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RESEARCH

Associations between physical activity patterns and among hypertensive older adults: a logistic and principal component analysis

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Abstract

Background: Physical activity is essential for maintaining health and (QoL), especially among older adults living with hypertension. This study aimed to examine how different types of physical activity relate to QoL among older adults with hypertension and to identify underlying patterns of activity.
Methods: A cross-sectional study was conducted among older adults with hypertension who completed the ten-item QPAR and WHOQOL-BREF questionnaires (n = 131). Logistic regression analyses were used to examine associations between each QPAR item and four QoL domains (physical, psychological, social, and environmental). Variables with $p < 0.2$ in univariate analysis were included in adjusted models. PCA with varimax rotation was performed to identify latent components of physical activity, and the resulting component scores were correlated with QoL domains.
Results: In the adjusted logistic regression model, moderate and light forms of physical activity were associated with better QoL in the crude analyses, whereas vigorous activity was associated with poorer physical QoL (p = 0.002). After adjustment for sex and education and correction for multiple testing, total physical activity remained significantly associated only with the social QoL domain (aOR = 1.12, 95% CI: 1.04–1.22).Principal component analysis (PCA) identified three underlying patterns of physical activity explaining 64.3% of the total variance: (1) mobility and independence-related activities, (2) moderate-intensity daily activities, and (3) light or socially engaging activities. Among these, the socially engaging and outdoor activities pattern showed the strongest positive correlation with physical QoL (r = 0.43), followed by social (r = 0.31) and psychological (r = 0.27) domains.
Conclusion: Physical activity was associated with QoL primarily through socially engaging and independence-related activities rather than vigorous exercise. These findings highlight the importance of sustainable, socially embedded forms of activity for hypertensive older adults.
Keywords: Hypertension, elderly, physical activity, , principal component analysis, QPAR, WHOQOL-BREF

Introduction

Hypertension is one of the most common chronic conditions in older adults and a major contributor to cardiovascular morbidity and mortality [1, 2]. In this population, maintaining adequate blood pressure control requires not only pharmacological therapy but also sustainable lifestyle habits, particularly regular physical activity [3, 4]. Physical activity improves vascular health, endothelial function, and metabolic regulation, while also enhancing mental well-being and perceived (QoL) [5]. However, the intensity and type of activity that most benefit hypertensive older adults remain debated [6].
Although exercise interventions have shown beneficial effects on cardiovascular outcomes, vigorous activity may

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not always be suitable or acceptable for older adults with hypertension [5, 7, 8]. Factors such as medication use, limited mobility, or fear of exertion can reduce tolerance for high-intensity activity [9]. In contrast, light or moderate activity integrated into daily routines such as walking, household tasks, or community participation may be more appropriate [5]. Yet, evidence on how these different activity types relate to specific domains of QoL remains limited, particularly in community-based populations.

The questionnaire for physical activity rating (QPAR) provides a simple, multidimensional measure of habitual activity that captures both structured exercise and incidental movements [10]. When analyzed item by item, it allows a more detailed assessment of which aspects of activity contribute most to well-being. The WHOQOL-BREF, on the other hand, evaluates QoL across four domains, namely physical, psychological, social, and environmental [11, 12]. The quality-of-life instrument provides a comprehensive view of perceived health beyond physical symptoms alone, as previously recommended [13].

Previous studies have often treated physical activity as a single composite score, which may obscure the unique contribution of different types or intensities of movement [14, 15]. An item-level approach combined with principal component analysis (PCA) enables the identification of latent activity patterns that better reflect the real behavior of older adults. In published literature, there are some examples on the use of PCA in epidemiological studies to support the statistical models in emphasizing the relationships between variables [16-18]. Understanding these activity structures and their relationships with QoL may provide insights for designing more tailored and feasible health promotion strategies for hypertensive individuals. Therefore, this study aimed to analyze the associations between physical activity and QoL among hypertensive older adults. Logistic regression was applied to evaluate the independent effects of each activity item on QoL domains, and PCA was used to identify underlying components of physical activity.

Methods

Study design

This cross-sectional study aimed to evaluate the association between physical activity patterns and QoL among hypertensive older adults in Lhokseumawe Municipality, Indonesia. The survey was conducted from October to November, 2025, and ethical approval was obtained from the Ethics Commission on Health Research of the POLTEKKES KEMENKES Aceh (No. DP.04.03/12.7/405/2025). Eligible respondents were selected through a random sampling method and participated voluntarily after signing written informed consent.

