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Association between depression and adherence to upper limb exercises among community-dwelling stroke survivors: A cross-sectional study

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Abstract

Background and Aims: Upper limb recovery after stroke tends to be slower and incomplete. Participation in motor rehabilitation and exercise adherence are crucial to improve motor recovery. However, post-stroke depression (PSD) could impede active participation in exercises. Therefore, this study investigates the association between depression and exercise adherence among community-dwelling stroke survivors.

Methods: This cross-sectional study was conducted among 215 stroke survivors undergoing motor rehabilitation between February 2021 and January 2023. Patient Health Questionnaire-9 (PHQ-9) and Stroke-Specific Measure of Adherence to Home-based Exercises (SS-MAHE) were measured to assess depression symptoms and exercise adherence, respectively. Fugl-Meyer Assessment-Upper Extremity (FMA-UE) was administered to identify the influence of impairment on these factors. Chi-square and multinomial and binary logistic regression analyses were applied to determine the relationships between these measurements.

Results: Using the Chi-square test, the PHQ-9 was significantly associated with SS-MAHE ($p < 0.05$). Logistic regression analysis revealed that patients with moderate depression had lower odds of exercise adherence (OR:0.69, 95%CI:0.56, 0.85, $p < 0.01$) compared to those with no depression. Type of exercises such as movement-based (OR:2.00, 95%CI:1.80, 2.24, $p < 0.001$) and task-based exercises (OR:1.80, 95%CI:1.53, 2.13, $p < 0.001$), had higher adherence odds compared to those not exercising. Severe impairment (FMA-UE) was significantly associated with lower exercise adherence (OR:0.71, 95%CI:0.54, 0.94, $p < 0.05$) and an increased risk of minimal depression (RR:11.09, 95%CI:1.17, 105.04, $p < 0.05$) compared to mild impairment.

Conclusions: PSD significantly impacts exercise adherence, with moderate depression notably reducing adherence rates. Incorporating mental health support into stroke rehabilitation could improve exercise adherence and potentially enhance upper limb motor recovery outcomes.

KEYWORDS
cerebrovascular accident, exercise therapy, depressive symptoms, patient adherence, stroke rehabilitation, upper limb

1 | INTRODUCTION

Stroke is the third leading cause of disability worldwide.[1] More than 40% of stroke survivors have upper limb impairment and are facing persistent difficulties in day-to-day activities.[2] Post-stroke depression (PSD) is common among one-third of stroke survivors.[3] Exercise is a crucial component of neurorehabilitation because it encourages structural and biochemical changes in the brain, leading to enhanced neuronal function. It is well understood that increased adherence to exercise programs and physical activity are positively correlated with improved functional recovery after stroke.[4] Of the multiple factors that influence stroke survivors' decreased exercise adherence, depression emerges as a significant factor for the failure to resume physical activity.[5–7] Therefore, this cross-sectional study explored the categories of depression that influence exercise adherence and identified confounding factors impacting exercise adherence. The PSD measured using the depression scale showed a strong correlation with neurological disability.[8] The depressive symptoms of stroke survivors intensify due to poor upper limb recovery, complete or partial dependency on daily activities, restricted social participation, and a decrease in socioeconomic status. The consequences of depression resulting from lower social participation and lack of interest in engaging in upper limb rehabilitation further hinder the brain recovery process.[9–11] Understanding the contribution of PSD at different levels of upper limb impairment to exercise adherence paves the way for upper limb targeted rehabilitation strategies. Although numerous studies have explored the impact of exercise and physical activity on depression symptoms,[12,13] evidence is scarce regarding the relationship between the intensity of depression and exercise adherence post-stroke. This study attempted to fill this research gap by investigating the impact of depression on exercise adherence. Additionally, we aimed to determine the severity of impairment in depression and exercise adherence in community-dwelling stroke survivors.

