract]) OR (exercise[Title/Abstract])) OR (training[Title/Abstract])) OR (sports[Title/Abstract])) OR (walk*[Title/Abstract])) OR (running[Title/Abstract])) OR (jogging[Title/Abstract])) OR (yoga[Title/Abstract])) OR (pilates[Title/Abstract])) OR (qi-gong[Title/Abstract])) OR (tai-chi[Title/Abstract])) OR (sedentary[Title/Abstract])) OR (inactivity[Title/Abstract])	1,025,051
2	((((((((((((((((((((((("mental health"[Title/Abstract]) OR ("mental disorder"[Title/Abstract])) OR ("mental disorders"[Title/Abstract])) OR ("mental illness"[Title/Abstract])) OR (emotion*[Title/Abstract])) OR (psycholog*[Title/Abstract])) OR (psychiatric[Title/Abstract])) OR (depress*[Title/Abstract])) OR (anxiety[Title/Abstract])) OR (loneliness[Title/Abstract])) OR (stress*[Title/Abstract])) OR (distress[Title/Abstract])) OR (mood[Title/Abstract])) OR (self-efficacy[Title/Abstract])) OR (self-esteem[Title/Abstract])) OR (self-concept[Title/Abstract])) OR (trauma*[Title/Abstract])) OR (PTSD[Title/Abstract])) OR (sucid*[Title/Abstract])) OR (panic[Title/Abstract])) OR (resilien*[Title/Abstract])) OR (well-being[Title/Abstract])) OR (agitation[Title/Abstract])) OR (confidence[Title/Abstract])) OR (sleep[Title/Abstract])) OR ("quality of life"[Title/Abstract])) OR (QOL[Title/Abstract])	3,505,429
3	((((((((((((military[Title/Abstract]) OR ("armed forces"[Title/Abstract])) OR (soldier*[Title/Abstract])) OR (servicemember*[Title/Abstract])) OR (servicemen[Title/Abstract])) OR (servicewomen[Title/Abstract])) OR (army[Title/Abstract])) OR (navy[Title/Abstract])) OR ("air force"[Title/Abstract])) OR ("marine corps"[Title/Abstract])) OR ("self-defense force"[Title/Abstract])) OR ("self-defense forces"[Title/Abstract])) OR (conscript*[Title/Abstract])) OR (cadet*[Title/Abstract])	85,813
4	#1 AND #2 AND #3	4,217

EMBASE (~ March 5, 2022)

	Query	Results
1	'physical activity':ab,ti OR exercise:ab,ti OR training:ab,ti OR sports:ab,ti OR walk*:ab,ti OR running:ab,ti OR jogging:ab,ti OR yoga:ab,ti OR pilates:ab,ti OR 'qi gong':ab,ti OR 'tai chi':ab,ti OR sedentary:ab,ti OR inactivity:ab,ti	1,025,051
2	'mental health':ab,ti OR 'mental disorder':ab,ti OR 'mental disorders':ab,ti OR 'mental illness':ab,ti OR emotion*:ab,ti OR psycholog*:ab,ti OR psychiatric:ab,ti OR depress*:ab,ti OR anxiety:ab,ti OR loneliness:ab,ti OR stress*:ab,ti OR distress:ab,ti OR mood:ab,ti OR 'self efficacy':ab,ti OR 'self esteem':ab,ti OR 'self concept':ab,ti OR trauma*:ab,ti OR ptsd:ab,ti OR sucid*:ab,ti OR panic:ab,ti OR 'well being':ab,ti OR resilien*:ab,ti OR agitation:ab,ti OR confidence:ab,ti OR sleep:ab,ti OR 'quality of life':ab,ti OR qol	3,505,429
3	military:ab,ti OR 'armed forces':ab,ti OR servicemember*:ab,ti OR servicemen:ab,ti OR servicewomen:ab,ti OR army:ab,ti OR navy:ab,ti OR 'air force':ab,ti OR 'marine corps':ab,ti OR 'self-defense force':ab,ti OR 'self-defense forces':ab,ti OR conscript*:ab,ti OR cadet*	85,813
4	#1 AND #2 AND #3	4,217

CINAHL (~ March 5, 2022)

	Query	Results
1	TI ("physical activity" OR exercise OR training OR sports OR walk* OR running OR jogging OR yoga OR pilates OR qi-gong OR tai-chi OR sedentary OR inactivity) OR AB ("physical activity" OR exercise OR training OR sports OR walk* OR running OR jogging OR yoga OR pilates OR qi-gong OR tai-chi OR sedentary OR inactivity)	466,739
2	TI ("mental health" OR "mental disorder" OR "mental disorders" OR "mental illness" OR emotion* OR psycholog* OR psychiatric OR depress* OR anxiety OR loneliness OR stress* OR distress OR mood OR self-efficacy OR self-esteem OR self-concept OR trauma* OR PTSD OR sucid* OR panic OR well-being OR resilien* OR agitation OR confidence OR sleep OR "quality of life" OR QOL) OR AB ("mental health" OR "mental disorder" OR "mental disorders" OR "mental illness" OR emotion* OR psycholog* OR psychiatric OR depress* OR anxiety OR loneliness OR stress* OR distress OR mood OR self-efficacy OR self-esteem OR self-concept OR trauma* OR PTSD OR sucid* OR panic OR well-being OR resilien* OR agitation OR confidence OR sleep OR "quality of life" OR QOL)	1,149,674
3	TI (military OR "armed forces" OR soldier* OR servicemember* OR servicemen OR servicewomen OR army OR navy OR "air force" OR "marine corps" OR "self-defense force" OR "self-defense forces" OR conscript* OR cadet*) OR AB (military OR "armed forces" OR soldier* OR servicemember* OR servicemen OR servicewomen OR army OR navy OR "air force" OR "marine corps" OR "self-defense force" OR "self-defense forces" OR conscript* OR cadet*)	29,457
4	S1 AND S2 AND S3	1,951

PsycINFO (~ March 7, 2022)