Sample size and randomization

The sample size was calculated using OpenEpi (https://www.openepi.com/), based on a 95% confidence level, 80% power, and a ratio of unexposed to exposed of 1:1. Using an estimated 50% prevalence of adequate physical activity among hypertensive elderly in the study area, the minimum required sample size was 96 participants. To enhance statistical strength, a total of 131 respondents were recruited. Randomization was performed by entering residential districts and household numbers into an open-source online randomizer. Enumerators visited each household in the randomized order, and when eligibility criteria were not met or consent was refused, the next household on the list was approached.

Eligibility criteria

Participants were eligible if they were aged ≥60 years, had a clinical diagnosis of hypertension for at least one year, and were residents of Aceh Province verified by an identity card. Blood pressure was classified according to systolic blood pressure (SBP) as normotension (< 120 mmHg), pre-hypertension (120–139 mmHg), hypertension grade I (140–159 mmHg), grade II (160–179 mmHg), and critical hypertension (≥ 180 mmHg). Individuals with secondary hypertension, emergency hypertension, history of cardiovascular or cerebrovascular events, or severe physical disabilities were excluded.

Data collection and variables

Demographic data included age, sex, education, occupation, marital status, ethnicity, body mass index (BMI), waist circumference, and blood pressure. BMI was calculated as weight (kg) divided by height squared (m^2). Physical activity was evaluated using the QPAR, which consists of 10 items (QP1–QP10) describing different contexts and intensities of activity, including vigorous, moderate, and light movements. Each item was scored from 1 to 5, and summed to obtain the QPAR total score (QP_total), with higher scores indicating higher physical activity levels. QoL was measured using the World Health Organization -BREF (WHOQOL-BREF) instrument. It includes 26 items distributed into four domains: physical (QL_D1), psychological (QL_D2), social (QL_D3), and environmental (QL_D4). Each item was scored on a 1–5 Likert scale, then converted to a 0–100 scale following WHO guidelines, with higher scores indicating better QoL.

Statistical analysis

All analyses were conducted using RStudio version 4.5.0. Descriptive statistics were expressed as means ± standard deviations (SD) for continuous variables and frequencies with percentages for categorical variables. For univariate analysis, characteristics and quality-of-life domains were compared across physical activity levels using ANOVA for continuous variables and chi-square tests for categorical variables. Subsequently, binary logistic regression was used to estimate the association between each QPAR item, the overall QPAR score, and each WHOQOL-BREF domain. Each QoL domain was dichotomized at its median value into “low” and “high” QoL groups. Both crude odds ratios (cOR) and adjusted odds ratios (aOR) were reported, with adjustments made for sex and education level. Results were presented with 95% confidence intervals

Table 1. Characteristics and of older adults diagnosed with hypertension.

Variables	Physical activity, *n* (%)		*P*-value
	Low (*n* = 68)	High (*n* = 63)	
Age (years)	70.3 ± 4.9	69.7 ± 4.5	0.700
Sex			
Female	53 (78)	57 (90)	0.051
Male	15 (22)	6 (9.5)	
Married			
Married	38 (56)	35 (56)	0.999
Unmarried	30 (44)	28 (44)	
Education			
Diploma	3 (4.4)	3 (4.8)	0.001
None	9 (13)	0 (0)	
Primary education	34 (50)	24 (38)	
Secondary education	22 (32)	34 (54)	
Undergraduate education	0 (0)	2 (3.2)	
Occupation			
Manual workers	9 (13)	5 (7.9)	0.400
Private sector employees	0 (0)	2 (3.2)	
Public sector employees	2 (2.9)	4 (6.3)	
Self-employed	3 (4.4)	1 (1.6)	
Unemployed	54 (79)	51 (81)	
Body mass index (kg/m²)	25.2 ± 4.8	24.7 ± 5.7	0.500
Waist circumference (cm)	91 ± 11	89 ± 15	0.400
Systolic BP (mmHg)	157 ± 12	157 ± 10	0.900
Diastolic BP (mmHg)	91 ± 16	95 ± 13	0.110
WHOQOL-BREF			
Physical QoL (Domain 1)	56 ± 15	62 ± 10	0.005
Psychological QoL (Domain 2)	54 ± 15	64 ± 16	< 0.001
Social QoL (Domain 3)	60 ± 17	77 ± 20	< 0.001
Environmental QoL (Domain 4)	53 ± 17	71 ± 23	< 0.001

Notes: QoL, quality of life; SD, standard deviation

(CIs) and $p < 0.05$ was considered statistically significant. To control for multiple comparisons across the logistic regression models, the Benjamini–Hochberg false discovery rate (FDR) correction was applied to the *p*-values.

