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Improving executive function and vitamin D levels by outdoor walking

Dyah Gita Rambu Kareri[a], Agung Pranoto[b,c]*, Damayanti Tinduh[c,d]

[a]Doctoral Program of Medical Science, Faculty of Medicine, Universitas Airlangga, Indonesia
[b]Department of Internal Medicine, Faculty of Medicine, Universitas Airlangga, Indonesia
[c]Dr. Soetomo General Hospital, Indonesia
[d]Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Airlangga, Indonesia

Abstract

Engaging in physical activity outside with sun exposure yields advantages from both the exercise and the synthesis of vitamin D in the body. A lipophilic molecule with antioxidant properties, vitamin D is necessary to maintain the mineral balance in the body. The skin can produce vitamin D internally by exposure to UV light from the sun. Walking is a physical activity that necessitates advanced executive functions. Walking enhances executive function and vitamin D levels, and this study aimed to establish the link between the two. The study used a quasi-experimental approach, including randomized pre- and post-test control groups. Random assignment was used to place study participants into either the walking intervention group or the control group. Both groups underwent pre- and post-testing to ascertain the variance in average executive function and vitamin D levels. All participants had their executive function and vitamin D levels measured. The results indicate substantial alterations in pre- and post-executive function scores and levels of vitamin D in the walking intervention and control groups, both of which had $p<0.05$. A positive correlation was discovered between walking, executive function, and vitamin D levels. Outdoor walking is an effective physical activity for preserving executive function and vitamin D levels.

Keywords: Walking, Physical activity, Executive function, Vitamin D

1. Introduction

Acute physical activity (KET-PA) has been demonstrated to have a powerful protective impact against physical and mental illnesses. Although there are several empirical links between physical exercise and positive health indicators, it is still unclear what mechanisms of action underlie these associations. Physical activity immediately and over time changes the structure and function of the brain, according to research on both people and animals. The frontal and hippocampus parts of the cortex, which are involved in memory and problem-solving, contain more gray matter when PA levels are higher (Bailey & Kang, 2022). According to a study, healthy environmental stimulation is necessary to support executive function from childhood until old life. Frequent physical activities that enhance cognitive and executive function include aerobics and tai chi (Adriani et al., 2023; Maleki et al., 2025).

The executive function explains several self-regulation activities, such as behavior to identify mistakes and resolve conflicts (Chae, 2022). This function also includes a number of systems that enable people to focus and control their thoughts in order to act with intention and attention. One aerobic physical activity that can enhance cognitive function—which includes language, executive function, memory, attention, perception, and psychomotor function—is walking. This encompasses the ability to think, work, learn, and remember clearly (Adriani et al., 2023).

Exercise and the production of vitamin D by the body are two benefits of being physically active outside in the sun. Vitamin D, a lipophilic material with antioxidant properties, is essential to the body's mineral homeostasis (Bendik et al., 2014; Khan et al., 2024). In general, 25-hydroxyvitamin D {(25(OH)D)} is the most accurate measure of vitamin D levels in the body. Serum 25(OH)D concentrations may be influenced by numerous factors, such as lifestyle, skin tone, and sun exposure (Kareri et al., 2023; Moghavvemi et al., 2025). When exposed to UV rays from the sun, the skin can internally synthesize vitamin D (Bendik et al., 2014; Khan et al., 2024). Engaging in physical activity outdoors while exposed to sunlight has advantages for the body's production and function of vitamin D in addition to the physical activity itself (Bârsan et al., 2023).

One element that can positively impact vitamin D levels is moderate-intensity physical exercise, both indoors (without direct sunshine) and outdoors

Correspondence: Agung Pranoto, Department of Internal Medicine, Faculty of Medicine, Universitas Airlangga, Indonesia, **e-mail:** agung-p@fk.unair.ac.id, **Received:** August 26, 2025 **Accepted:** October 27, 2025

(with sunlight exposure) (Kareri et al., 2023). In addition to enhancing blood circulation and metabolism, regular exercise can help people sleep more soundly and pleasantly. Walking is one of the many forms of exercise that can help people overcome sleep problems and prevent vitamin D insufficiency. Nordic walking was identified as one of the most effective types of exercise for reducing vitamin D insufficiency (Podsiadło et al., 2021).

A recently conducted study has shown that physical inactivity is a substantial risk factor for vitamin D deficiency as well as for the morbidity and mortality of chronic non-communicable diseases (Katzmarzyk et al., 2022). Multiple research studies have demonstrated a strong positive relationship between levels of physical activity and 25(OH)D levels, as well as a link between exercise routines and the preservation of vitamin D nutritional status (Adamkiewicz et al., 2019; Khan et al., 2024; Zhang & Cao, 2022). Based on that, this study aimed to demonstrate that walking enhances executive function and vitamin D levels and ascertain their correlation

2.Materials and Methods

This study employed a randomized control group design before and after the test as part of a quasi-experimental research methodology. The two randomized groups in this study were the intervention group and the control group. To assess the mean levels of vitamin D and executive function in the control and intervention groups, a pre-test and a post-test will be administered to both groups.