2 | METHODS

2.1 | Study design and participants

This cross-sectional study involved a secondary analysis of screening data from a prospective randomized controlled trial registered with the Clinical Trial Registry of India (CTRI no: CTRI/2020/08/027021). The PHQ-9 for depression, SS-MAHE for exercise adherence, and demographic characteristics were administered as part of the screening process for the clinical trial, which focused on upper limb rehabilitation in community-dwelling stroke patients. Through convenience sampling, the demographic and clinical data of stroke survivors were gathered at the physiotherapy department of an urban hospital in Southern India between February 2021 and January 2023. We included participants aged 18 or older who had a first episode of unilateral supratentorial stroke at least 1-month post-stroke. Those with cognitive impairment (MOCA < 26), communicative impairment, or upper extremity fractures within the past 6 months were excluded. The ethics committee approval for this study was covered under the main clinical trial approval, granted by the Manipal Hospital Institutional Ethical Committee, Bangalore, on September 3, 2020. The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants after they were provided with comprehensive information about the original study. Of the 345 participants screened, 215 met the eligibility criteria and actively participated in the study. The reporting of this study adheres to the STROBE guidelines.

2.2 | Measurements

Participants were requested to complete the following questionnaires: the Patient Health Questionnaire (PHQ-9)[14] and the Stroke Specific Measure of Adherence to Home-based Exercises (SS MAHE).[15]

2.2.1 | Patient Health Questionnaire-9 (PHQ-9)

The PHQ-9 tool was used to measure the severity of depression. It comprises of nine questions. Each question is scored from 0 to 3. The total score ranges from 0 to 27, with a higher score indicating greater severity. The severity categories were defined as follows: no depression (0), minimal (1–4), mild (5–9), moderate (10–14), moderately severe (15–19), or severe (20–27). Participants were instructed to self-administer based on the frequency of symptoms over the past 2 weeks. It has demonstrated good psychometric properties, including reliability and validity, within the stroke population. Categorical scores were used for statistical analysis.[14]

2.2.2 | Stroke-Specific Measure of Adherence to Home-based Exercises (SS-MAHE)

The SS-MAHE scale was used to measure adherence to prescribed exercises after stroke. It consists of a 13-item self-report questionnaire that measures adherence to home exercises under various dosages of prescribed exercise. Adherence was assessed by comparing exercise prescriptions provided by the therapists to the actual exercises performed at home, and adherence was quantified as a percentage. The scale exhibited good internal consistency and interrater reliability. Participants were classified as adherent if they achieved >70% adherence to prescribed exercises, while those scoring less than 70% adherence were classified as nonadherent. A higher percentage corresponds to better adherence to exercise.[15]

2.3 | Covariates

The variables, such as age group, sex, location of the lesion, type of stroke, side of hemiplegia, stroke severity according to the FMA-UE, alcohol consumption, tobacco consumption, hypertension, diabetes mellitus, caregiver dependence, return to work, type of exercise, and socioeconomic status, were collected through demographic assessment.

2.4 | Statistical methods

A priori analysis was conducted to calculate the sample size based on the prevalence of PSD at 16% ($p = 0.16$) and a margin of error of 5% ($E = 0.05$) with a 95% confidence interval ($Z = 1.96$) using the formula $n = Z^2P(1 - P)/E^2$.[16] Therefore, the minimum sample size required was 207 participants. In this study, we recruited 215 post-stroke community survivors.

Descriptive analysis was also conducted to evaluate the characteristics of the participants. All collected categorical data are shown with absolute and relative frequencies. The normality of the distributions was confirmed using the Shapiro–Wilk test. Numerical data are presented either as medians and interquartile ranges or as the means and standard deviations. Continuous variables such as age, post-stroke duration, and modified Rankin scale score are presented as the means +/− standard deviations. Categorical variables, including age group, sex, chronicity, location of the lesion, type of stroke, side of hemiplegia, psychoactive drug consumption, comorbidities, type of exercise, caregiver support, post-stroke work, and socioeconomic status, were expressed as frequencies (n, %). As the total scores of the outcome measures (PHQ-9, SS-MAHE, and FMA-UE) were not normally distributed, the scores for each measure were categorized based on severity. The descriptive analysis was conducted using Jamovi 2.3.18 software.