Due to small and imbalanced subgroup sizes, stratified logistic regression was not performed to avoid the violation of the events-per-variable assumption, which could yield unstable estimates. To explore heterogeneity without loss of power, a k-means clustering analysis based on PCA component scores was performed. The PCA was applied to the ten QPAR items. Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity. Components with eigenvalues > 1 were retained and rotated using the varimax method. The resulting component scores were correlated with the WHOQOL-BREF domains to explore relationships between latent physical activity patterns and perceived .

Results

Characteristics of the participants

Characteristics of 131 hypertensive older adults involved in this study are presented in Table 1. The mean age of participants was comparable between groups (70.3 ± 4.9 years *vs*. 69.7 ± 4.5 years, $P = 0.700$). Females constituted the majority in both groups, and the proportion was slightly higher in the high activity group ($n = 57$, 90%) compared to the low activity group ($n = 53$, 78%), with a *p*-value of 0.051. Marital status did not differ between groups, with approximately 56% of participants in both groups being married ($P = 0.999$). Educational background showed a significant difference between physical activity groups ($P = 0.001$). Participants with higher education levels (secondary or undergraduate) were more represented in the high activity group, whereas those without formal education or with only primary education were more common among individuals with low activity levels. No significant differences were observed in occupational status ($P = 0.400$), as most participants in both groups were unemployed. BMI, waist circumference, and SBP were similar between groups ($P > 0.05$). Although diastolic blood pressure tended to be higher among those with higher activity levels (95 ± 13 mmHg *vs*. 91 ± 16 mmHg), the difference did not reach statistical significance ($P = 0.110$).

Associations between physical activity and quality of life

The associations between physical activity items and the four WHOQOL-BREF domains among hypertensive older adults are presented in Table 2. In the physical QoL domain, significant protective associations were observed for several QPAR items. QP1 (light household activity) was associated with lower odds of poor physical QoL in the unadjusted model (OR = 0.54, 95% CI: 0.31–0.90, $P = 0.021$), although the association was attenuated after adjustment ($P = 0.155$). QP3 (moderate routine activity; aOR = 0.51, 95% CI: 0.28–0.87, $P = 0.018$), QP4 (mobility-related task; aOR = 0.38, 95% CI: 0.23–0.59, $P < 0.001$), and QP8 (outdoor activity; aOR = 0.53, 95% CI: 0.33–0.82, $P = 0.006$) remained significant predictors of higher physical QoL. In contrast, QP2 (vigorous activity) showed a positive association with poor physical QoL after adjustment (aOR = 2.32, 95% CI: 1.38–4.08, $P = 0.002$). The total QPAR score was significantly associated with better physical QoL both before (OR = 0.88, 95% CI: 0.82–0.94, $P < 0.001$) and after adjustment (aOR = 0.91, 95% CI: 0.83–0.99, $P = 0.027$). For the psychological domain, significant protective associations were observed

Table 2. Associations between physical activity items (QP1–QP10) and domains (WHOQOL-BREF) among hypertensive older adults.