The sample size was determined using the purposive sampling technique on a known population (N) to meet the inclusion conditions. Respondents provided information about the study. Acquiring respondents' consent by having them fill out the sample characteristics questionnaire and consent form. Taking measurements of weight and height. Completing initial evaluations of vitamin D levels and executive function. Vitamin D levels were measured by experts at the Prodia laboratory in Kupang, Indonesia. The Trail Making Test, Part B (TMT B), was used in executive function assessments. The intervention group engaged in moderate-intensity walking exercises three times a week for 30 minutes with a minimum distance of 3,000 feet over four weeks.

The Statistical Package for Social Sciences (SPSS) for Windows version 22 was used to analyze the data at a 95% confidence level. Ethical approval was given by the Faculty of Medicine's Committee of Ethics at Nusa Cendana University in Kupang, Indonesia. Study participants or their families submit written (informed consent) consent. All costs associated with the study are entirely the researcher's responsibility. Information about a patient's identity will be kept confidential and never shared without permission.

3. Results

The study's sample consisted of 26 people from the Faculty of Medicine and Veterinary Medicine, the Faculty of Law, the Faculty of Public Health, the Faculty of Education and Science, and the Institute for Research and Community Service, Nusa Cendana University, Kupang, Indonesia. The demographic data collected for the research is shown in Table 1.

Table 1. Demographic Characteristics

Variable	Control group		Intervention group		p
	Frequency (n=13)	Percentage (%)	Frequency (n=13)	Percentage (%)	
Gender					
Male	9	69.2	8	61.5	1.000¥
Female	4	30.8	5	38.5	
Age	42.46 ± 8.45		39.54 ± 7.23		0.353§
TDS	126.92 ± 12.13		131.77 ± 10.82		0.293§
TDD	83.23 ± 8.48		87.85 ± 7.73		0.160§

¥Chi-Square; § Independent-t

According to Table 1, male samples dominate female samples in both the control and intervention groups. There are nine men (69.2%) and four women (30.8%) in the control group with a gender difference. While in the intervention

group, there are eight men (61.5%) and five women (38.5%). The average age of the respondents is 42.46 years in the control group and 39.54 in the intervention group. The results of the executive function test are shown in Table 2, while the vitamin D level test results are shown in Table 3.

Table 2. Statistical tests of differences in executive functions

Executive Functions	Group		p
	Intervention	Control	
Pre	74.85 ± 29.77	64.92 ± 33.00	0.270‡
Post	49.69 ± 19.09	49.54 ± 25.50	0.739‡
p	<0.001¶*	0.050†*	
Difference	-25.15 ± 18.77	-15.38 ± 28.39	0.117‡

*Significant (p < 0,05); ‡ Mann-Whitney; ¶ Paired t; † Wilcoxon

In contrast to the control group, which had a p-value of 0.050 (p < 0.05), the intervention group showed a significant difference in pre- and post-executive function, with a p-value of < 0.001 (p < 0.05). A significance coefficient of 0.270 (p-value > 0.05) was obtained from the unpaired difference test comparing the pre-executive function of the intervention and control groups, indicating no significant difference. According to the statistics, there is no significant difference in executive function, as indicated by the p-values of 0.739 (p > 0.05) for post-executive function and 0.117 (p-value > 0.05) for executive function difference.

Table 3. Statistical tests of differences in Vitamin D

Vitamin D	Group		p
	Intervention	Control	
Pre	25.71 ± 7.41	24.65 ± 6.58	0.538‡
Post	34.27 ± 13.22	30.10 ± 7.82	0.340§
p	0.001†*	<0.001¶*	
Difference	8.56 ± 8.41	5.45 ± 3.25	0.817‡

*Significant (p < 0,05); ‡ Mann-Whitney; § Independent t; † Wilcoxon; ¶ Paired t

The Vitamin D difference test comparing levels before and after the intervention showed a p-value of 0.001 (p < 0.05) for the intervention group, indicating a statistically significant difference. The control group showed a significant difference with a p-value < 0.001 (p < 0.05). The results of the unpaired difference test showed that the difference in vitamin D levels between the intervention and control groups was p-valued at 0.817 (p > 0.05), p-valued at 0.538 (p > 0.05) for pre-intervention vitamin D levels, and p-valued at 0.340 (p > 0.05) for post-intervention vitamin D levels. Therefore, the findings suggest that there isn't a substantial difference. Table 4 displays the results of a study looking at the relationship between vitamin D and executive function.

