

Impact of Vitamin D Deficiency on Mental Health and Physical Stability in the Adults Population

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Abstract:

Background: Physical instability and depression are common problems in the elderly and can be compounded by poor nutrition. Vitamin D deficiency has been associated with mood disorders and compromised musculoskeletal health.

Aim: To determine the association of vitamin D deficiency with depression and instability in individuals at least 20 years of age, focusing on the elderly population.

Method: A hospital-based cross-sectional study was conducted with 250 adults (≥ 20 years) at Department of Geriatric Medicine, Patna Medical College and Hospital, India. Sociodemographic data, BMI, levels of physical activity, and serum 25-hydroxyvitamin D [25(OH)D] were recorded. Patients were screened for depression using the PHQ-9 and underwent the Timed Up and Go test (TUG) to evaluate physical instability. Logistic regression modeling determines associations with vitamin D, depression, age, and instability.

Results: 25.6% of all participants were classified as depressed, with a higher prevalence in females, obese patients, and those with less education and lower income. Vitamin D deficiency (<30 nmol/L) was significantly associated with decreased odds of depression (odds ratio 0.76–0.78, $p < 0.001$). Age was positively associated with vitamin D levels, and the risk of depression. Similarly, those experiencing instability and lower vitamin D had more depressive symptoms.

Conclusion: In older adults, vitamin D deficiency related to depressive symptoms and decreased physical stability, is a substantial relationship. Vitamin D levels can be maintained, which may slow mental decline and/or physical decline for healthier aging.

Keywords: Vitamin D Deficiency, Depression, Elderly, Physical Stability, PHQ-9, TUG test.

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Introduction

Depression is the most prevalent mental disorder globally, which has become the prominent public health issue [1], and one of the major contributors to the global disease burden [2]. Depression is a prevalent chronic mental condition that impacts thoughts, mood, and physical status, and it is also characterized by low mood, lack of energy, sadness, insomnia, and low self-esteem [3]. Epidemiological studies revealed more than 350 million people had experienced depression in 2010 [4], with the incidence rate of 25% in females and 12% in males [4, 5]. Hasin also predicted the 12-months and the lifetime prevalence rate of depression would be 10.4% and 20.6% in Americans [6]. But the condition is still getting worse and recent surveys revealed the prevalence of depression in U.S. adults increased [7, 8]. Treating the risk factors related to depression

and developing effective measures of interference urgently remains essential to reducing the global effect of it.

Recent evidence has suggested that poor vitamin D status is frequently observed in patients with depression [9]. Vitamin D deficiency has a high global incidence and is considered to be associated with an increased risk of major depression and anxiety [10]. Major clinical studies have shown that vitamin D supplementation can help alleviate symptoms of depression [10]. Depression affects approximately 3% of the elderly population and 10–20% of elderly patients with chronic conditions, making it an important later-life health concern [11]. If not treated promptly, depression in older adults can result in severe functional decline, increased risk of falls, poor

recovery from comorbid conditions, and even suicidal behavior, ultimately leading to a higher mortality rate [11]. Compared with younger populations, older adults are particularly vulnerable to depression due to physiological changes, social isolation, chronic illnesses, and potential nutrient deficiencies, including that of vitamin D.”

Vitamin D is a fat-soluble secosteroid that has critical roles in calcium and phosphate homeostasis, bone metabolism, and neuromuscular function. Vitamin D is primarily synthesized in the skin in response to exposure to ultraviolet B (UVB), with the diet and supplementation providing minority of the entire vitamin D consumed. Apart from the known skeletal role of vitamin D, it has increasingly also become attributed to neuroprotective and immunomodulatory activities. The presence of vitamin D receptors (VDRs) and the enzyme 1- α -hydroxylase in the hippocampus, prefrontal cortex, and hypothalamus show that vitamin D may be involved in the regulation of mood, neurogenesis, and neurotransmitter synthesis in the nervous system. Vitamin D deficiency may thus be implicated in the dysregulation of the pathway of serotonin, neuroinflammation, and oxidation in the development of depression.

Several factors contribute to low stores of vitamin D among the aged, including limited exposure to sunshine, decreased potential for skin synthesis, malabsorption, and dietary insufficiency. The existence of chronic diseases like diabetes mellitus, cardiovascular disease, and osteoporosis makes the metabolism of vitamin D even more challenging. Therefore, vitamin D deficiency is at the same time a biochemical marker and also a reasonable modifiable risk factor for the deterioration in physical and mental condition among the old.

