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Assessing the impact of physical activity on bone density, cardiopulmonary function, and metabolic health in stroke survivors

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Abstract

Stroke survivors often face motor impairments leading to decreased physical activity, which can, in turn, result in secondary health-related issues like cardiovascular and pulmonary impairment and osteoporosis. This research finds out the impact of physical activity on bone mineral density, cardiopulmonary health, and metabolic status in stroke survivors. The goal is to generate knowledge to inform rehabilitation strategies, emphasizing the significant role of regular exercise in enhancing the health of individuals recovering from stroke. This study was conducted using a cross-sectional study design, and involved 100 stroke survivors selected through stratified random sampling. Physical activity was measured using the validated Stroke-Specific Physical Activity Questionnaire. Health outcomes were assessed through various means: bone mineral density via the OSTEOKJ3000 ultrasonic bone densitometer; resting heart rate and blood pressure via an automated monitor; lipid profiles through the CardioChek PA analyzer; Hb1Ac levels via the A1CNow + System; and respiratory parameters through a spirometer. Statistical analysis revealed bone mineral density is positively correlated with physical activity ($R = 0.53$, $P < .001$). Additionally, an association was found between physical activity and improved cardiopulmonary function (resting heart rate $r = -0.45$, $P < .001$; forced expiratory volume in one second $R = 0.30$, $P = .0023$; forced vital capacity $R = 0.28$, $P = .0041$). Moreover, higher physical activity levels correlated with lower low-density lipoprotein cholesterol levels ($r = -0.35$, $P = .0007$), higher high-density lipoprotein cholesterol levels ($R = 0.33$, $P = .0012$), and better glycaemic control (HbA1c $r = -0.40$, $P = .0002$). This study highlights the significant benefits of physical activity for stroke survivors, showing positive impacts on bone density, cardiopulmonary function, and metabolic health. It underscores the need to include regular exercise in rehabilitation strategies to mitigate secondary health complications and enhance the overall health of stroke survivors. Future research should continue investigating the potential benefits of physical activity in this population.

Abbreviations: FEF = forced expiratory flow, FEV1 = forced expiratory volume in one second, FVC = forced vital capacity, LDL = low-density lipoprotein, HDL = high-density lipoprotein, SSPAQ = stroke-specific physical activity questionnaire.

Keywords: bone mineral density, cardiovascular health, cross-sectional study, metabolic health, physical activity, pulmonary function, stroke survivors

1. Introduction

Stroke is a major global health concern, with an estimated 13.7 million new stroke cases reported annually, contributing to 5.5 million deaths. It stands as a significant contributor to fatalities and prolonged disabilities worldwide, often leading to profound motor impairments and a substantial decrease in physical activity among those affected.[1] In fact, approximately 50% to 70% of stroke survivors suffer from reduced mobility within the first year, significantly increasing their risk for secondary health complications such as cardiovascular and pulmonary disorders and osteoporosis.[2]

Such complications not only hinder the recovery process of stroke survivors but also significantly affect their quality of life, emphasizing a critical health concern that necessitates immediate attention and practical solutions.[3] Various strategies, including physical activity, have been employed in stroke rehabilitation to counter these poststroke complications. Physical activity, a central element of these strategies, has been shown to improve cardiovascular and pulmonary

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function and bone health.[4] Physical activity plays a pivotal role in promoting a range of health outcomes. Specifically, regular exercise stimulates bone formation and mineralization, enhancing bone density.[5] Additionally, it can positively influence cardiopulmonary health by improving cardiovascular efficiency and lung capacity, thereby reducing the risk of cardiovascular diseases.[6] Furthermore, physical activity plays a vital role in metabolic health, as it enhances insulin sensitivity, regulates blood glucose levels, and combats metabolic syndrome, among other benefits.[7] Considering these potential benefits, our hypothesis posits that structured physical activity poststroke could improve bone density, cardiopulmonary function, and overall metabolic health among stroke survivors.