	Query	Results
1	TI ("physical activity" OR exercise OR training OR sports OR walk* OR running OR jogging OR yoga OR pilates OR qi-gong OR tai-chi OR sedentary OR inactivity) OR AB ("physical activity" OR exercise OR training OR sports OR walk* OR running OR jogging OR yoga OR pilates OR qi-gong OR tai-chi OR sedentary OR inactivity)	430,671
2	TI ("mental health" OR "mental disorder" OR "mental disorders" OR "mental illness" OR emotion* OR psycholog* OR psychiatric OR depress* OR anxiety OR loneliness OR stress* OR distress OR mood OR self-efficacy OR self-esteem OR self-concept OR trauma* OR PTSD OR sucid* OR panic OR well-being OR resilien* OR agitation OR confidence OR sleep OR "quality of life" OR QOL) OR AB ("mental health" OR "mental disorder" OR "mental disorders" OR "mental illness" OR emotion* OR psycholog* OR psychiatric OR depress* OR anxiety OR loneliness OR stress* OR distress OR mood OR self-efficacy OR self-esteem OR self-concept OR trauma* OR PTSD OR sucid* OR panic OR well-being OR resilien* OR agitation OR confidence OR sleep OR "quality of life" OR QOL)	1,867,860
3	TI (military OR "armed forces" OR soldier* OR servicemember* OR servicemen OR servicewomen OR army OR navy OR "air force" OR "marine corps" OR "self-defense force" OR "self-defense forces" OR conscript* OR cadet*) OR AB (military OR "armed forces" OR soldier* OR servicemember* OR servicemen OR servicewomen OR army OR navy OR "air force" OR "marine corps" OR "self-defense force" OR "self-defense forces" OR conscript* OR cadet*)	42,191
4	S1 AND S2 AND S3	3,622

SPORTDiscus (~ March 5, 2022)

	Query	Results
1	TI ("physical activity" OR exercise OR training OR sports OR walk* OR running OR jogging OR yoga OR pilates OR qi-gong OR tai-chi OR sedentary OR inactivity) OR AB ("physical activity" OR exercise OR training OR sports OR walk* OR running OR jogging OR yoga OR pilates OR qi-gong OR tai-chi OR sedentary OR inactivity)	626,291
2	TI ("mental health" OR "mental disorder" OR "mental disorders" OR "mental illness" OR emotion* OR psycholog* OR psychiatric OR depress* OR anxiety OR loneliness OR stress* OR distress OR mood OR self-efficacy OR self-esteem OR self-concept OR trauma* OR PTSD OR sucid* OR panic OR well-being OR resilien* OR agitation OR confidence OR sleep OR "quality of life" OR QOL) OR AB ("mental health" OR "mental disorder" OR "mental disorders" OR "mental illness" OR emotion* OR psycholog* OR psychiatric OR depress* OR anxiety OR loneliness OR stress* OR distress OR mood OR self-efficacy OR self-esteem OR self-concept OR trauma* OR PTSD OR sucid* OR panic OR well-being OR resilien* OR agitation OR confidence OR sleep OR "quality of life" OR QOL)	209,646
3	TI (military OR "armed forces" OR soldier* OR servicemember* OR servicemen OR servicewomen OR army OR navy OR "air force" OR "marine corps" OR "self-defense force" OR "self-defense forces" OR conscript* OR cadet*) OR AB (military OR "armed forces" OR soldier* OR servicemember* OR servicemen OR servicewomen OR army OR navy OR "air force" OR "marine corps" OR "self-defense force" OR "self-defense forces" OR conscript* OR cadet*)	14,381
4	S1 AND S2 AND S3	865

Web of Science (~ March 6, 2022)

	Query	Results
1	"physical activity" OR exercise OR training OR sports OR walk* OR running OR jogging OR yoga OR pilates OR qi-gong OR tai-chi OR sedentary OR inactivity	2,459,824
2	"mental health" OR "mental disorder" OR "mental disorders" OR "mental illness" OR emotion* OR psycholog* OR psychiatric OR depress* OR anxiety OR loneliness OR stress* OR distress OR mood OR self-efficacy OR self-esteem OR self-concept OR trauma* OR PTSD OR sucid* OR panic OR well-being OR resilien* OR agitation OR confidence OR sleep OR "quality of life" OR QOL	5,013,347
3	military OR "armed forces" OR soldier* OR servicemember* OR servicemen OR servicewomen OR army OR navy OR "air force" OR "marine corps" OR "self-defense force" OR "self-defense forces" OR conscript* OR cadet*	222,599
4	#3 AND #2 AND #1	5,125

Appendix 3. Newcastle-Ottawa Scale for cross-sectional studies

Selection: (Maximum of 4 stars)

1. Representativeness of the sample:
   a) Truly representative of the average in the target population. (all subjects or random sampling) *
   b) Somewhat representative of the average in the target population. (non-random sampling) *
   c) Selected group of users.
   d) No description of the sampling strategy.
2. Sample size:
   a) Justified and satisfactory. *
   b) Not justified.
3. Ascertainment of exposure:
   a) Validated measurement tool. *
   b) Non-validated measurement tool, but the tool is available or described. *
   c) No description of the measurement tool.
4. Non-respondents:
   a) Comparability between respondents and non-respondents characteristics is established, and the response rate is satisfactory. *
   b) The response rate is unsatisfactory, or the comparability between respondents and non-respondents is unsatisfactory.
   a) No description of the response rate or the characteristics of the responders and the non-responders.

Comparability: (Maximum of 2 stars)

1. The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled:
   a) The study controls for the most important factor (sex, age). *
   b) The study controls for at least one additional factor on the following list. *
   (body mass index, smoking status, educational level, military branch/rank/unit, marital status)

Outcome: (Maximum of 2 stars)

1. Assessment of outcome:
   a) Independent blind assessment. *
   b) Record linkage. *
   c) Self-report. *
   d) No description.
2. Statistical test:
   a) The statistical test used to analyze the data is clearly described and appropriate, and the measurement of the association is presented, including confidence intervals or probability level (p-value). *
   b) The statistical test is not appropriate, not described, or incomplete.