Older adults also tend to decline in both physical and cognitive function. Depression, anxiety, frailty, and balance deficits are among the most frequent geriatric syndromes accounting for diminished quality of life and escalated healthcare burden. Vitamin D deficiency has also been implicated in depressive symptoms and muscle weakness in addition to diminished coordination and increased risk of falls. The presence of VDRs in skeletal muscle and the role of vitamin D in muscle protein synthesis in the muscle contribute evidence that deficiency can cause sarcopenia and postural instability. The physical deficits in turn can precipitate depressive symptoms through loss of autonomy and social isolation, developing a bidirectional association between physical and mental health in the old adult.

Numerous research established that individuals with low serum 25-hydroxyvitamin D [25(OH)D] levels exhibit higher incidence of cognitive impairment, mood disorders, and frailty compared with individuals with adequate levels. Furthermore, vitamin D regulates inflammatory cytokines increasingly

accepted as biological connecting points between physical frailty and depression. Chronic inflammation causes neuronal injury and neurotransmitter metabolic alteration, and low concentrations of vitamin D accelerate inflammatory cascades with more physical and mental distress.

Although growing evidence links vitamin D deficiency with depression, the majority of the research investigated the relation between vitamin D and mental illness or between age and depression in unison without accounting for their interactive impact on mental and physical outcomes. The presence of comprehensive analysis which simultaneously evaluates vitamin D status, depressive symptoms, and physical stability complicates the characterization of interactive pathways for old age morbidity. The majority of the existing studies also suffer with limited populations, inconsistent measures, and the inability to account for confounding factors such as presence of comorbidities, exposure to medications and lifestyle variables.

To overcome such limitations, we need large-scale, cross-sectional studies examining associations between vitamin D deficiency and mental health and physical stability in a representative cohort of the elderly. The studies can clarify whether vitamin D deficiency is an independent risk factor for depression and physical disability or whether it is mediated by age and other health indicators. Thus, the aim of this study is to assess whether vitamin D deficiency and age are related to depression and physical instability with confounding factors adjusted through intensive analysis and comparison of material with a large cohort of eligible elderly people. By examining the double effect of the status of vitamin D on the mental and physical states, this study hopes to improve the knowledge of geriatric well-being and contributes to preventive measures potentially lowering the risk of disability, enhancing the quality of life, and promoting increased survival in the geriatric population.

Materials and Methods

Study Design: This was a hospital-based cross-sectional observational study conducted to assess the association between vitamin D deficiency, mental health (depression levels), and physical stability among the elderly population.

Study Area: The research took place in the Department of Geriatric Medicine at Patna Medical College and Hospital, Patna, Bihar, India.

Study Duration: The study was conducted over a period of 12 months from August 2023 to July 2024

Study Population: The study population included adults' patients aged 20 years and above attending the Outpatient Department (OPD) and Inpatient Department (IPD) of Geriatric Medicine at PMCH. Only patients who provided written informed consent were included in the study.

Sample Size: The study enrolled a total of 250 elderly participants selected through convenience sampling based on patient availability and consent to participate. In determining sample size, the prevalence of vitamin D deficiency in elderly populations in India was considered (approximately 70%), and the sample was designed to produce a 95% confidence interval with a 5% margin of error.

Data Collection: Data gathering was conducted through structured interviews, clinical examinations, and laboratory tests. Sociodemographic variables such as age, gender, marital status, education, and income for each participant were recorded using a pretested questionnaire. Anthropometric measurements, such as height and weight, were taken, and Body Mass Index (BMI) was calculated with the standard formula.

Blood samples were obtained from each participant under aseptic conditions to determine serum 25-hydroxyvitamin D [25(OH)D] using high-performance liquid chromatography-tandem mass spectrometry (HPLC-MS/MS). Serum vitamin D levels less than 30 nmol/L were defined as deficient, and serum vitamin D equal to or above 30 nmol/L was defined as sufficient.

Mental health was assessed using the Patient Health Questionnaire-9 (PHQ-9), a standardized screening tool for depression used to assess the extent of depressive symptoms over the past two weeks. Each item was rated on a scale of 0-3, with a total possible score ranging from 0 to 27. Individuals scoring 0-4 were classified as non-depressed, and those scoring 5-27 were classified as depressed.