Survivors' willingness and ability to exercise regularly limit the benefits' effectiveness. This highlights the need for personalized and adaptable physical activity programs, and a greater comprehension of the specific effects of physical activity on the aforementioned health parameters.[8]

These limitations signify a crucial gap in stroke rehabilitation: a comprehensive understanding of the role of physical activity and its impact on stroke survivors' bone density, cardiopulmonary function, and metabolic health. Addressing this gap could potentially enhance rehabilitation programs' efficacy and ultimately improve stroke survivors' overall well-being.[9]

Our study attempts to bridge this knowledge gap by assessing the impact of physical activity on stroke survivors' health in a more detailed and focused manner. We aim to investigate the association between physical activity levels and various health outcomes, including bone mineral density, cardiovascular health, pulmonary function, and metabolic health. We focus to derive significant insights that could inform and enhance current rehabilitation strategies.[10]

Through our study, we aspire to reinforce the importance of tailored, comprehensive, and regular physical activity in stroke rehabilitation. Our ultimate goal is to enhance the health outcomes of stroke survivors, making strides toward solving the daunting problem of secondary health complications following stroke.[11]

2. Methodology

Before initiating the research procedures, participants provided informed consent after comprehensively explaining the study's objectives and procedures. This study was conducted using a cross-sectional study design. The research population comprised 100 individuals who had previously experienced a stroke. These participants were selected via stratified random sampling.[12] Jazan University Hospital, a tertiary care center renowned for its specialized stroke rehabilitation unit, served as the recruitment location for study subjects. This location was chosen due to its diverse patient demographics, allowing for a comprehensive understanding of physical activity's impact on stroke survivors with differing clinical and demographic characteristics.[13]

To achieve statistically significant results, the required sample size was determined prior to participant selection. This calculation was based on a 95% confidence level, a population proportion presumption of 50%, and a margin of error of 5%. Consequently, it was deduced that the minimum required sample size was 100 stroke survivors.[14]

The sampling process incorporated stratification by age and duration poststroke to ensure representation across different strata. The study aimed to enroll 100 stroke survivors, with the inclusion criteria stipulating that participants should: (a) have experienced an ischemic or hemorrhagic stroke at least 3 months prior to the study; (b) be over the age of 18; and c) possess adequate communication abilities. The exclusion criteria included individuals who: (a) had a mental health disorder (evidenced by a score of <21 on the Mini-Mental State Examination); (b) suffered from severe perceptual or communication problems; or (c) had severe concurrent cardiac or pulmonary disease.[15]

Physical activity levels were assessed using the validated Stroke-Specific Physical Activity Questionnaire (SSPAQ), a reliable tool designed to measure physical activity among stroke survivors. The SSPAQ (Short Self-Paced Questionnaire) is commonly used to measure levels of physical activity, particularly in stroke patients or older adults. It provides a comprehensive assessment of an individual's physical activity in various domains, such as leisure-time, household, and transportation-related activities.[16]

We used the OSTEOKJ3000 ultrasonic bone densitometer to assess the affected lower limb's bone mineral density. Participants placed the ankle of their affected limb on the force plate. Subsequently, the device calculated the mineral bone density of the ankle. We selected this site for its accessibility and rich trabecular bone content. This noninvasive and reliable tool is known for its capability to detect bone mineral density changes related to physical activity.[17]

Cardiopulmonary function was assessed using resting heart rate and blood pressure measurements, collected via an automated monitor, and respiratory parameters, evaluated with a spirometer in accordance with American Thoracic Society guidelines.[18] This chosen for their rigorous standardization, widespread acceptance, and emphasis on patient safety in respiratory assessments. Resting heart rate: resting heart rate is a vital cardiovascular health and fitness indicator. It is particularly relevant for stroke survivors since cardiovascular health is intricately linked with the potential for subsequent strokes and overall cardiovascular-related morbidity.

Blood pressure: Elevated blood pressure is a significant risk factor for stroke. Monitoring blood pressure in stroke survivors can offer insights into the effectiveness of interventions and the risk of future cerebrovascular events.

Lipid profile: Dyslipidaemia is a recognized risk factor for atherosclerosis, which can lead to ischemic strokes. Evaluating the lipid profile helps assess the risk for future strokes and the efficacy of interventions to reduce this risk.

HbA1c: Elevated HbA1c levels indicate poor long-term glucose control, putting patients at a higher risk for diabetic complications, including macrovascular conditions that can precipitate strokes. Monitoring HbA1c provides an assessment of the metabolic health of stroke survivors, which can have implications for their overall health trajectory and rehabilitation outcomes.

Metabolic health was gauged using the CardioChek PA analyzer, a reliable device that measures lipid profiles. Additionally, HbA1c levels, indicative of long-term glucose control, were determined using the A1CNow + System. This portable, point-of-care testing device offers rapid and accurate HbA1c results, facilitating effective monitoring of diabetes control.[19]

To ensure the reliability and validity of the outcome measures, the study employed validated and standardized tools. Protocols for data collection included double-checking measurements and performing repeated measurements as needed.