Physical activity	Unadjusted model		Adjusted model	
	OR (95% CI)	*P*-value	aOR	*P*-value
Physical QoL (Domain 1)				
QP1	0.54 (0.31 – 0.90)	0.021	0.62 (0.31 – 1.18)	0.155
QP2	1.294 (0.88 – 1.92)	0.191	2.32 (1.38 – 4.08)	0.002
QP3	0.43 (0.26 – 0.67)	< 0.001	0.51 (0.28 – 0.87)	0.018
QP4	0.40 (0.27 – 0.57)	< 0.001	0.38 (0.23 – 0.59)	< 0.001
QP5	0.721 (0.51 – 1.00)	0.055	0.94 (0.62 – 1.44)	0.79
QP6	0.734 (0.51 – 1.04)	0.084	0.91 (0.57 – 1.42)	0.679
QP7	0.81 (0.58 – 1.12)	0.204	0.956 (0.63 – 1.44)	0.827
QP8	0.52 (0.35 – 0.73)	< 0.001	0.531 (0.33 – 0.82)	0.006
QP9	0.73 (0.52 – 1.01)	0.058	0.76 (0.50 – 1.14)	0.188
QP10	0.74 (0.50 – 1.06)	0.103	0.672 (0.41 – 1.06)	0.096
Overall	0.88 (0.82 – 0.94)	< 0.001	0.91 (0.83 – 0.99)	0.027
Psychological QoL (Domain 2)				
QP1	0.59 (0.34 – 0.97)	0.042	0.64 (0.35 – 1.15)	0.144
QP2	1.02 (0.70 – 1.50)	0.915	1.17 (0.75 – 1.82)	0.486
QP3	0.59 (0.38 – 0.90)	0.017	0.70 (0.43 – 1.11)	0.138
QP4	0.60 (0.43 – 0.83)	0.002	0.615 (0.42 – 0.89)	0.012
QP5	0.69 (0.49 – 0.96)	0.028	0.78 (0.52 – 1.15)	0.208
QP6	0.72 (0.50 – 1.02)	0.070	0.79 (0.51 – 1.19)	0.263
QP7	0.90 (0.65 – 1.24)	0.515	0.99 (0.67 – 1.45)	0.955
QP8	0.68 (0.48 – 0.95)	0.025	0.74 (0.50 – 1.10)	0.139
QP9	0.78 (0.56 – 1.08)	0.136	0.81 (0.55 – 1.18)	0.271
QP10	0.85 (0.59 – 1.21)	0.362	0.79 (0.51 – 1.21)	0.289
Overall	0.91 (0.85 – 0.97)	0.005	0.92 (0.85 – 1.00)	0.045
Social QoL (Domain 3)				
QP1	0.57 (0.33 – 0.95)	0.038	0.64 (0.34 – 1.16)	0.154
QP2	1.02 (0.69 – 1.50)	0.931	1.30 (0.82 – 2.07)	0.270
QP3	0.59 (0.38 – 0.91)	0.019	0.73 (0.44 – 1.17)	0.197
QP4	0.48 (0.33 – 0.67)	< 0.001	0.51 (0.34 – 0.75)	0.001
QP5	0.57 (0.38 – 0.81)	0.003	0.63 (0.41 – 0.94)	0.029
QP6	0.63 (0.43 – 0.91)	0.018	0.70 (0.44 – 1.06)	0.102
QP7	0.73 (0.52 – 1.02)	0.072	0.80 (0.54 – 1.17)	0.251
QP8	0.59 (0.41 – 0.83)	0.003	0.63 (0.42 – 0.94)	0.024
QP9	0.82 (0.59 – 1.13)	0.226	0.88 (0.61 – 1.29)	0.525
QP10	0.65 (0.44 – 0.95)	0.029	0.60 (0.38 – 0.93)	0.025
Overall	0.88 (0.82 – 0.94)	< 0.001	0.89 (0.82 – 0.96)	0.006
Environmental QoL (Domain 4)				
QP1	0.61 (0.36 – 1.01)	0.063	0.80 (0.43 – 1.46)	0.480
QP2	0.82 (0.56 – 1.21)	0.326	1.06 (0.67 – 1.68)	0.788
QP3	0.73 (0.48 – 1.09)	0.132	0.99 (0.62 – 1.60)	0.977

Table 2 continued. Associations between physical activity items (QP1–QP10) and domains (WHOQOL-BREF) among hypertensive older adults.

Physical activity	Unadjusted model		Adjusted model	
	OR (95% CI)	*P*-value	aOR	*P*-value
QP4	0.74 (0.54 – 1.01)	0.059	0.95 (0.65 – 1.37)	0.775
QP5	0.63 (0.44 – 0.89)	0.010	0.78 (0.52 – 1.16)	0.227
QP6	0.72 (0.50 – 1.02)	0.069	0.89 (0.58 – 1.34)	0.581
QP7	0.75 (0.53 – 1.04)	0.085	0.91 (0.61 – 1.33)	0.617
QP8	0.88 (0.63 – 1.22)	0.432	1.10 (0.74 – 1.65)	0.623
QP9	0.90 (0.64 – 1.24)	0.500	1.03 (0.70 – 1.52)	0.878
QP10	0.94 (0.65 – 1.34)	0.714	1.11 (0.73 – 1.70)	0.617
Overall	0.93 (0.87 – 0.98)	0.016	0.99 (0.92 – 1.06)	0.745