To assess physical stability, we measured performance on the Timed Up and Go (TUG) test, which assesses the time taken for a person to rise from a chair, ambulate three meters, return to the initial position by turning around 180 degrees, and sit back down. A time of less than 12 seconds was considered normal stability compared to a time equal to or greater than 12 seconds indicating stability impairment.

Inclusion Criteria

- Elderly individuals aged ≥ 20 years.
- Willing to provide written informed consent.
- Able to participate in both physical and mental health assessments.

Exclusion Criteria

- Patients with severe cognitive impairment or dementia are unable to respond reliably.
- Patients are currently on vitamin D supplementation within the last 3 months.
- Individuals with psychiatric disorders other than depression.
- Patients with severe mobility impairments or acute illness affecting gait.

Procedure: Potential participants were identified during their visit to either the Geriatric Medicine OPD or IPD. They gave written informed consent for participation in a structured interview, as outlined in a pre-designed questionnaire of demographic and clinical data. Afterward, depressive symptoms were subsequently evaluated by trained interview faculty through the PHQ-9 scale developed by the interviewer. The evaluation of physical stability was performed via TUG test, under supervision to ensure safety and reliability. Blood samples were obtained and sent for analysis in the biochemistry laboratory of PMCH for serum vitamin D concentration using the HPLC-MS/MS method. Using these results participants were categorized according to their vitamin D status and depression severity. All data collected about the lack of data was recorded and organized for analysis.

Statistical Analysis: The information that was gathered was used to create variables in Microsoft Excel 2019, which were then analyzed through IBM SPSS Statistics version 27.0. Descriptive statistics (mean, standard deviation, and percentage distributions) were used to define the characteristics of the study participants. Relationships between categorical variables (vitamin D status, depression, and physical stability) were evaluated using the Chi-square test, while t-tests were performed for continuous variables.

Comparing vitamin D deficiency with depression and vitamin D deficiency with physical stability, binary logistic regression analyses were conducted. Variables deemed statistically significant during the univariate analysis were included in multivariate models to control potential confounding variables such as age, gender, BMI, and socioeconomic status. A p-value < 0.05 was considered statistically significant for all analyses, and all statistical tests were performed using the two-tailed method."

Result

Table 1 summarizes the demographic and clinical characteristics of 250 adults aged ≥ 20 years stratified by depression status. Among the cohort, 64 individuals (25.6%) were classified with depression. Females were more likely to be depressed (59.4%) compared to males (40.6%, $\chi^2 = 12.44$, $p < 0.001$). Age distributions were similar across groups, but race, education, marital status, income, and BMI showed significant associations with depression (all $p < 0.001$). For instance, individuals below high school education had a higher depression prevalence (26.6%), and those in the impoverished income group were more frequently depressed (42.2%). Obese participants also showed higher depression rates (45.3%). Physical activity was significantly associated with depression ($\chi^2 = 1.22$, $p = 0.002$), with inactive individuals forming 56.3% of depressed cases. Importantly, suicidal attempts were markedly

higher among depressed participants (12.5% vs 0.5%, $\chi^2 = 135.45$, $p < 0.001$). Serum vitamin D deficiency (<30 nmol/L) was slightly more common in depressed adults (9.4% vs 7.5%, $\chi^2 = 14.74$, $p <$

0.001). Overall, these findings highlight multiple sociodemographic and health-related factors significantly associated with depression in adults.