The study received ethical approval from Standing Committee for Scientific Research- Jazan University REC-44/07/520 and was conducted in compliance with the Helsinki Declaration's principles, prioritizing the rights, safety, and well-being of the study participants.

2.1. Statistical analysis

The statistical analysis was carried out using the SPSS software. Initially, the normality of the data was verified through the Shapiro–Wilk test. The results indicated that all data sets followed a normal distribution, meeting the preconditions necessary for conducting further statistical analyses. The Pearson correlation analysis was then employed to explore the relationship between physical activity levels, as measured by the SSPAQ, and various health parameters. A significance level of 0.05 was established a priori for all statistical tests.

3. Results

3.1. Patient characteristics

The demographic and clinical characteristics of the 100 stroke survivors were analyzed. The sample consisted of 61 males (61%) and 39 females (39%). The age of the participants ranged from 18 to 75 years, with a mean age of 58.2 years (SD = 9.3). In terms of the type of stroke, 74 participants (74%) had an ischemic stroke, and the remaining 26 (26%) had a hemorrhagic stroke.

Time since stroke occurrence varied from 3 months to 15 years, with a median of 2 years. Regarding comorbidities, 55% of the participants had hypertension, 36% had diabetes mellitus, and 21% had heart disease.

As for physical activity levels assessed through the SSPAQ, scores ranged from 15 to 75 with an average of 38.7 (SD = 16.5), suggesting a moderate level of physical activity among the study participants.

The average resting heart rate among the participants was 75.6 beats per minute (SD = 12.2), and the mean blood pressure was 130/80 mm Hg. Respiratory parameters varied across participants, with an average Forced Expiratory Volume in the first second (FEV1) of 2.1L (SD = 0.5).

As for metabolic parameters, the average Total Cholesterol level was 5.1 mmol/L (SD = 1.2), high-density lipoprotein (HDL) cholesterol was 1.3 mmol/L (SD = 0.3), and the mean HbA1c level was 6.8% (SD = 1.1). The average bone mineral density was 2.4 g/cm2 (SD = 0.5).The details of patient characteristics shows in Table 1.

1. Association of the level of physical activity with the bone mineral density of the ankle:
   - A strong positive correlation was observed between the level of physical activity and the bone mineral density at the ankle ($R = 0.53$, $P = .0001$). This suggests that higher levels of physical activity may positively influence bone health, especially in the ankle region, among stroke survivors.
2. Association of the level of physical activity with respiratory parameters:
   - FEV1: A statistically significant positive correlation was found between the level of physical activity and FEV1 ($R = 0.30$, $P = .0023$), indicating that higher physical activity levels were associated with better forced expiratory volume in the first second.
   - Forced vital capacity (FVC): Similarly, a statistically significant positive correlation was observed between the level of physical activity and FVC ($R = 0.28$, $P = .0041$), suggesting that higher physical activity levels were linked to better forced vital capacity.
   - Forced expiratory flow (FEF)25-75: A statistically significant positive correlation was found between the level of physical activity and FEF25-75 ($R = 0.31$, $P = .0018$), indicating that higher physical activity levels were associated with better FEF at 25% to 75% of the pulmonary volume.
   - FEV1/FVC ratio: No significant association was found between physical activity and the ratio of FEV1/FVC ($P = .0721$).
3. Association of the level of physical activity with resting heart rate, blood pressure, lipid profile, and HbA1c:
   - Resting heart rate: The results showed a moderate negative correlation between the level of physical activity and resting heart rate ($r = -0.45$, $P < .0001$), indicating that higher levels of physical activity were associated with a lower resting heart rate.
   - Blood Pressure: No statistically significant association was found between physical activity and blood pressure (systolic $P = .11$, diastolic $P = .17$). This might be attributable to the high prevalence of hypertension in the sample.
   - Lipid Profile: Higher physical activity levels were associated with lower low-density lipoprotein cholesterol levels ($r = -0.35$, $P = .0007$), higher HDL cholesterol levels ($R = 0.33$, $P = .0012$), and lower triglyceride levels ($r = -0.28$, $P = .0038$). No significant association was found between physical activity and total cholesterol levels ($P = .06$).
   - HbA1c: A significant negative correlation was observed between physical activity levels and HbA1c levels ($r = -0.40$, $P = .0002$), suggesting that higher levels of physical activity may contribute to improved glycaemic control in stroke survivors. The details of correlation of various parameters with physical activity shows in Table 2.
   - All significant correlations are at the 0.05 level (2-tailed).
   - Negative correlations represent inverse relationships (as one increase, the other decreases).
   - Positive correlations represent direct relationships (as one increases, the other also increases).