Note: QP1-10s are items from the QPAR instrument.

for QP1 (OR = 0.59, 95% CI: 0.34–0.97, $P = 0.042$), QP3 (OR = 0.59, 95% CI: 0.38–0.90, $P = 0.017$), QP4 (aOR = 0.62, 95% CI: 0.42–0.89, $P = 0.012$), QP5 (OR = 0.69, 95% CI: 0.49–0.96, $P = 0.028$), and QP8 (OR = 0.68, 95% CI: 0.48–0.95, $P = 0.025$) in crude models. After adjustment, only QP4 retained significance, while the total QPAR score remained significantly associated with better psychological QoL (aOR = 0.92, 95% CI: 0.85–1.00, $P = 0.045$). As for the social QoL domain, significant associations were observed for QP1 (OR = 0.57, $P = 0.038$), QP3 (OR = 0.59, $P = 0.019$), QP4 (aOR = 0.51, $P = 0.001$), QP5 (aOR = 0.63, $P = 0.029$), QP6 (OR = 0.63, $P = 0.018$), QP8 (aOR = 0.63, $P = 0.024$), and QP10 (aOR = 0.60, $P = 0.025$). The total QPAR score was again significantly associated with improved social QoL in both unadjusted (OR = 0.88, $P < 0.001$) and adjusted models (aOR = 0.89, $P = 0.006$). Meanwhile, in the environmental QoL domain, only QP5 (OR = 0.63, 95% CI: 0.44–0.89, $P = 0.010$) demonstrated a significant association in the unadjusted model, while none of the items remained significant after adjustment ($P > 0.05$). The total QPAR score showed an association in the unadjusted model (OR = 0.93, 95% CI: 0.87–0.98, $P = 0.016$) but not after adjustment ($P = 0.745$). After adjustment for sex and education and correction for multiple testing using the Benjamini–Hochberg procedure, the total QPAR score remained significantly associated only with the social quality-of-life domain (aOR = 1.12, 95% CI: 1.04–1.22, FDR-adjusted $P = 0.040$). The associations with physical and psychological domains were no longer significant after correction.

PCA results

The Kaiser–Meyer–Olkin measure of sampling adequacy was 0.70, indicating good suitability for factor analysis. Item-level MSA values ranged from 0.63 to 0.84, and all exceeded the minimum acceptable threshold. Bartlett's test of sphericity was significant ($\chi^2(45) = 480.32$, $P < 0.001$). PCA of the 10 QPAR items extracted three principal components with eigenvalues greater than 1, explaining a cumulative variance of 64.3% (Figure 1). The first component (PC1) had an eigenvalue of 3.47, accounting for 35.3% of the total variance, followed by PC2 with an eigenvalue of 1.93 (16.1%) and PC3 with 1.03 (12.9%). Loadings from PC1 indicated strong contributions from mobility- and independence-related QPAR items (QP5, QP6, QP7, and QP10 with loading values of 0.85, 0.86,

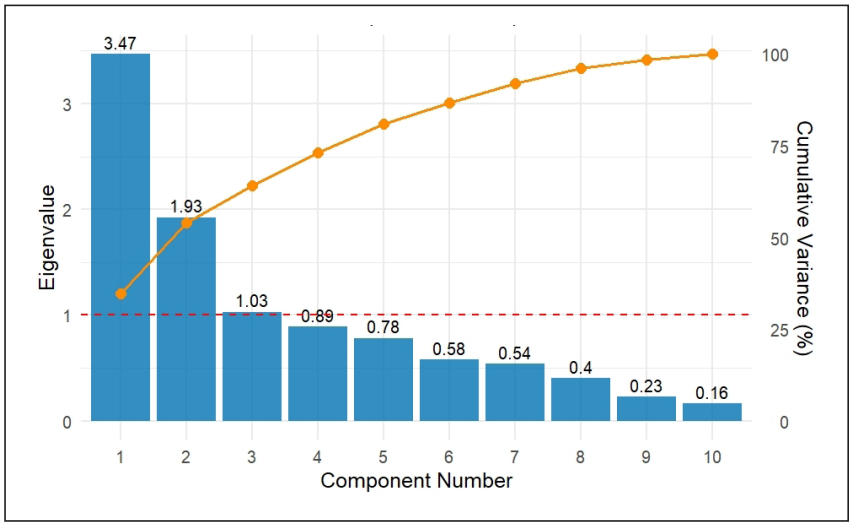

Figure 1. Scree plot of the QPAR principal component analysis (older adults). The plot displays the eigenvalues for each component and the cumulative variance explained. The dashed red line indicates the eigenvalue threshold of 1.