Appendix 4. Newcastle-Ottawa Scale for cohort studies

Selection: (Maximum of 4 stars)

1. Representativeness of the exposed cohort
   a) truly representative of the average military personnel in the community *
   b) somewhat representative of the average military personnel in the community *
   c) selected group of users eg nurses, volunteers
   d) no description of the derivation of the cohort
2. Selection of the non-exposed cohort
   a) drawn from the same community as the exposed cohort *
   b) drawn from a different source
   c) no description of the derivation of the non-exposed cohort
3. Ascertainment of exposure
   a) secure record (eg surgical records) *
   b) structured interview *
   c) written self-report
   d) no description
4. Demonstration that outcome of interest was not present at start of study
   a) yes *
   b) no

Comparability: (Maximum of 2 stars)

1. Comparability of cohorts on the basis of the design or analysis
   a) study controls for age and sex *
   b) study controls for any additional factor *
      (body mass index, smoking status, educational level, military branch/rank/unit, marital status)

Outcome: (Maximum of 3 stars)

1. Assessment of outcome
   a) independent blind assessment *
   b) record linkage *
   c) self-report
   d) no description
2. Was follow-up long enough for outcomes to occur
   a) yes (≥ 1 year) *
   b) no
3. Adequacy of follow up of cohorts
   a) complete follow up - all subjects accounted for *
   b) subjects lost to follow up unlikely to introduce bias - small number lost - > 70 %
      follow up, or description provided of those lost *
   c) follow up rate < 70 % and no description of those lost
   d) no statement

Appendix 5. Characteristics of study samples across amount of PA

Characteristics	Total	Amount of PA (MET-min/wk)				
		0-999	1000-1999	2000-3999	4000-5999	≥6000
Psychological distress						
No	93.34	16.76	16.26	27.36	17.19	22.43
Yes	6.66	22.07	13.44	24.32	14.24	25.92
Suicidal ideation						
No	96.91	17.07	16.05	27.10	17.00	22.78
Yes	3.09	18.64	14.46	26.32	15.48	25.12
Sex						
Male	96.65	16.47	15.83	27.28	17.28	23.14
Female	3.35	35.82	22.91	23.69	8.56	9.01
Age group (year)						
19-24	72.56	15.36	15.00	27.19	17.86	24.59
25-29	12.19	20.52	18.30	25.80	15.41	19.97
30-39	10.24	24.36	19.49	28.28	13.46	14.42
≥40	5.01	19.47	19.13	27.76	15.41	18.24
BMI category (kg/m^2)						
Underweight (≤18.5)	1.54	22.33	20.93	27.09	15.18	14.48
Normal weight (18.5-23)	49.71	17.59	15.71	26.72	17.32	22.66
Overweight (23-24.9)	24.38	15.14	15.59	27.02	17.68	24.57
Obese (≥25)	24.37	17.81	16.98	28.20	15.74	21.28
Education level						
≤High school graduate	18.25	17.87	15.30	25.21	15.99	25.63
University or college	78.95	16.75	16.11	27.61	17.31	22.21
≥Graduate school	2.80	22.53	19.71	27.02	14.47	16.27
Marital status						
Unmarried	84.08	16.11	15.61	27.06	17.56	23.66
Divorced/separated/widowed	3.66	23.71	17.58	26.16	12.68	19.87
Married	12.26	22.05	18.75	28.15	14.38	16.66
Smoking status						
Non-smoker	51.00	19.06	17.48	27.84	16.43	19.19
Former smoker	8.35	17.33	15.05	27.16	18.53	21.93
Current smoker	40.65	14.63	14.51	26.30	17.38	27.17
Military unit						
Army	58.77	14.79	15.06	26.82	18.08	25.25
Navy/Marine corps	19.07	18.87	15.46	28.51	15.53	21.63
Air force	22.16	21.77	19.27	26.89	15.35	16.72
Military rank						
Enlisted	55.64	13.89	14.56	27.14	18.41	26.00
Officer	44.36	21.16	17.96	27.17	15.21	18.49
Military branch						
Combat	62.71	15.84	15.34	26.99	17.30	24.53
Technical service	26.15	17.07	15.87	27.50	17.52	22.03
Administrative support	6.94	22.44	21.23	26.74	14.70	14.90
Special	4.21	27.65	19.67	28.28	12.87	11.54

Appendix 6. Logistic regression between amount of physical activity and psychological distress with complete cases (n=8,331)

Amount of physical activity (MET-min/wk)	OR (95% CI) of psychological distress		
	Model 1	Model 2	Model 3
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	**0.55 (0.40-0.76)**	**0.55 (0.40-0.76)**	0.52 (0.38-0.72)
2000-3999	**0.59 (0.45-0.77)**	**0.59 (0.45-0.78)**	0.57 (0.43-0.75)
4000-5999	**0.56 (0.41-0.76)**	**0.56 (0.41-0.77)**	0.53 (0.39-0.72)
≥ 6000	0.92 (0.71-1.19)	0.92 (0.71-1.20)	0.85 (0.66-1.12)
P for trend	0.884	0.858	0.764

Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status.
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

Appendix 7. Logistic regression between amount of physical activity and suicidal ideation with complete cases (n=8,331)

Amount of physical activity (MET-min/wk)	OR (95% CI) of psychological distress		
	Model 1	Model 2	Model 3
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	0.78 (0.51-1.20)	0.79 (0.51-1.22)	0.76 (0.49-1.18)
2000-3999	0.72 (0.49-1.05)	0.73 (0.49-1.07)	0.70 (0.48-1.04)
4000-5999	**0.64 (0.41-0.99)**	0.65 (0.42-1.00)	**0.61 (0.39-0.96)**
≥ 6000	0.83 (0.57-1.22)	0.82 (0.56-1.20)	0.77 (0.52-1.14)
P for trend	0.326	0.275	0.178

Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status.
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

Appendix 8. Logistic regression between amount of physical activity and psychological distress in male military personnel

Amount of physical activity (MET-min/wk)	OR (95% CI) of psychological distress		
	Model 1	Model 2	Model 3
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	**0.64 (0.56-0.89)**	**0.64 (0.46-0.89)**	**0.62 (0.44-0.86)**
2000-3999	**0.69 (0.54-0.89)**	**0.70 (0.54-0.89)**	**0.67 (0.52-0.86)**
4000-5999	**0.65 (0.49-0.86)**	**0.66 (0.50-0.87)**	**0.62 (0.47-0.83)**
≥ 6000	0.89 (0.69-1.15)	0.89 (0.69-1.15)	0.84 (0.65-1.08)
P for trend	0.732	0.744	0.419