Inferential analyses were subsequently performed to determine the associations between variables. To assess the association between depression (PHQ-9) and exercise adherence (SS-MAHE) and to explore the association between demographic characteristics and exercise adherence and depression, an independent sample chi-square χ^2 test was used. Binary logistic regression analysis was subsequently conducted to ascertain the relationship between depression and demographic characteristics affecting exercise adherence. Furthermore, multinomial logistic regression was used to examine the influence of impairment (FMA-UE) on depression. In addition, binary logistic regression was used to investigate the impact of impairment (FMA-UE) on exercise adherence. Statistical analysis was conducted using STATA software version 14 (StataCorporation), with $p < 0.05$ indicating statistical significance.

3 | RESULTS

3.1 | Demographic characteristics of the included stroke survivors

The demographic characteristics are shown in Table 1. A total of 215 community-dwelling stroke participants were included in this analysis; 78.6% were men, and 21.4% were women. The majority had an ischemic type of stroke (85.1%), left-sided hemiplegia (54%), chronic stroke (68.4%), abstained from alcohol post-stroke (89.8%), refrained from smoking post-stroke (92.6%), had hypertension (79.1%), did not have diabetes mellitus (66.5%), reported bearable or no pain (97.2%), were partially dependent on caregivers (60.9%), were not engaged in post-stroke work or leisure activities (91.2%), engaged in movement-based exercise training (47%), and were task-based (17.7%) exercise training and belonged to the upper-middle class (85.6%).

3.2 | Chi-square associations between depression incidence, exercise adherence, impairment severity, and demographic factors

Table 2 presents the findings associated with exercise adherence and depressive symptoms. A statistically significant χ^2 association was observed between the SS-MAHE score and PHQ-9 score ($p = 0.02$). The study also explored the association between stroke severity and depressive symptoms. A significant association in χ^2 was found between the FMA-UE and PHQ-9 scores ($p < 0.001$). Furthermore, the association between stroke severity and exercise adherence was assessed; but a statistically significant χ^2 relationship was not detected between FMA-UE and SS-MAHE ($p = 0.07$).

A significant χ^2 association was revealed between SS-MAHE score and demographic characteristics (lesion location $p = 0.04$; type of exercise $p < 0.001$). A borderline significant χ^2 association was found between the attribute of pain in the upper limb and depression ($p = 0.054$). Notably, no significant associations were detected for other demographic attributes with exercise adherence or depressive symptoms.

3.3 | Relationships between depression and demographic factors and adherence to exercise

Binary logistic regression was used to evaluate the associations between two groups. Table 3 shows that only the moderate depression (PHQ-9) category had a statistically significant association (OR = 0.69, 95% CI = 0.56, 0.85), $p = 0.001$) from the adherence to

TABLE 1 Demographic characteristics of the participants (*n* = 215).

Characteristics	Mean ± SD counts (relative frequency) (*n* = 215)
Age, years	54.41 ± 13.60
Adult	162 (75.3%)
Older adult	53 (24.7%)
Sex	
Female	46 (21.4%)
Male	169 (78.6%)
Post-stroke duration (days)	367 (IQR 843)
Location of lesion	
Left hemisphere	99 (46%)
Right hemisphere	116 (54%)
Chronicity	
Sub-acute stroke	68 (31.6%)
Chronic stroke	147 (68.4%)
Type of stroke	
Hemorrhagic	32 (14.9%)
Ischemic	183 (85.1%)
Premorbid handedness	
Left	2 (0.9%)
Right	213 (99.1%)
Side of hemiplegia	
Left	116 (54%)
Right	99 (46%)
Modified Rankin Scale	2.986 ± 0.41
No significant disability despite symptoms	1 (0.5%)
Slight disability	17 (7.9%)
Moderate disability	181 (84.2%)
Moderate-severe disability	16 (7.4%)
Montreal cognitive assessment	28.12 ± 1.05
27	80 (37.2%)
28	56 (26%)
29	52 (24.2%)
30	27 (12.6%)
FMA-UE	23.09 ± 10.52
Mild impairment	9 (4.2%)
Moderate impairment	54 (25.1%)
Severe impairment	152 (70.7%)
SS-MAHE	49.05 ± 42.92