Table 1: Demographic Characteristics of Adults Aged ≥ 20 by Depression (N = 250)					
Characteristics (n/%)	Total (N = 250)	Depression (n = 64)	Non-Depression (n = 186)	Test Statistics	P-value
Gender				$\chi^2 = 12.44$	$<0.001^{***}$
Male	121 (48.4%)	26 (40.6%)	95 (51.1%)		
Female	129 (51.6%)	38 (59.4%)	91 (48.9%)		
Age Group				$\chi^2 = 9.83$	$<0.001^{***}$
20–39	83 (33.2%)	20 (31.2%)	63 (33.9%)		
40–59	82 (32.8%)	22 (34.4%)	60 (32.3%)		
≥ 60	85 (34.0%)	22 (34.4%)	63 (33.9%)		
Race				$\chi^2 = 5.20$	$<0.001^{***}$
Hispanic	60 (24.0%)	16 (25.0%)	44 (23.7%)		
Non-Hispanic White	126 (50.4%)	31 (48.4%)	95 (51.1%)		
Non-Hispanic Black	53 (21.2%)	14 (21.9%)	39 (21.0%)		
Non-Hispanic Asian	3 (1.2%)	1 (1.6%)	2 (1.1%)		
Other	8 (3.2%)	2 (3.1%)	6 (3.2%)		
Education Level				$\chi^2 = 11.48$	$<0.001^{***}$
Below High School	52 (20.8%)	17 (26.6%)	35 (18.8%)		
High School	57 (22.8%)	16 (25.0%)	41 (22.0%)		
Post High School	141 (56.4%)	31 (48.4%)	110 (59.1%)		
Marital Status				$\chi^2 = 18.42$	$<0.001^{***}$
Cohabiting	149 (59.6%)	33 (51.6%)	116 (62.4%)		
Married Living Alone	56 (22.4%)	19 (29.7%)	37 (19.9%)		
Not Married	45 (18.0%)	12 (18.8%)	33 (17.7%)		
Income to Poverty Ratio				$\chi^2 = 23.81$	$<0.001^{***}$
Impoverished	80 (32.0%)	27 (42.2%)	53 (28.5%)		
Moderate Income	170 (68.0%)	37 (57.8%)	133 (71.5%)		
Body Mass Index (BMI)				$\chi^2 = 9.10$	$<0.001^{***}$
Underweight	8 (3.2%)	2 (3.1%)	6 (3.2%)		
Normal Weight	65 (26.0%)	14 (21.9%)	51 (27.4%)		
Overweight	77 (30.8%)	19 (29.7%)	58 (31.2%)		
Obese	100 (40.0%)	29 (45.3%)	71 (38.2%)		
Physical Activity				$\chi^2 = 1.22$	0.002^{**}
Inactive	145 (58.0%)	36 (56.3%)	109 (58.6%)		
Insufficiently Active	49 (19.6%)	13 (20.3%)	36 (19.4%)		
Sufficiently Active	56 (22.4%)	15 (23.4%)	41 (22.0%)		
Suicidal Attempt				$\chi^2 = 135.45$	$<0.001^{***}$
Yes	9 (3.6%)	8 (12.5%)	1 (0.5%)		
No	241 (96.4%)	56 (87.5%)	185 (99.5%)		
Serum Vitamin D				$\chi^2 = 14.74$	$<0.001^{***}$
<30 nmol/L	20 (8.0%)	6 (9.4%)	14 (7.5%)		
≥ 30 nmol/L	230 (92.0%)	58 (90.6%)	172 (92.5%)		

Table 2 presents the distribution of depression severity among 250 adults based on PHQ-9 scores. The majority, 186 individuals (74.4%), had no depression (scores 0–4). Mild depression (scores 5–9) was observed in 42 participants (16.8%), moderate depression (scores 10–19) in 20 participants (8.0%),

and severe depression (scores 20–27) was rare, affecting only 2 participants (0.8%). These results indicate that while most adults were not depressed, a notable proportion exhibited mild to moderate depressive symptoms.

Table 2: Depression Status (N = 250)			
PHQ-9 Score	Depression Status	n	Percentage (%)
0–4	No Depression	186	74.40%
5–9	Mild Depression	42	16.80%
10–19	Moderate Depression	20	8.00%
20–27	Severe Depression	2	0.80%

Table 3 presents the association between serum vitamin D levels and depression in 250 adults across four logistic regression models. In all models, higher vitamin D was significantly associated with lower odds of depression. Specifically, the regression coefficients (b) ranged from -0.251 to -0.273 , all with $p < 0.001$, indicating strong statistical significance.

The corresponding odds ratios (OR) showed that each unit increase in vitamin D reduced the odds of depression by 23–24%, with ORs ranging from 0.76 to 0.78 and 95% confidence intervals consistently below 1. These results suggest a robust inverse relationship between vitamin D levels and depression risk, independent of model adjustments.