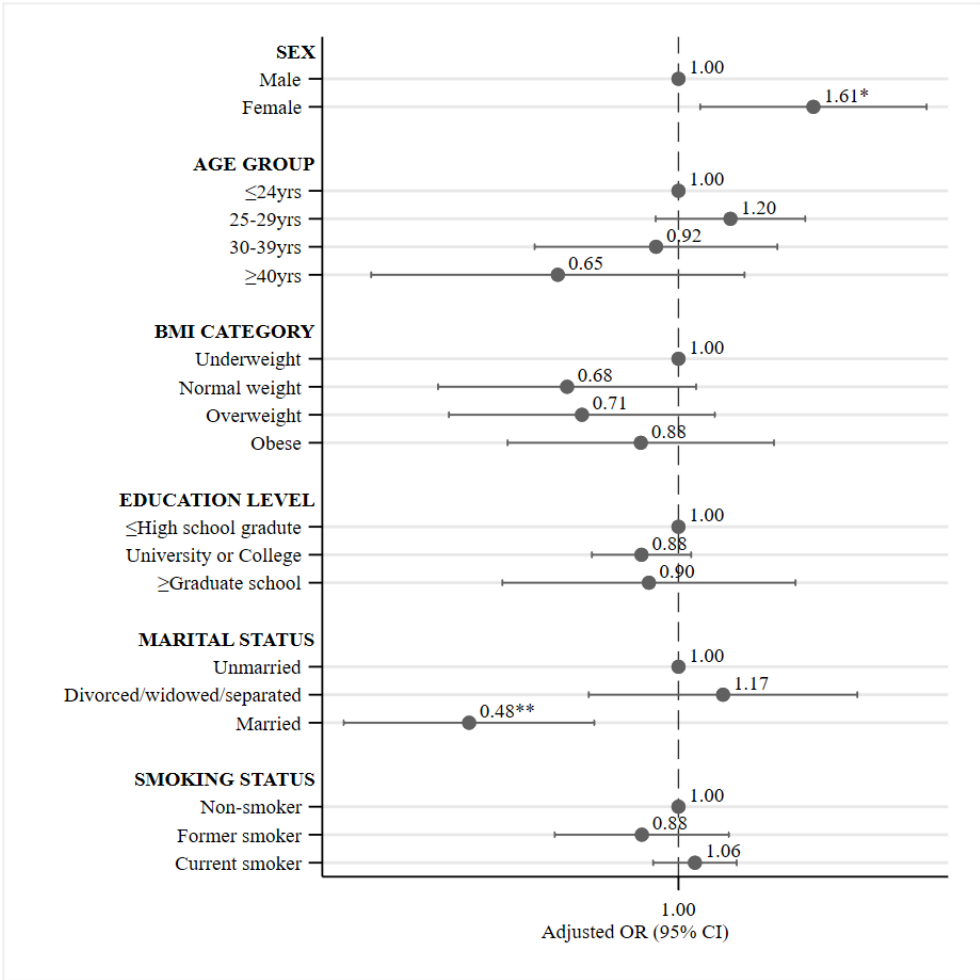
Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status.
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

Appendix 9. Logistic regression between amount of physical activity and suicidal ideation in male military personnel

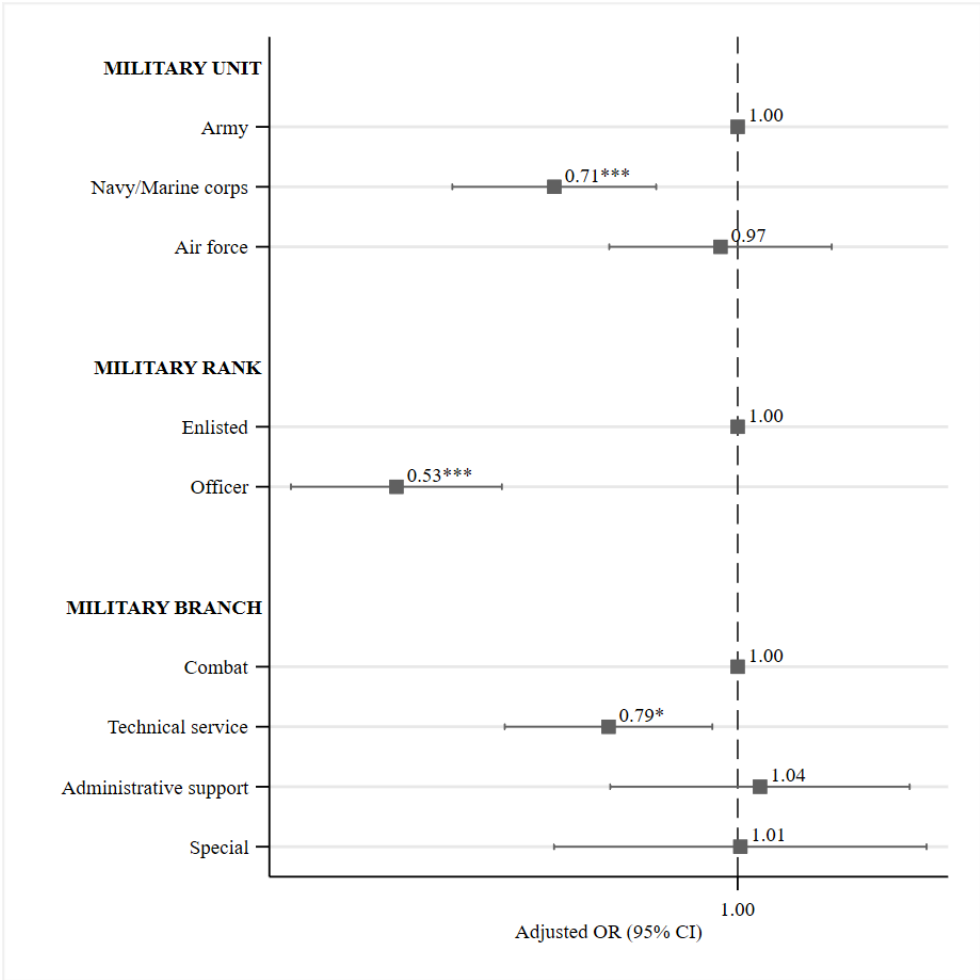
Amount of physical activity (MET-min/wk)	OR (95% CI) of psychological distress		
	Model 1	Model 2	Model 3
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	0.85 (0.54-1.32)	0.85 (0.55-1.33)	0.82 (0.53-1.27)
2000-3999	0.80 (0.56-1.15)	0.82 (0.57-1.17)	0.77 (0.54-1.11)
4000-5999	0.74 (0.49-1.13)	0.75 (0.49-1.15)	0.70 (0.46-1.08)
≥ 6000	0.93 (0.65-1.31)	0.93 (0.65-1.31)	0.85 (0.60-1.21)
P for trend	0.625	0.637	0.348

Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status.
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

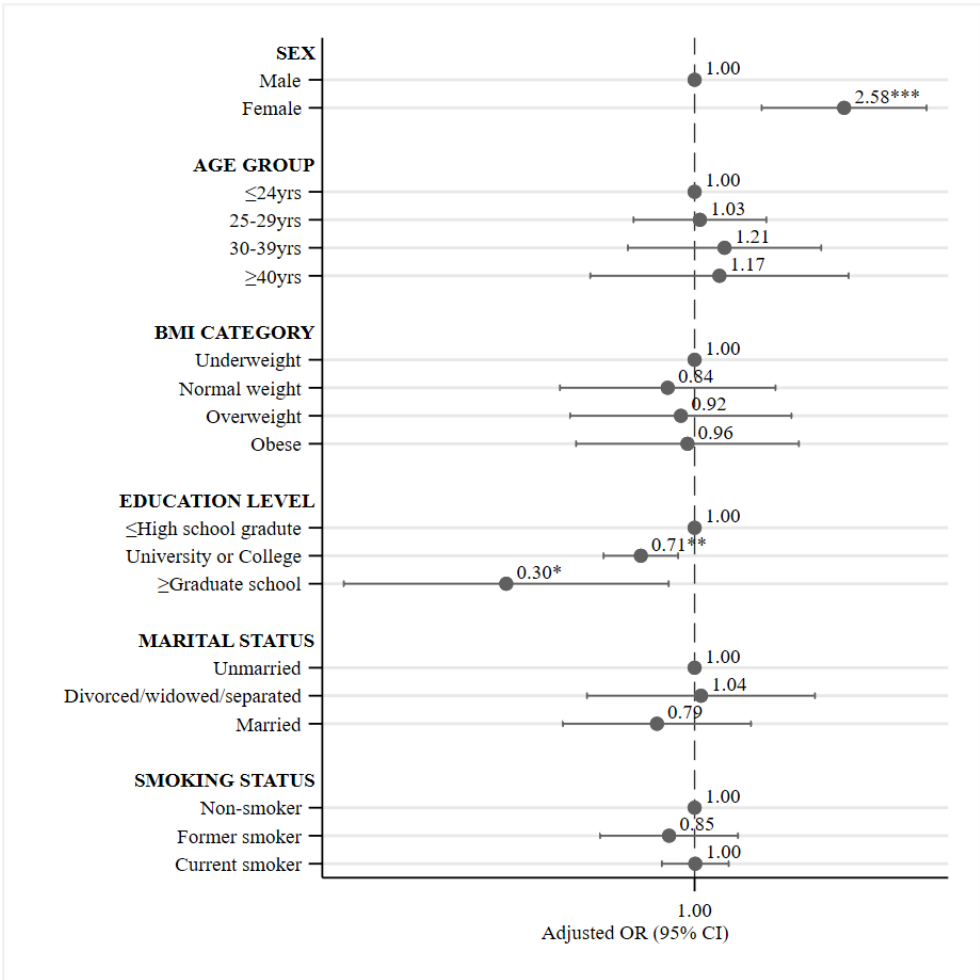
Appendix 10. Odds ratios of psychological distress by sociodemographic factors



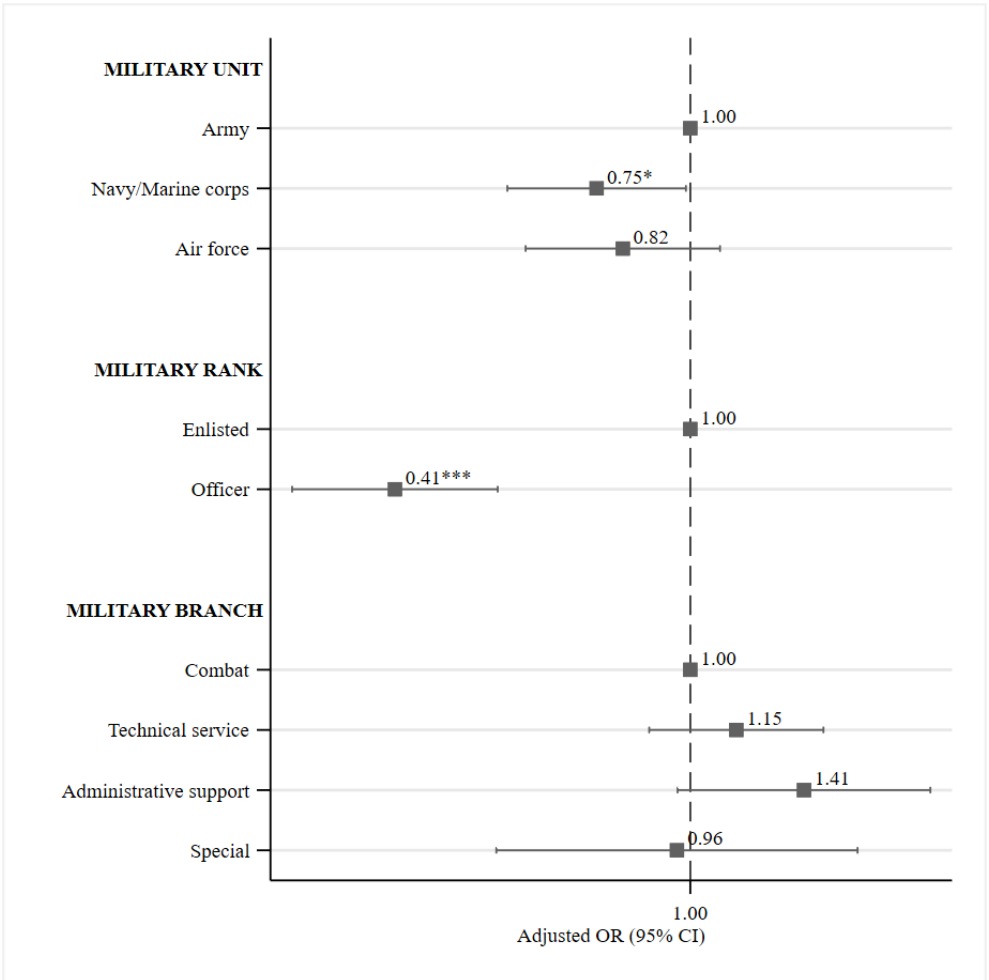
Appendix 11. Odds ratios of psychological distress by military-related factors