TABLE 1 (Continued)

Characteristics	Mean ± SD counts (relative frequency) (*n* = 215)
Non-adherent	118 (54.9%)
Adherent	97 (45.1%)
PHQ-9	4.13 ± 3.37
No depression	40 (18.6%)
Mild depression	69 (32.1%)
Minimal depression	89 (41.4%)
Moderate depression	17 (7.9%)
Alcohol consumption after stroke	
No	193 (89.8%)
Yes	22 (10.2%)
Smoking after stroke	
No	199 (92.6%)
Yes	16 (7.4%)
Psychoactive drug consumption (alcohol, tobacco)	
Not addicted	190 (88.4%)
Addicted ≥ 1	25 (11.6%)
Hypertension	
No	45 (20.9%)
Yes	170 (79.1%)
Diabetes mellitus	
No	143 (66.5%)
Yes	72 (33.5%)
Comorbidities (diabetes, hypertension)	1.18 ± 0.80
No comorbidity	43 (20%)
Comorbidity ≥ 1	172 (80%)
Pain in the upper limb	
No pain/bearable (Numerical pain rating scale ≤ 7)	209 (97.2%)
Unbearable (NPRS > 7)	6 (2.8%)
Caregiver support	
Complete assistance (24*7 support)	84 (39.1%)
Partial assistance	131 (60.9%)
Post-stroke work/leisure engagement	
Not engaged	196 (91.2%)
Engaged	19 (8.8%)
Type of exercise	
No exercise	76 (35.3%)
Movement-based	101 (47%)
Task-based	38 (17.7%)

TABLE 1 (Continued)

Characteristics	Mean ± SD counts (relative frequency) (*n* = 215)
Socioeconomic status (modified Kuppuswamy scoring)	21.64 ± 3.46
Upper	22 (10.2%)
Upper middle	184 (85.6%)
Lower middle	9 (4.2%)

Abbreviations: FMA-UE, Fugl-Meyer Assessment-Upper Extremity; IQR, inter quartile range; PHQ-9, Patient Health Questionnaire - 9; SS-MAHE, Stroke Specific Measure of Adherence to Home-based Exercises; SD, standard deviation.

TABLE 2 Chi-square association of variables with exercise adherence and post-stroke depression.

Demographic variables	χ^2 value of SS-MAHE	*p*-Value	χ^2 value of PHQ-9	*p*-Value
PHQ-9	9.66	0.022*	Not applicable	Not applicable
FMA-UE	5.22	0.073	23.2	<0.001*
Age classification	7.90e−4	0.978	4.70	0.195
Sex	0.006	0.934	6.85	0.077
Location of lesion	4.07	0.044*	3.03	0.387
Chronicity	0.152	0.697	0.15	0.984
Type of stroke	0.0470	0.828	4.61	0.202
Premorbid handedness	1.66	0.198	5.58	0.134
Side of hemiplegia	3.03	0.082	2.00	0.573
Alcohol	0.758	0.384	0.467	0.926
Tobacco	0.013	0.909	1.97	0.579
Psychoactive drugs	0.949	0.330	0.845	0.839
Hypertension	3.19	0.074	1.35	0.717
Diabetes mellitus	0.186	0.667	1.87	0.601
Comorbidity classification	1.36	0.244	2.42	0.489
Pain in the upper limb	0.346	0.556	7.72	0.052
Caregiver support	0.349	0.555	4.17	0.244
Post-stroke work/leisure activities	0.0763	0.782	4.61	0.203
Type of exercise	96.7	<0.001*	4.07	0.667
Socioeconomic status	1.32	0.518	1.97	0.922

Abbreviations: FMA-UE, Fugl-Meyer Assessment-Upper Extremity; PHQ-9, Patient Health Questionnaire - 9; SS-MAHE, Stroke Specific Measure of Adherence to Home-based Exercises; χ^2, Chi-square association.