Table 4. The results of the connection between executive functions and vitamin D levels

Vitamin D	Group		p
	Intervention	Control	
Pre	25.71 ± 7.41	24.65 ± 6.58	0.538‡
Post	34.27 ± 13.22	30.10 ± 7.82	0.340§
P	0.001†*	<0.001¶*	
Difference	8.56 ± 8.41	5.45 ± 3.25	0.817‡

Based on the result, there is no significant link between the difference in executive function and the difference in vitamin D, as indicated by the p-value of 0.854 (p > 0.05) and the r-value of 0.038 (0 - < 0.2).

Discussion

The study found that walking greatly enhanced executive function and vitamin D levels. The executive function data showed that walking can increase vitamin D in the intervention group, whereas in the control group, there is discernible change. Physical activity has been shown to reduce musculoskeletal ailments and major non-communicable diseases. Practice that is regular and adjusted might also aid with mental health problems. Being physically active increases the release of endorphins, substances that improve mood. Vitamin D levels were effectively boosted by walking. Adequate vitamin D connected to physical activity improves two neuromuscular functions: the development of type II muscle fibers and the regulatory function of the immune system (Trovato et al., 2023). Walking effectively raised vitamin D levels. The growth of type II muscle fibers and the immune system's regulatory function are two neuromuscular functions that are improved by adequate vitamin D linked to physical activity.

The (25(OH)D) is frequently regarded as the most precise method for determining the body's vitamin D level. Numerous observational studies have shown a substantial positive correlation between physical activity levels and 25(OH)D

concentrations, as well as a link between exercise habits and the preservation of vitamin D nutritional status (Cheng et al., 2017; Kim & Park, 2022; Zhang & Cao, 2022). According to a previous study resistance training can considerably raise serum 25(OH)D levels in those who don't get enough vitamin D, but it has no noticeable effect on participants with appropriate vitamin D levels. The only intervention that significantly raises serum 1,25(OH)2D levels is persistent resistance exercise, although the effect may vary by gender (Zhang & Cao, 2022). Another study discovered that walking has a considerable effect on vitamin D levels. The outcomes are consistent with earlier studies that discovered that walking for 12 weeks changed the patient's vitamin D blood levels (Bailey & Kang, 2022; Trovato et al., 2023).

Type of exercise, intensity, gender, and vitamin D nutritional status may all have an impact on how exercise affects 25(OH)D levels (Zhang & Cao, 2022). It established that exercise maintains serum vitamin D levels by enhancing absorption efficiency, reducing calcium excretion, and building local bone mass. Exercise may also enhance the release of vitamin D from adipose tissue, resulting in elevated serum levels of vitamin D. Exercise is known to increase the rate of lipolysis and result in lower body weight (Al-othman et al., 2012; Fernandez et al., 2017).

Additionally, certain physical activities can conducted outdoors, enhancing exposure to sunlight. Multiple research studies show that physical outdoor activity has a higher positive impact on mood and mental health than indoors, possibly as a result of exposure to sunlight (Trovato et al., 2023). The current study found that exposure to sunlight was associated with reduced perceived stress, with this relationship being significant among individuals who participated in moderate to high levels of physical activity (Pathways et al., 2018). Moreover, because UVB rays transform 7-dehydrocholesterol into pre-vitamin D3, which isomerizes it to vitamin D, sunlight is essential for the metabolism of vitamin D. This could explain how sunshine reduces stress. Furthermore, it was found that higher vitamin D intake was inversely connected with perceived stress, particularly among those who reported moderate to high levels of physical activity (Bikle, 2020).

Depending on the frequency and intensity of the activity, it has been demonstrated to enhance cognitive performance and/or postpone degeneration (Bârsan et al., 2023). Frequent and intense engagement in physical activity (PA) has been associated with enhanced cognitive performance and may serve as an effective preventive strategy against physical and mental diseases (Bailey & Kang, 2022; Nakagawa et al., 2020). Regular physical activity has many benefits for people, but it can also be harmful due to a number of demographic, social, physical, environmental, economic, and psychological issues. Vitamin D affects the cardiovascular, musculoskeletal, and immunological systems and is necessary for intestinal calcium absorption. Thus, the results of this study also apply to the possible advantages of walking for executive function and vitamin D.

5. Conclusions

Walking exercise has significantly affected executive function and vitamin D levels.

Ethical considerations

This study has received ethical approval from the Health Research Ethics Commission of the Faculty of Medicine, University of Nusa Cendan.

Conflict of interest

The authors declare no conflicts of interest.

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