Appendix 12. Odds ratios of suicidal ideation by sociodemographic factors



Appendix 13. Odds ratios of suicidal ideation military-related factors



Appendix 14. Characteristics of sample across amounts of aerobic PA(n=14,001)

Characteristics	Total	Amount of aerobic PA (MET-min/wk)				
		0-999	1000-1999	2000-3999	4000-5999	6000-
Psychological distress						
No	93.34	16.76	16.26	27.36	17.19	22.43
Yes	6.66	22.07	13.44	24.32	14.24	25.92
Suicidal ideation						
No	93.34	16.76	16.26	27.36	17.19	22.43
Yes	6.66	22.07	13.44	24.32	14.24	25.92
Sex						
Male	96.65	16.47	15.83	27.28	17.28	23.14
Female	3.35	35.82	22.91	23.69	8.56	9.01
Age group (year)						
19-24	72.56	15.36	15.00	27.19	17.86	24.59
25-29	12.19	20.52	18.30	25.80	15.41	19.97
30-39	10.24	24.36	19.49	28.28	13.46	14.42
≥40	5.01	19.47	19.13	27.76	15.41	18.24
BMI category (kg/m^2)						
Underweight (≤18.5)	1.54	22.33	20.93	27.09	15.18	14.48
Normal weight (18.5-23)	49.71	17.59	15.71	26.72	17.32	22.66
Overweight (23-24.9)	24.38	15.14	15.59	27.02	17.68	24.57
Obese (≥25)	24.37	17.81	16.98	28.20	15.74	21.28
Education level						
≤High school graduate	18.25	17.87	15.30	25.21	15.99	25.63
University or college	78.95	16.75	16.11	27.61	17.31	22.21
≥Graduate school	2.80	22.53	19.71	27.02	14.47	16.27
Marital status						
Unmarried	84.08	16.11	15.61	27.06	17.56	23.66
Divorced/separated/widowed	3.66	23.71	17.58	26.16	12.68	19.87
Married	12.26	22.05	18.75	28.15	14.38	16.66
Smoking status						
Non-smoker	51.00	19.06	17.48	27.84	16.43	19.19
Former smoker	8.35	17.33	15.05	27.16	18.53	21.93
Current smoker	40.65	14.63	14.51	26.30	17.38	27.17
Military unit						
Army	58.77	14.79	15.06	26.82	18.08	25.25
Navy/Marine corps	19.07	18.87	15.46	28.51	15.53	21.63
Air force	22.16	21.77	19.27	26.89	15.35	16.72
Military rank						
Enlisted	55.64	13.89	14.56	27.14	18.41	26.00
Officer	44.36	21.16	17.96	27.17	15.21	18.49
Military branch						
Combat	62.71	15.84	15.34	26.99	17.30	24.53
Technical service	26.15	17.07	15.87	27.50	17.52	22.03
Administrative support	6.94	22.44	21.23	26.74	14.70	14.90
Special	4.21	27.65	19.67	28.28	12.87	11.54
Muscle-strengthening activity (days/wk)						
0	20.95	36.29	21.08	22.43	9.32	10.88
1	12.68	23.27	21.14	29.72	11.78	14.09
2	15.79	15.74	19.95	31.00	16.67	16.65
3	18.33	11.59	15.66	31.25	18.82	22.67
4	9.00	7.85	13.37	30.80	21.81	26.16
5	23.25	5.36	7.52	22.78	23.66	40.69

Appendix 15. Logistic regression between the amount of aerobic PA and frequency of MSA and psychological distress with complete cases(n=8,309)

	ORs (95% CIs) of psychological distress		
Physical activity	**Model 1**	**Model 2**	**Model 3**
Aerobic PA (MET-min/wk)			
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	**0.54 (0.39-0.75)**	**0.54 (0.39-0.74)**	**0.51 (0.37-0.71)**
2000-3999	**0.59 (0.45-0.77)**	**0.59 (0.45-0.78)**	**0.57 (0.43-0.75)**
4000-5999	**0.56 (0.41-0.76)**	**0.56 (0.41-0.77)**	**0.53 (0.39-0.72)**
≥ 6000	0.91 (0.71-1.18)	0.92 (0.71-1.19)	0.85 (0.65-1.11)
P for trend	0.875	0.180	0.772
MSA (days/wk)			
0	1.00 (reference)	1.00 (reference)	1.00 (reference)
1	**0.48 (0.34-0.68)**	**0.49 (0.35-0.69)**	**0.50 (0.35-0.70)**
2	**0.51 (0.38-0.69)**	**0.52 (0.39-0.70)**	**0.53 (0.39-0.71)**
3	**0.50 (0.37-0.66)**	**0.51 (0.38-0.67)**	**0.49 (0.37-0.66)**
4	**0.48 (0.33-0.68)**	**0.49 (0.34-0.70)**	**0.47 (0.33-0.68)**
≥ 5	**0.53 (0.41-0.67)**	**0.54 (0.42-0.70)**	**0.50 (0.38-0.64)**
P for trend	<0.001	<0.001	<0.001