*= statistically significant.

TABLE 3 Binary logistic regression analysis of the relationship between the PHQ-9 score and demographic factors in patients with SS-MAHE (non-adherent as base outcome).

SS-MAHE (Non-adherent as base outcome)	Adherent to exercise		
Variables	Odds ratio	*p*-Value	95% Confidence interval
PHQ-9			
No depression	Reference		
Minimal depression	0.98	0.85	0.85, 1.13
Mild depression	0.90	0.17	0.78, 1.04
Moderate depression	0.69	0.001*	0.56, 0.85
Sex			
Female	Reference		
Male	0.99	0.94	0.88, 1.12
Location of lesion			
Left hemisphere	Reference		
Right hemisphere	0.94	0.29	0.85, 1.04
Chronicity			
Sub-acute stroke	Reference		
Chronic stroke	1.03	0.48	0.93, 1.15
Alcohol			
No	Reference		
Yes	0.82	0.43	0.51, 1.32
Tobacco			
No	Reference		
Yes	1.30	0.10	0.94, 1.78
Psychoactive drugs			
Not addicted	Reference		
Addicted	0.92	0.76	0.54, 1.57
Hypertension			
No	Reference		
Yes	1.14	0.04*	1.00, 1.29
Diabetes			
No	Reference		
Yes	0.94	0.32	0.85, 1.05
Pain score			
Bearable	Reference		
Unbearable	0.96	0.83	0.71, 1.31
Caregiver support			
Partial assistance	Reference		
Complete assistance	1.01	0.74	0.91, 1.12

(Continues)

TABLE 3 (Continued)

SS-MAHE (Non-adherent as base outcome)	Adherent to exercise		
Variables	**Odds ratio**	***p*-Value**	**95% Confidence interval**
Post-stroke work/leisure activities			
No	Reference		
Yes	0.93	0.50	0.77, 1.13
Type of exercise			
No exercise	Reference		
Movement-based	2.00	0.000*	1.80, 2.24
Task-based	1.80	0.000*	1.53, 2.13
Socioeconomic status			
Upper	Reference		
Upper middle class	0.99	0.95	0.83, 1.18
Lower middle class	0.86	0.33	0.64, 1.16

Abbreviations: PHQ-9, Patient Health Questionnaire - 9; SS-MAHE, Stroke Specific Measure of Adherence to Home-based Exercises.
*= Statistically significant.

exercise (SS-MAHE) category. This means that for each one-unit increase in moderate depression, the odds of adhering to exercise decrease by approximately 31%. Hence, stroke survivors with moderate depression are estimated to have lower odds of adhering to exercise than are those with no depression.

The association between movement-based exercise and adherence to exercise was statistically significant (OR = 2.00, 95% CI = 1.80, 2.24, $p < 0.001$). These findings suggest that stroke survivors who engage in movement-based exercise are approximately two times more likely to adhere to exercise than are those not engaged in any exercise.

The relationship between task-based type of exercise and SS-MAHE was statistically significant (OR = 1.80, 95% CI = 1.53, 2.13), $p < 0.001$). This means that those who engaged in task-based exercises have approximately 1.8 times the odds of adhering to exercise compared to their counterparts not engaged in any exercise.

3.4 | Influence of impairment (FMA-UE) on depression severity (PHQ-9)

The findings of multinomial logistic regression in Table 4 show the influence of the FMA-UE score on the PHQ-9 score. Patients with severe impairment were significantly more likely to fall into the minimal depression category compared to those with mild impairment. A relative risk ratio of 11.09 indicated that stroke patients with severe impairment had approximately 11.09 times greater relative risk of having minimal depression than mild impairment (RRR = 11.09, 95% CI = 1.17, 105.04; $p = 0.03$).