Figures 1–3 illustrates that the scatter diagram showing highly significant variables, in which, coefficient of 0.0147 represents the estimated change in Bone Mineral Density for a one-unit increase in Physical Activity. This means that, on average, for every 1 unit increase in Physical Activity, the predicted Bone Mineral Density is expected to increase by approximately 0.0147 units. Whereas, a negative coefficient (in this case, −0.0171) indicates an inverse relationship, suggesting that as Physical Activity increases, the predicted HbA1C tends to decrease. The coefficient of 0.0137 represents the estimated change in FEF25-75 for a one-unit increase in Physical Activity.

Table 1

Patient characteristics.

Characteristic	Result
Gender (males)	61%
Gender (females)	39%
Age (range)	18–75 years
Age (mean ± SD)	58.2 ± 9.3
Stroke type (ischemic)	74%
Stroke type (hemorrhagic)	26%
Time since stroke (median)	2 years
Hypertension	55%
Diabetes mellitus	36%
Heart disease	21%
SSPAQ score (range)	15–75
SSPAQ score (mean ± SD)	38.7 ± 16.5
Resting heart rate (mean ± SD)	75.6 ± 12.2 bpm
Blood pressure (mean)	130/80 mm Hg
FEV1 (mean ± SD)	2.1 ± 0.5 L
FVC (mean ± SD)	3.0 ± 0.7 L
FEV1/FVC% (mean ± SD)	70.2 ± 8.3 %
FEF25-75 (mean ± SD)	2.2 ± 0.6 L/s
Total cholesterol (mean ± SD)	5.1 ± 1.2 mmol/L
HDL cholesterol (mean ± SD)	1.3 ± 0.3 mmol/L
LDL cholesterol (mean ± SD)	3.1 ± 0.8 mmol/L
Triglycerides (mean ± SD)	1.8 ± 0.6 mmol/L
HbA1c (mean ± SD)	6.8 ± 1.1 %
Bone mineral density (mean ± SD)	2.4 ± 0.5 g/cm

LDL = low-density lipoprotein, HDL = high-density lipoprotein, SSPAQ = stroke-specific physical activity questionnaire.

4. Discussion

This cross-sectional study investigated the impact of physical activity on bone mineral density, cardiopulmonary function, and metabolic health in stroke survivors. The findings suggest that engaging in physical activity can have numerous health benefits for stroke survivors, emphasizing its importance in the management and rehabilitation of these individuals.

Our study results exhibit a profound association between physical activity levels and several health parameters among stroke survivors. Notably, the findings underline the potential benefits of physical activity for bone health, cardiopulmonary function, and metabolic control.

In alignment with earlier studies,[20,21] our study showed a strong positive correlation between physical activity and bone mineral density, particularly at the ankle. This suggests that physical activity might promote bone health among stroke survivors, potentially decreasing their risk of osteoporosis and associated fractures, which are common secondary complications poststroke. Our findings reiterate the crucial role of weight-bearing activities in enhancing bone mineral density, as they stimulate bone formation and reduce bone resorption, as proposed by Marques et al[22]

Furthermore, we observed significant positive correlations between physical activity levels and pulmonary parameters, including FEV1, FVC, and FEF25-75. Our findings resonate with those of Billinger et al,[23] who reported improved pulmonary function among stroke survivors engaged in regular exercise. Physical activity may promote respiratory muscle strength and endurance, thereby improving lung function.[24] Nevertheless, the lack of significant association between physical activity and FEV1/FVC ratio is noteworthy and might reflect a balanced effect of physical activity on both FEV1 and FVC.