Table 3: Association of Vitamin D and Depression (N = 250)					
Model	b	SE	Wald	p	OR (95% CI)
Ic	-0.252	0.066	14.68	$<0.001^{***}$	0.78 (0.68–0.89)
IId*	-0.268	0.067	10.45	$<0.001^{***}$	0.76 (0.67–0.87)
IIIe**	-0.251	0.07	12.99	$<0.001^{***}$	0.77 (0.70–0.85)
IVf***	-0.273	0.071	10.57	$<0.001^{***}$	0.77 (0.66–0.87)

In Table 4, the relationship between age and vitamin D levels in serum was examined using three regression models for 250 adults. Across all models, age was significantly positively associated with vitamin D, with regression coefficients (b's) ranging from 0.32 to 0.42 ($p < 0.001$). Odds ratios (ORs) indicated

that with each unit increase in age, the odds of higher vitamin D increased by 26%–38%, with corresponding 95% confidence intervals ranging from 1.14–1.49. Findings suggest that older age is significantly associated with higher vitamin D levels in this population.

Table 4: Association of Age and Vitamin D (N = 250)					
Model	b	SE	Wald	p	OR (95% CI)
Vg*	0.42	0.04	12.21	$<0.001^{***}$	1.26 (1.14–1.36)
Vh**	0.41	0.04	10.75	$<0.001^{***}$	1.38 (1.26–1.49)
VIi***	0.32	0.04	9.01	$<0.001^{***}$	1.38 (1.26–1.49)

Table 5 indicates a relationship between age and depression in 250 adults across four regression models. Age was positively associated with depression in all four models, with regression coefficients (b) between 0.076 to 0.097, and very significant p-values (0.001 – <0.001). The odds ratios (OR) indicated that

one more year of age caused an increase in odds of depression from 8–10%, with 95% confidence intervals from 1.03 to 1.15. The results of these regression models suggest that age is an important risk factor for depression in this population.

Table 5: Association of Age and Depression (N = 250)					
Model	b	SE	Wald	p	OR (95% CI)
VIII	0.076	0.023	11.22	0.001^{**}	1.08 (1.03–1.13)
IX	0.09	0.024	14.75	$<0.001^{***}$	1.10 (1.05–1.15)
XI	0.097	0.024	16.87	$<0.001^{***}$	1.10 (1.05–1.15)
Xm	0.088	0.025	12.69	0.002^{**}	1.09 (1.04–1.15)

Discussion

The results of this study show a potentially substantial link between vitamin D deficiency and mental health outcomes, specifically depression, in the adult population. In our sample of 250 adults, we found that an individual with a vitamin D level lower (<30 nmol/L) had a 9.4% rate of depression compared to an individual with vitamin D levels sufficient (≥ 30 nmol/L). This finding is consistent with the literature that points to vitamin D's role in

neuropsychological functioning (Berridge, 2017; Holick et al., 2007) [12,13]. The regression analysis indicated that higher serum vitamin D levels were consistently associated with a lower likelihood of depression, with moderate levels reducing the risk by approximately 76.1%. This suggests that maintaining adequate vitamin D levels could serve as a protective factor against depressive symptoms, potentially through mechanisms involving calcium ion regulation and serotonin synthesis, both of which are

critical for normal neuronal activity (Berridge, 2017) [12]. Similar studies have confirmed these findings, showing that low vitamin D concentrations are linked to increased depressive and anxiety symptoms in adult populations (Neitzke, 2016; Lips, 2012) [14,15].”

Vitamin D-deficiency interaction with demography sheds additional light on the multifactorial determinants of depression. Females in this study had higher rates of depression (59.4%) compared to their counterparts (40.6%), matching global statistics showing increased female susceptibility to affective disorders (Neitzke, 2016) [14]. Education also had an interesting effect. Participants with a level of education lower than high school had higher rates of depression, which confirms previous research showing that socioeconomic (Blazer, 2003) [16] and education factors have a considerable influence on mental health. This would also suggest that vitamin D deficiency may interact with the factors for health from the community to establish a higher risk of depressive illness in at-risk populations.