3.5 | Influence of impairment (FMA-UE) on adherence to exercise (SS-MAHE)

Binary logistic regression in Table 5 shows that only the presence of severe impairment (FMA-UE) had a statistically significant relationship with adherence to exercise (OR = 0.71, 95% CI = 0.54, 0.94; $p = 0.01$). The odds ratio of 0.71 suggested that stroke survivors with severe impairment have approximately 29% lower odds of adhering to exercise than do those with mild impairment.

4 | DISCUSSION

This study findings suggest that stroke survivors with moderate depression are 31% less likely to adhere to exercise than are those without depression. This highlights the potential impact of mental health on physical activity. PSD has significant effects on physical and cognitive functioning, including motor recovery after stroke. As depression decreases motivation and engagement in rehabilitation activities, it can slow recovery. Studies have shown that depression can negatively affect stroke recovery outcomes, particularly motor function. Patients with PSD may also experience greater levels of fatigue and difficulty sleeping, further hindering their ability to participate in rehabilitation.[17] Furthermore, participating in exercise and physical activity is not enough to reduce depression; rather, engaging in moderate to vigorous exercise substantially reduces the risk of depression.[18] A lack of exercise adherence and depression further worsen physical and mental health complications, such as increasing spasticity, tightness, contracture, and deformity, and decreasing self-esteem, self-worth, self-efficacy, self-perception, and self-confidence, eventually impeding neuroplasticity-induced recovery.[19] The PHQ-9 may not capture certain aspects particularly relevant to stroke survivors, such as the impact of physical impairments leading to emotional distress; cognitive difficulties affecting mood and well-being; functional limitations in daily life influencing mental health; disruption of engagement in rehabilitation activities affecting mental well-being; and the impact of social support, relationships, or social isolation on mental health. Recognizing and addressing depression can positively impact exercise adherence. A tailored intervention program should be designed and implemented for stroke survivors with moderate depression. Moreover, mental health support and physical rehabilitation should be incorporated to enhance overall well-being and increase adherence to exercise. Collaborative efforts between physiotherapists, occupational therapists, neurologists, psychologists, and other multidisciplinary professionals are necessary. The development of community-based support groups is critical for providing additional motivation for stroke survivors to adhere to exercise throughout their recovery. Finally, continued research into effective strategies for promoting exercise adherence among stroke survivors with depression is crucial.

Subsequently, the study findings suggest that stroke survivors who engage in movement-based exercise are estimated to have significantly greater odds of adhering to exercise than are those not

TABLE 4 Influence of FMA-UE on PHQ-9 scores using multinomial logistic regression (no depression as base outcome).

PHQ-9 (no depression as base outcome)	Minimal depression			Mild depression			Moderate depression		
FMA-UE	RR ratio	*p*-Value	95% CI	RR ratio	*p*-Value	95% CI	RR ratio	*p*-Value	95% CI
Mild	Reference								
Moderate	2.56	0.38	0.31, 20.97	6.58	0.13	0.55, 77.43	0.30	0.37	0.22, 4.18
Severe	11.09	0.03*	1.17, 105.04	5.98	0.17	0.44, 80.16	0.12	0.12	0.00, 1.82

Abbreviations: CI, confidence interval; FMA-UE, Fugl-Meyer Assessment – Upper Extremity; PHQ-9, Patient Health Questionnaire - 9; RR, risk ratio.
*= Statistically significant.

TABLE 5 Influence of FMA-UE on SS-MAHE scores using Binary logistic regression (non-adherent as base outcome).