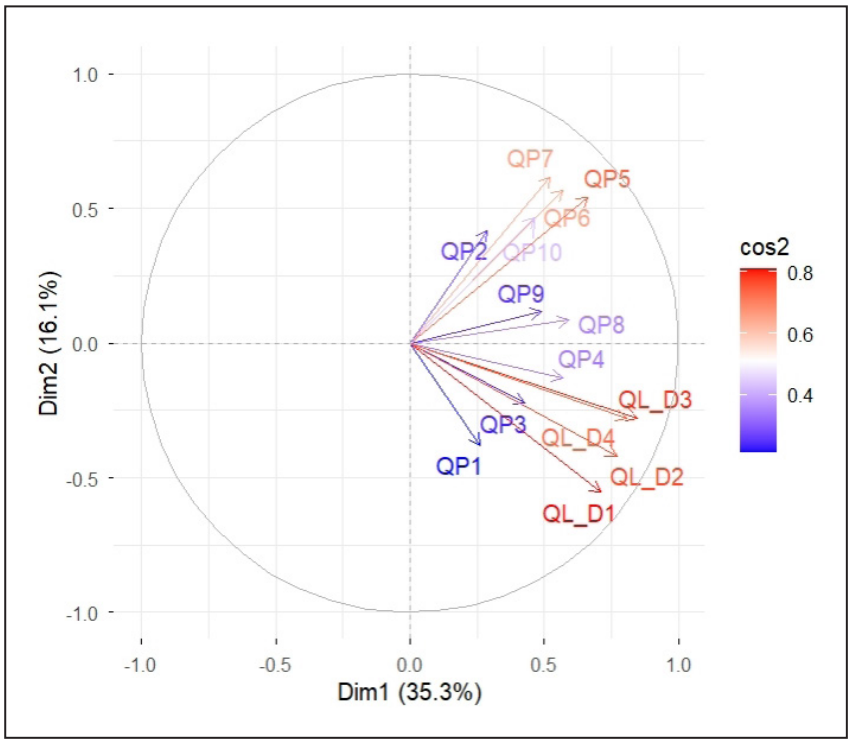

Figure 2. Correlation circle of QPAR items and WHOQOL-BREF domains among hypertensive older adults. Blue arrows represent QPAR items, and red arrows represent QoL domains. Vectors in similar directions indicate positive correlations, while divergent orientations indicate weak or negative associations.

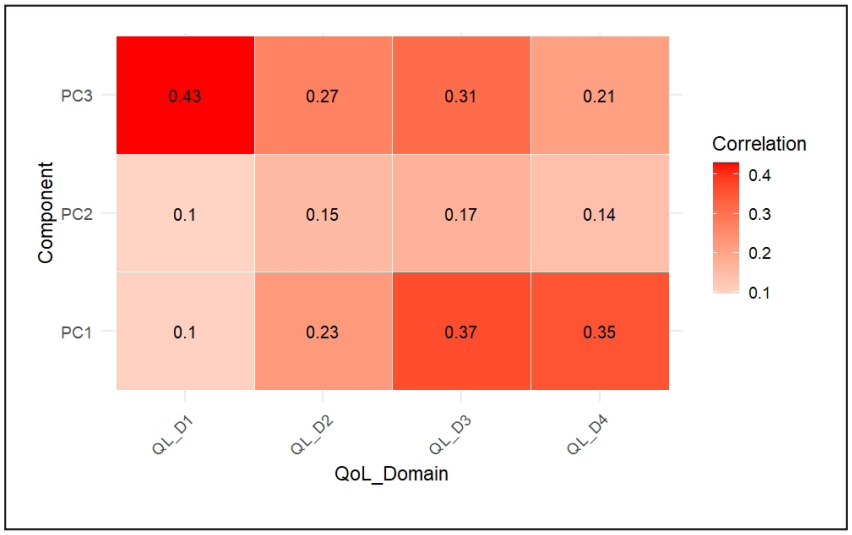

Figure 3. Heatmap showing correlations between PCA components (PC1–PC3) and QoL domains (QL_D1–QL_D4). The color gradient represents the correlation strength, with higher values shown in red.