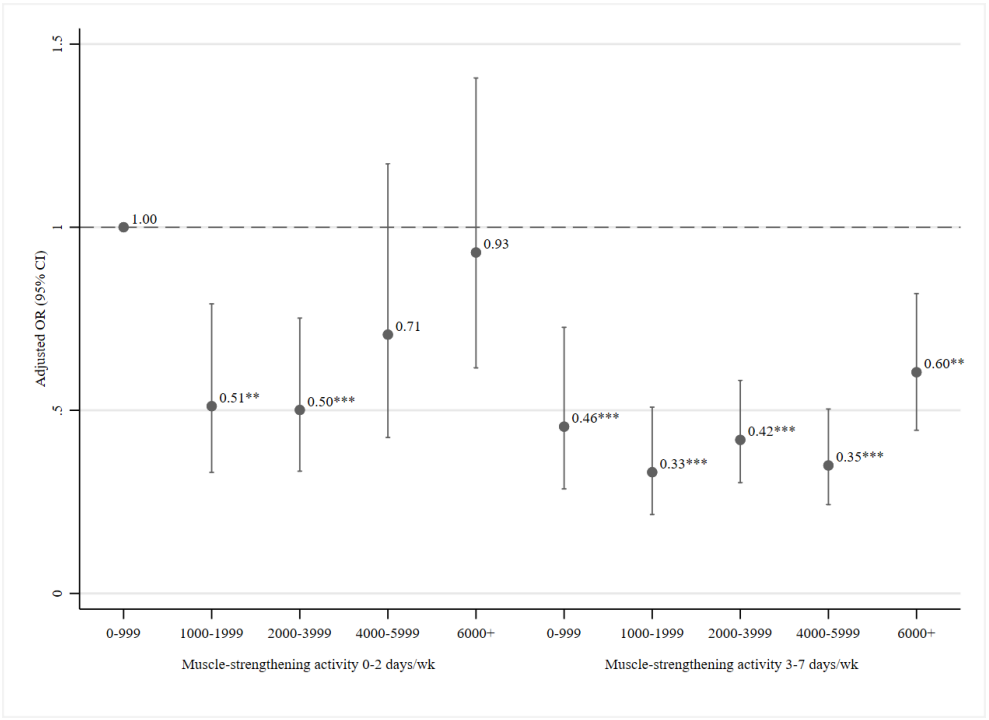
PA, physical activity; MSA, muscle-strengthening activity; OR, odds ratio; CI, confidence interval.
Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

Appendix 16. Logistic regression between the amount of aerobic PA and frequency of MSA and suicidal ideation with complete cases (n=8,309)

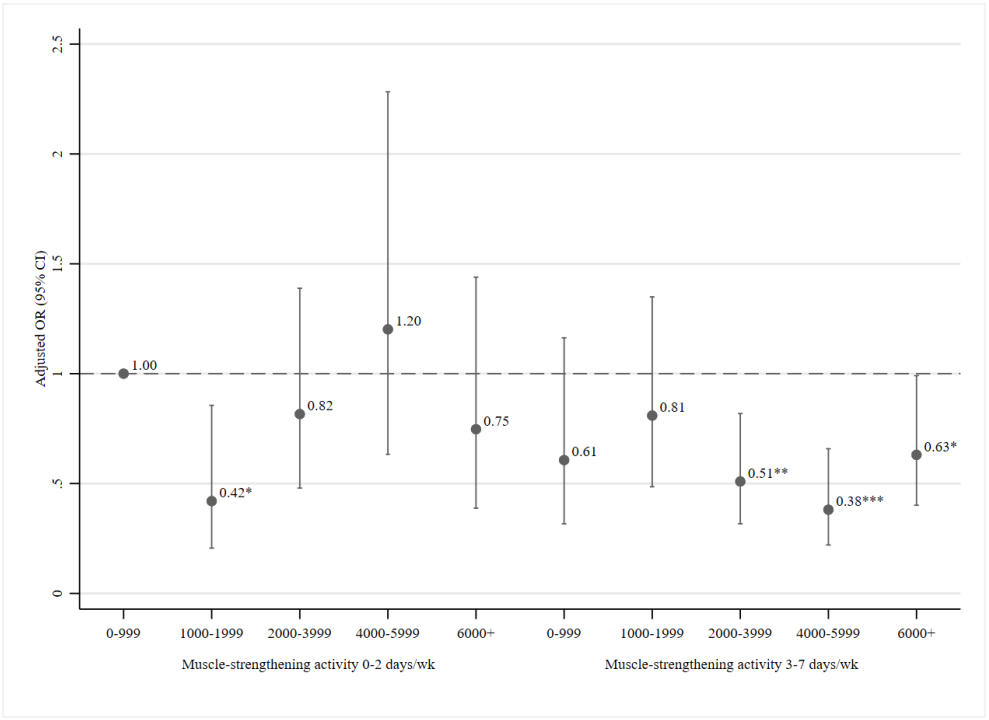
	ORs (95% CIs) of suicidal ideation		
Physical activity	**Model 1**	**Model 2**	**Model 3**
Aerobic PA (MET-min/wk)			
0-999	1.00 (reference)	1.00 (reference)	1.00 (reference)
1000-1999	0.78 (0.50-1.20)	0.79 (0.51-1.22)	0.76 (0.49-1.18)
2000-3999	0.71 (0.49-1.05)	0.72 (0.49-1.06)	0.70 (0.48-1.03)
4000-5999	**0.63 (0.41-0.99)**	**0.64 (0.41-1.00)**	0.61 (0.39-0.95)
≥ 6000	0.83 (0.57-1.22)	0.81 (0.55-1.20)	0.77 (0.52-1.14)
P for trend	0.315	0.265	0.170
MSA (days/wk)			
0	1.00 (reference)	1.00 (reference)	1.00 (reference)
1	**0.67 (0.42-1.05)**	**0.67 (0.42-1.06)**	**0.71 (0.45-1.12)**
2	**0.74 (0.50-1.09)**	**0.75 (0.50-1.11)**	**0.80 (0.54-1.18)**
3	**0.56 (0.37-0.84)**	**0.57 (0.38-0.86)**	**0.58 (0.39-0.88)**
4	**0.75 (0.47-1.19)**	**0.76 (0.48-1.21)**	**0.76 (0.47-1.21)**
≥ 5	**0.52 (0.35-0.75)**	**0.52 (0.35-0.75)**	**0.49 (0.33-0.71)**
P for trend	0.001	0.001	<0.001

PA, physical activity; MSA, muscle-strengthening activity; OR, odds ratio; CI, confidence interval.
Model 1 adjusted sex, age group.
Model 2 adjusted sex, age group, body mass index, education level, marital status, smoking status
Model 3 adjusted sex, age group, body mass index, education level, marital status, smoking status, military unit, military rank, military branch.