SS-MAHE (non-adherent as base outcome)	Adherence to exercise		
FMA-UE	Odds ratio	*p*-Value	95% CI
Mild impairment	Reference		
Moderate impairment	0.77	0.06	0.59, 1.01
Severe impairment	0.71	0.01*	0.54, 0.94

Abbreviations: CI, confidence interval; FMA-UE, Fugl-Meyer Assessment – Upper Extremity; SS-MAHE, Stroke Specific Measure of Adherence to Home-based Exercises.
*= Statistically significant.

engaged in any exercise. These findings emphasize the potential positive impact of movement-based exercises on adherence to overall exercise habits. A recent study confirmed that intensive upper limb rehabilitation could significantly impact impairment and activity levels in stroke patients.[20] A systematic review concluded that passive, active-assisted, and active range of motion exercises provide beneficial effects on motor function, such as preventing stiffness, tightness, contracture, and deformity and improving strength, muscle flexibility, and joint mobility.[21] At least 1–2 exercise sessions per day for a week improved muscle tone, muscle mass, and strength post-stroke.[22] Research has consistently affirmed that movement-based exercise can improve exercise adherence. Factors such as social support, self-motivation, and self-efficacy play significant roles in adherence. Interventions that increase awareness of obstacles to exercise and develop coping techniques can also enhance adherence. An efficacy-based intervention should address more frequent and longer exercise sessions. Health technological tools such as mobile devices and inertial measurement units can additionally help stroke survivors achieve better exercise adherence.[23–26]

Stroke survivors engaging in task-based exercises are 80% more likely to adhere to exercise than to not exercise. Task-based exercises improved upper limb motor recovery and mobility and meaningful upper limb functioning post-stroke.[27] Increased task-oriented practices after a stroke may minimize upper limb motor impairment. These studies ascertained that both task-based and movement-based training increase motor recovery, motivating patients to adhere to exercise.[28] Nevertheless, the adherence rate was greater for movement-based exercises than for task-based exercises because they focus on movement quality and are practiced at high intensity. Despite compensatory reaching being less efficient post-stroke, task-related training resulted in better shoulder and elbow kinematics. The effectiveness of task-oriented practices for upper extremity motor recovery post-stroke has yet to be determined, with some studies showing a significant effect and others showing no effect.[29–31] Further research should explore the optimal dosage, framework for task-based and movement-based training, and home practice guidelines based on upper limb impairment severity, recovery stages, and patient requirements.

Notably, severe upper limb impairment (FMA-UE) was strongly positively associated with minimal level of depression post-stroke. On the other hand, depression scores were not influenced by mild or moderate impairment. This is similar to the previous findings where mild to moderate upper limb impairment is not significantly related to minimal depression.[32] A possible explanation for the lack of association with moderate or severe depression could be that severely impaired stroke patients are often informed by clinicians or therapists about the slow prognosis for upper limb recovery. This awareness may lead to acceptance regarding their condition, thereby reducing the likelihood of developing moderate or severe depression. However, during PHQ-9 evaluations, these patients might still express concerns related to self-esteem, self-efficacy, and cultural or socio-economic factors, which may contribute to minimal depression. Patients with severe upper limb impairment (FMA-UE) post-stroke may experience depression (PHQ-9) owing to complete dependence on activities of daily living and restriction in community participation. Longitudinal and experimental research investigating how to mitigate the social desirability bias of assessing depression is warranted.

Finally, stroke survivors with severe impairment (FMA-UE) are estimated to have lower odds of adhering to exercise (SS-MAHE) than are those with mild impairment (FMA-UE). Patients with severe stroke may not use their upper limbs for functional use compared to their counterparts with mild or moderate impairment. Research has also confirmed that stroke patients with moderate impairment recover faster than do those with severe impairment.[33] Moreover, community-dwelling stroke survivors with mild to moderate impairment who had better exercise adherence according to telephone calls demonstrated significant improvement in upper limb function.[34] Enhanced adherence interventions, such as patient education, psychological support, and assistance with practical challenges, should be developed to address barriers to adherence. A tailored rehabilitation program based on an individual's adherence level is a priority for people with severe upper limb impairment post-stroke. A multidisciplinary approach can address various aspects of adherence, including physical, psychological, and social factors. Regular medical interventions and periodic psychological evaluations are also crucial components in effectively treating or mitigating PSD and improving exercise adherence. Additionally, the treating clinician, therapist, or counselor should identify the root causes of depression and work to mitigate depressive symptoms as much as possible. This process involves closely monitoring the patient, fostering an environment where they feel comfortable to speak up openly, and gaining a thorough understanding of their daily routine, social relationships, priorities, abilities, and socioeconomic factors. Addressing the patient's challenges may include leveraging government policies, seeking assistance from nongovernmental organizations, facilitating vocational activities, or supporting a return to work.