As for cardiovascular health, our study revealed a significant negative correlation between physical activity levels and resting heart rate, indicative of the potential cardioprotective effects of physical activity. These findings echo those of Tjønna et al,[25] who suggested that regular physical activity reduces resting heart rate, potentially through autonomic nervous system modulation and increased cardiac efficiency. In contrast, we found no significant association between physical activity and blood pressure. This might be attributed to the high prevalence of hypertension in our sample and the concurrent use of antihypertensive medications, which, as noted by Sharman and Stowasser (2009), can interfere with the blood pressure responses to physical activity.[26]

Our results also showed a significant association between physical activity and metabolic parameters. We found significant negative correlations between physical activity levels and low-density lipoprotein cholesterol, triglycerides, and HbA1c levels, as well as a significant positive correlation with HDL cholesterol levels. These findings align with existing literature emphasizing the beneficial impact of physical activity on lipid profile and glucose control.[27,28] This might be attributable to the enhanced insulin sensitivity and increased energy expenditure induced by physical activity, leading to improved glycaemic control and lipid metabolism.[29]

Our investigation, though revealing in its scope, does carry certain limitations that should be acknowledged. The cross-sectional nature of our study design limits our ability to infer causality from the observed associations. Moreover, our reliance on self-reported physical activity data might have introduced

Table 2

Shows correlation of bone density, cardiopulmonary function, and metabolic health with physical activity.

Parameter	Correlation with physical activity (r)	*P*-value
Bone mineral density (Ankle)	0.53	.0001
Forced expiratory volume (FEV1)	0.30	.0231
Forced vital capacity (FVC)	0.28	.0411
Forced expiratory flow (FEF25-75)	0.31	.0001
FEV1/FVC ratio	0.07	.072
Resting heart rate	−0.45	.001
Systolic blood pressure	0.05	.111
Diastolic blood pressure	0.02	.171
LDL cholesterol	−0.35	.022
HDL cholesterol	0.33	.0011
Triglycerides	−0.28	.033
Total cholesterol	.04	.063
HbA1c	−0.40	.0002

LDL = low-density lipoprotein.

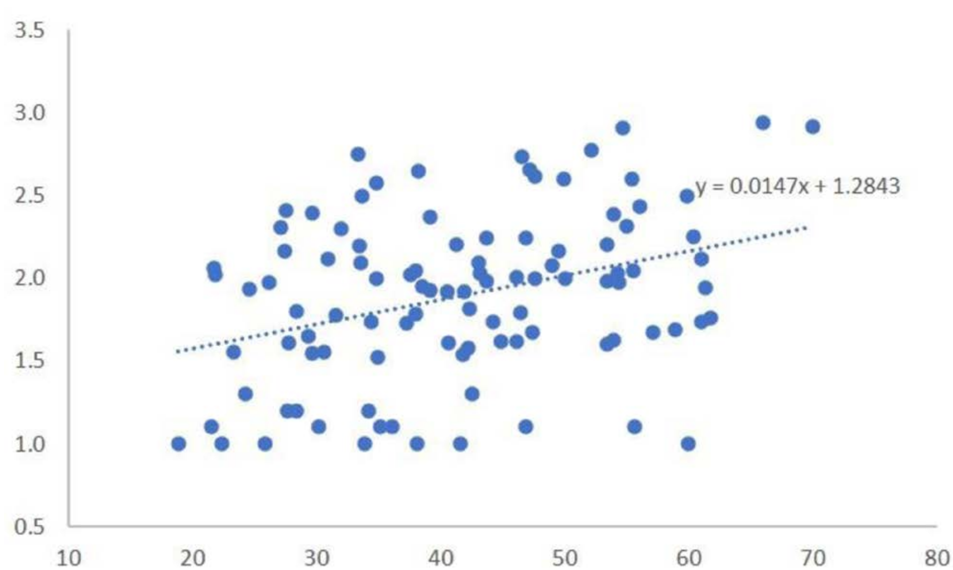

Figure 1. Physical activity with the bone mineral density.