Appendix 17. Joint associations between aerobic PA, MSA and psychological distress with complete cases (n=8,309)



Appendix 18. Joint associations between aerobic PA, MSA and suicidal ideation with complete cases (n=8,309)



ABSTRACT IN KOREAN

목적 본 연구의 목적은 한국 군인의 신체활동과 정신건강 간의 관련성을 확인하기 위해 첫째, 체계적 문헌고찰을 수행하여 군인의 신체활동과 정신건강 간의 종합적 근거를 확인하고, 둘째, 한국 군인의 신체활동과 정신건강 간의 용량-반응 관련성을 확인하며, 셋째, 한국 군인의 유산소 신체활동과 근력운동 간의 복합적 관련성을 분석하는 것이다.

방법 첫 번째 연구인 군인의 신체활동과 정신건강 관련 체계적 문헌고찰을 위해 신체활동, 정신건강 및 군인 관련 검색어를 선정하고 6개의 검색엔진 (Pubmed, EMBASE, CINAHL, PsycINFO, SPORTDiscus, and Web of Science)을 사용하여 문헌 검색을 수행하였다. 검색된 연구 중 선정된 문헌 포함 기준을 통해 제목 및 초록 검토와 전문 검토의 과정을 거쳐 문헌을 선정한 후 최종 선정된 문헌에 대한 고찰을 수행하였다.

두 번째, 군인의 신체활동과 정신건강 간의 용량-반응 관련성을 확인하기 위해 2014-2015 군 건강조사 자료를 사용하였다. 조사에 참여한 한국 군인 14,291명 중 정신건강 변인의 결측 및 신체활동 변인 오류를 가진 290명을 제외한 14,001명이 최종 분석에 포함되었다. 신체활동 및 공변인의 결측은 다중대체법을 사용하여 대체하여 분석하였다. 주당 신체활동량(MET-min/wk)에 따라 그룹을 분류한 뒤, 다중로지스틱회귀분석을 수행하여, 신체활동량과 심리적 고통 및 자살생각 여부 간의 관련성을 분석하였다. 비선형 관련성을 평가하기 위해 제한된 평활 스플라인 모델을 도출하였다. 또한, 군 종류(육군, 해군/해병대, 공군) 및 계급(병사, 간부)에 따라 관련성의 차이를 확인하였다.

세 번째, 유산소 신체활동과 근력운동 간의 복합적 관련성을 확인하기 위해 2014-2015 군 건강조사 자료를 사용하였으며, 분석에 포함된 대상자는 두 번째 연구와 동일하다. 유산소 신체활동, 근력운동 및 공변인의 결측은 다중대체법을 사용하여 대체하여 분석하였다. 주당 유산소 신체활동량(MET-min/wk)에 따라 5개의 그룹으로 분류하였으며, 주당 근력운동 참여빈도를 6개의 그룹(0일 ~ 5일

이상)으로 범주화하였다. 다중로지스틱회귀분석을 수행하여 심리적 고통 및 자살생각과의 독립적인 관련성을 분석하였다. 근력운동빈도를 2개 그룹(3일 미만, 3일 이상)으로 재분류한 뒤, 유산소 신체활동량 5개 그룹과 혼합하여 10개 그룹으로 분류하여, 정신건강 변인에 대한 유산소 신체활동량 및 근력운동 빈도의 복합적 관련성을 분석하였다.

결과 첫 번째, 검색 과정을 통해 10개의 문헌이 체계적 문헌고찰에 포함되었다. 이 중 7개는 관찰연구(단면연구 6, 코호트연구1), 3개는 중재연구(RCT 2, non-RCT 1)였다. 우울, 불안, PTSD, 삶의 질, 심리적 고통, 자살생각 등 총 9개의 정신건강 변인에 대해 조사되었으며, 불안은 4개, PTSD는 3개의 연구가 있었으나 다른 연구는 2개 이하의 연구에서 조사되었다. 문헌 고찰 결과, 신체활동이 군인의 불안을 낮추고 PTSD를 예방한다는 새로운 근거를 확인하였다. 그러나, 대부분 단면연구이며, 정신건강 변인별로 포함된 연구의 숫자가 불충분하며, 조사된 정신건강 및 신체활동 변인에 대한 이질성이 크고, 많은 연구에서 높은 편향 위험이 보고되어 종합적인 결론을 도출하기에는 제한이 있었다.

두 번째, 총 14,001명의 한국 군인 중 6.66%가 심리적 고통, 3.09%는 자살생각 경험을 가지고 있었다. 잠재적인 혼란변인을 모두 보정한 후, 분석한 결과, 주당 약 1,600 MET-min까지의 신체활동량과 심리적 고통 간에는 유의한 용량-반응 관련성이 있었으나 자살생각과는 유의한 관련성이 나타나지 않았다. 이러한 관련성은 계급 간에는 유사했으나 군 종류에 따라 다르게 나타났다.

세 번째, 잠재적인 혼란변인을 모두 보정한 후, 분석한 결과, 유산소 신체활동량과 근력운동빈도는 심리적 고통과 유의한 관련이 있었으나, 자살생각과는 관련이 없었다. 하지만, 유산소 신체활동과 근력운동빈도를 복합적으로 분석한 결과, 신체활동량과 상관없이 근력운동빈도가 높은 그룹에서 심리적 고통의 승산비가 낮았으며, 과도한 유산소 신체활동량에서도 낮은 유병률이 나타났다. 또한 근력운동빈도와 유산소 신체활동량이 가장 낮은 그룹과 비교하여 2일 이하의 근력운동빈도에서는 유산소 신체활동량과 자살

생각 간 유의한 관련이 없었으나, 3일 이상의 근력운동빈도에서는 일정량의 유산소 신체활동량은 낮은 자살생각 유병률과 관련이 있었다.

결론 한국 군인의 신체활동량과 정신건강 간에는 유의한 관련성이 있으며, 근력운동이 중요한 중재 변인이었다. 이러한 결과는 여가시간 신체활동 참여가 군인의 낮은 정신질환 유병과 관련이 있다는 것을 나타낸다. 그러나, 아직까지 군인의 신체활동과 정신건강에 대한 연구가 부족한 실정이며, 본 연구 또한 단면연구이므로 군인의 신체활동과 정신건강 간의 명확한 관련성을 확인하기 위해서는 종단적 연구 및 RCT 연구 기반의 추가적인 근거가 필요하다.

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주요어 : 신체활동, 운동, 정신질환, 우울, 불안, 자살, 군인

학 번 : 2019-30342