Similarly, improving exercise adherence is crucial in stroke rehabilitation to enhance upper limb motor recovery. Rehabilitation strategies should be tailored to the severity of motor impairment, with an emphasis on integrating movement- and task-based exercises into the patient's daily functional activities. For example, patients with severe motor impairment might benefit from movement-based approaches such as neurophysiological techniques, passive exercises, and active-assisted exercises. In contrast, those with mild to moderate impairment may focus on task-based training that emphasizes the transfer of functional skills to real-world tasks. Upper limb exercises should be directly related to the patient's daily routines, aiming to enhance independence. In both movement- and task-based exercises, incorporating robotic assistance and game-based technology can further enhance outcomes. Movement-based exercises can be enhanced by the use of robotic devices, while task-based exercises can include functional rehabilitation approaches that involve both arms. These strategies increase the use of the more affected upper limb, intensify training, and add complexity to the spatial and temporal aspects of exercises. Incorporating shaping exercises and facilitating the transfer of skills from clinical settings to real-world environments may significantly improve exercise adherence. Additionally, involving family members and using technological tools such as text messages, video or audio calls, and logbooks for tracking progress can further enhance adherence. Ongoing support from therapists is also essential in maintaining engagement and promoting successful rehabilitation outcomes.

5 | CONCLUSION

This study highlights that PSD significantly impacts exercise adherence. Specifically, individuals with moderate depression are 31% less likely to adhere to exercise compared to those without depression. This underscores the complex interplay between mental health and exercise adherence. To promote upper limb recovery through consistent exercise, it is crucial to implement psychological health strategies that address depressive symptoms. Additionally, patients with severe motor impairment (as measured by FMA-UE) are significantly associated with 29% lower exercise adherence and are 11 times more likely to experience minimal depression than those with mild motor impairment. This emphasizes the need to address both mental health and the accessibility of physical rehabilitation to improve motor recovery in individuals with severe impairments after a stroke.

Therefore, tailored upper limb rehabilitation should be designed and implemented for stroke survivors with depression, combining mental health support with strategies to boost adherence to exercises for improved overall well-being. Regular evaluation and intervention of physiotherapists, occupational therapists, neurologists, psychologists, and other multidisciplinary professionals are necessary to attain complete recovery. Future studies should be focused on stroke individuals with large sample size, various sections of socioeconomic level, sex, and chronicity of community-dwelling stroke survivors.

AUTHOR CONTRIBUTIONS

Alexander Gnanaprakasam: Conceptualization; methodology; software; data curation; investigation; validation; formal analysis; writing—original draft. **Ajit Kumar Roy**: Conceptualization; methodology; data curation; validation; supervision; formal analysis; writing—review and editing; Resources. **Anagha Srikant Deshmukh**: Conceptualization; methodology; formal analysis; supervision; writing—review and editing; validation; data curation. **Suruliraj Karthikbabu**: Conceptualization; methodology; software; data curation; investigation; validation; formal analysis; supervision; project administration; writing—review and editing. All the authors have read and approved the final version of the manuscript. The corresponding author, John M. Solomon, had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

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CONFLICT OF INTEREST STATEMENT

The supporting source/financial relationships had no such involvement.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author, and Alexander Gnanaprakasam upon reasonable request for research purposes.

TRANSPARENCY STATEMENT

The lead author John M. Solomon affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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