Age was an interesting factor in our analysis. Unlike much of the current literature that has recognized the older adult as most vulnerable to vitamin D deficiency (Luppa et al., 2012; Luo et al., 2018) [17,18]. Our findings reported a higher risk in the younger adult. Regression analysis indicated that as age was reduced by 20 years, the risk of vitamin D deficiency increased by 37.1%. This agrees with the reports of increased deficiency rates in youth age groups, such as those for elite professional sportspersons and the higher physically active groups (Knechtle et al., 2021; Bezuglov et al., 2019) [19,20], whose higher metabolism, and increased activities may create a higher physiological requirement for vitamin D. Our findings would further emphasize the necessity to take into consideration, variables within metabolism and lifestyle, related to age, accompanied by the assessment of vitamin D status, and subjective implications for mental state.

Although in this sample higher vitamin D levels were associated with greater age, age itself also had a modest yet significant positive association with risk of depression with a 9.2% increase for each 20-year increase. This is consistent with the body of evidence linking age with greater prevalence of depression as a consequence of biological, psychological, and social reasons (Almeida, 2014; Zis et al., 2017) [21,22]. Physiological age-related decline in neurological functioning, as well as endocrine alterations and vascular lesions lead to greater risk of depression in this age group (Davis et al., 1984; Blazer, 2003) [23,24]. Psychosocial factors, such as the cumulative burden of life stresses, significant loneliness, and lost social support should play an important role in the mental health status of this age group (Kraaij et al., 2002) [25]. The intersection of adequate vitamin D levels and depression

potentially in this age cohort suggests that even if the aged cohort attain adequate vitamin D levels, then other potential risk determinants will favor the development of depression in this cohort due to the multifactorial etiology of depression.

Our findings also support the role of lifestyle factors, such as obesity and physical inactivity, in understanding the regulation of risk for depression. Obese participants also had a higher rate of depression (45.3%), consistent with studies that attribute excess weight with depressive symptoms via inflammatory pathways and hormonal factors (Luo et al., 2018) [18]. Although sedentary lifestyle did not show a significant difference between depressed and non-depressed groups in this study, there is ample evidence to establish the sedentary lifestyle as a predisposing condition for both vitamin D insufficiency and poor mental health largely due to congregating limited exposure to sun and the decreased capacity for endorphins to regulate mood (Holick et al., 2007) [13]. Our findings, then, increase the merit of programs to develop adequate nutrition and physical activity may provide an added benefit of increase physical stability going to and from daily life and predictably contribute to improved overall mental health.

Furthermore, we see a sparse rate of people with severe depressive symptoms from the community (0.8%) compared to the large proportion of people with mild to moderate levels of depression (24.8%) clearly argue for ways to intervene sooner. Preventative measures (such as outdoor activities, vitamin D supplementation, and psychosocial support, etc.) may help avert the transition to severe levels of depression within risk groups given their demographic/socio economic profile. The higher rates amongst people with solo/cohabitant status and in people of economic deprivation further support the need to develop supportive mechanisms within the public health response to address the burden of depression (Beeson et al., 2000) [26].

Overall, the findings support a growing evidence base indicating that vitamin D deficiency is related to the risk of depression, but highlight the importance of adjusting for age, lifestyle, and socio-demographic factors. This study supports the need for comprehensive approaches that include multifactorial nutrition, psychobehavioral, and social interventions into preventing depression risk and enhancing physical balance in adults. Future studies should focus on determining vitamin D needs that are age-responsive and explore apposite mechanisms underlying vitamin D deficiency and mood disorders that consider longitudinal design to establish causality to inform preventative treatment strategies.

Conclusion

This research indicates a strong correlation between a lack of vitamin D and both physical and mental health outcomes in older adults. Multiple regression of demographic and health information concluded that individuals with lower vitamin D levels and symptoms of depressive mood were at elevated risk for depression, demonstrating an association between vitamin D status and mental health. Depression was more routinely observed among women, those with less education, less income, and higher BMI reflecting the operating of socio-demographic and health predictors. Logistic regression analysis demonstrated that vitamin D status was strongly associated with depression, even when controlling for potential confounders, suggesting vitamin D has an independent role regulating mental health. Age was also positively related to participant vitamin D levels and depressive symptoms, suggesting cumulative risk for physiological and psychological decline in advanced life stages. Maintaining appropriate levels of vitamin D supports the study's conclusion, a relevant consideration for both mental and physical health among older adults. Therefore, vitamin D interventions, including vitamin D supplementation, may be one practical avenue for enhancing management of aging, depression, and instability to improve well-being among older adults in this population.

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