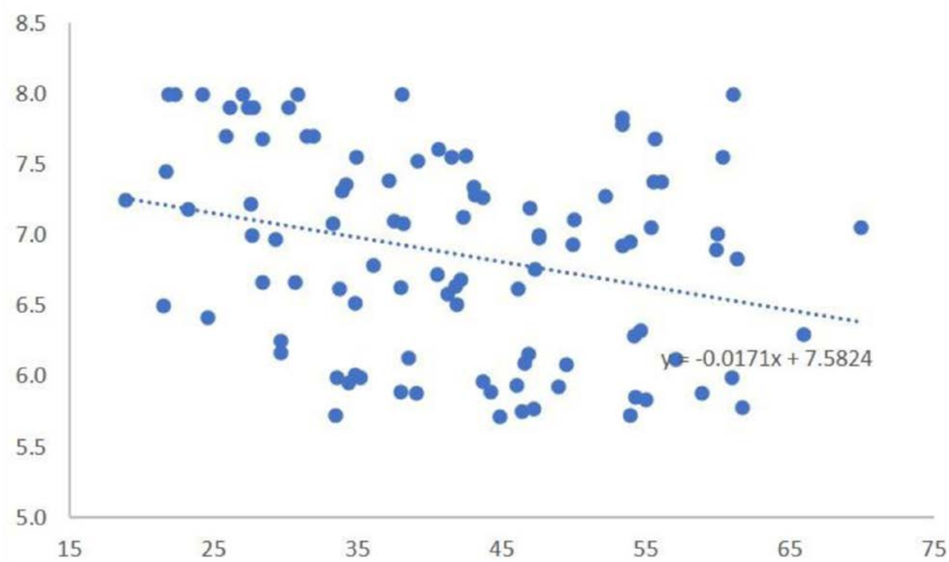

Figure 2. Physical activity with HbA1C.

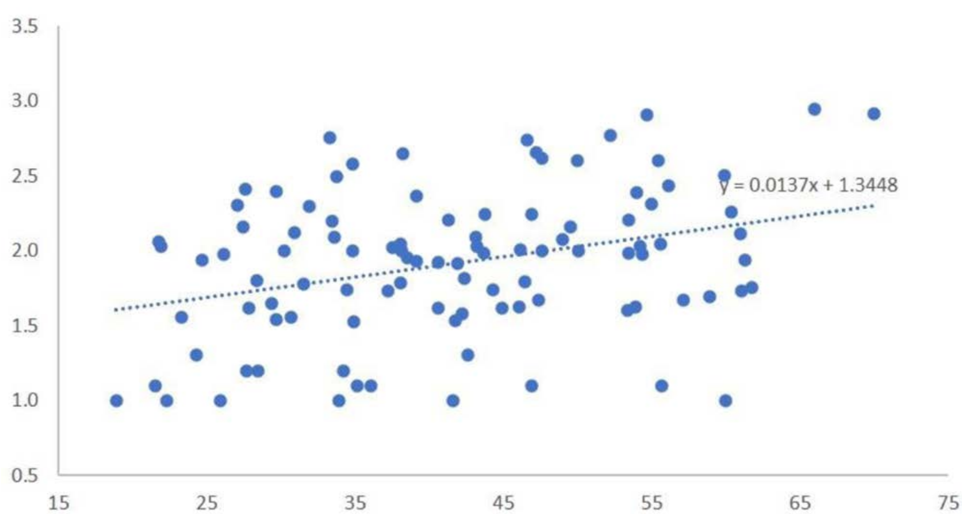

Figure 3. Physical activity with forced expiratory flow (FEF25-75).

reporting bias, potentially overestimating or underestimating the actual physical activity levels of participants. We also did not account for the potential impact of dietary intake and medication adherence, which could influence the health parameters under study. Future research should consider these factors and possibly incorporate more objective measures of physical activity, such as wearable technology, to achieve a more accurate assessment. Furthermore, our sample consisted predominantly of urban-dwelling participants, which may limit the generalizability of our findings to rural or other diverse populations.

Looking ahead, future prospective studies with larger, more diverse samples are recommended to validate our findings and further explore the relationships we identified. Additionally, randomized controlled trials could be valuable in isolating the direct effects of physical activity on health outcomes among stroke survivors. Further research into the mechanisms underlying these relationships could also be instrumental in enhancing our understanding of how physical activity promotes health among this population, which could inform the development of targeted interventions to improve the health and quality of life of stroke survivors

5. Conclusion

In conclusion, our study underscores the importance of physical activity in improving health outcomes among stroke survivors, including bone health, lung function, heart rate regulation, and metabolic control. The associations revealed by our research are compelling, highlighting physical activity as a potentially influential factor in managing the secondary complications of stroke, which bear significant health implications for this population.

Notably, our study is one of the few to illustrate these relationships in stroke survivors, specifically demonstrating the role of physical activity in enhancing bone health and respiratory function in this population. This contributes novel insights to the existing body of literature and sets the stage for further investigations.

The uniqueness of our research lies in its holistic approach, investigating multiple health parameters in tandem. We believe that our findings could have important clinical implications, informing future interventions and rehabilitation strategies for stroke survivors. By recognizing and harnessing the potential of physical activity, healthcare providers may be able to improve the long-term health and quality of life of stroke survivors, making strides towards more comprehensive, patient-centric care. Future research should continue to explore the benefits of physical activity poststroke, moving us closer to a more nuanced understanding of stroke recovery and rehabilitation.

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