0.75, and 0.69, respectively). PC2 was characterized mainly by routine and moderate-intensity activities (QP3 and QP4 with loading values of 0.82 and 0.70, respectively, while QP1 also showed a substantial loading of 0.61). Meanwhile, PC3 was dominated by socially interactive and outdoor activities (QP8 and QP9 with loading values of 0.83 and 0.86, respectively).

The correlation circle, as presented in Figure 2, demonstrated that the physical (QL_D1), psychological (QL_D2), and social (QL_D3) QoL domains were directionally aligned with QP3–QP8. In contrast, QP2 (vigorous activity) showed a divergent orientation from the QoL domains. The correlation heatmap of the PCA components and QoL domains presented in Figure 3, where the aforementioned patterns are confirmed. The highest correlation coefficients were observed between PC3 and physical QoL (r = 0.43). It was followed by moderate associations between PC1 and both social (r = 0.37) and environmental (r = 0.35) QoL domains. PC2 showed weak correlations across all domains (r = 0.10–0.17).

Distinct QoL profiles were observed across the three physical activity clusters, where the data are presented in Table 3. The lowest scores in all domains were found in one cluster (QL_D1 = 49.6, QL_D2 = 49.0, QL_D3 = 53.7, QL_D4 = 50.0), whereas another cluster showed consistently higher QoL (QL_D1 = 65.0, QL_D2 = 62.1, QL_D3 = 70.4, QL_D4 = 62.1). The highest social and environmental QoL were observed in the remaining cluster (QL_D3 = 76.4 and QL_D4 = 69.9), accompanied by favorable physical and psychological domain scores (QL_

Table 3. across physical activity clusters.

Cluster	Physical (QL_D1)	Psychological (QL_D2)	Social (QL_D3)	Environmental (QL_D4)
1	65.-	62.1	70.4	62.1
2	49.6	49.-	53.7	50.0
3	59.6	62.8	76.4	69.9

D1 = 59.6 and QL_D2 = 62.8).

Discussion

Findings form the present study revealed that light and moderate activities were consistently associated with better QoL across physical, psychological, and social domains. Meanwhile, vigorous activity showed no protective effect and, in some analyses, an inverse association. These findings suggest that the type and intensity of physical activity contribute differently to perceived well-being in older adults with hypertension. From the logistic regression analyses, moderate activities such as brisk walking or cycling, along with light or incidental movement, were associated with reduced odds of poor QoL across several domains. These results align with evidence showing that moderate-intensity activity improves vascular compliance and autonomic balance without provoking excessive cardiovascular strain [19-21]. As outlined in international guidelines, regular physical activity is a key complementary and non-pharmacological strategy in hypertension and cardiovascular disease management [5, 22].

The PCA further clarified the multidimensional nature of physical activity. The acceptable KMO value indicates that habitual physical activity behaviors in this population form a coherent multidimensional construct rather than isolated activities. Three main components were identified: routine moderate activities, vigorous activities, and light or incidental activities. Together, these explained 64% of the total variance. The third component, light or incidental activity, showed the strongest correlation with the physical QoL domain, suggesting that household tasks or casual walking play an important role in maintaining physical function and independence. These activities may also improve psychosocial well-being by enhancing mobility, self-efficacy, and participation in daily routines, as reported previously [23].

Interestingly, the weak contribution of vigorous activity to QoL, herein, implies that higher-intensity exercise may not be the optimal strategy for hypertensive older adults. Similar to the findings from the regression analysis, vigorous activity showed a non-protective association with physical QoL. After adjustment for sex and education and correction for multiple testing, total physical activity remained significantly associated only with the social QoL domain, indicating that the benefits of habitual activity in this population may be mediated primarily through enhanced social participation and interpersonal engagement rather than through perceived physical or environmental improvements. This pattern is possibly due to physiological limitations, medication effects, or perceived exertional discomfort in hypertensive individuals [24]. An intervention study of older adults with cardiovascular disease reported that vigorous exercise significantly improved hemodynamic parameters and physical fitness but did not translate into measurable improvements in QoL [7]. Nonetheless, there is possibility that the degenerative joint disease which is prevalent in this population confounded the inverse associations between vigorous physical activities and QoL [25, 26]. Therefore, vigorous exercise may not be generally accepted, but should be selectively prescribed and carefully monitored [27, 28].

Sustained engagement in light and moderate activities may promote adherence, resulting in gradual improvements in both physical capacity and psychological satisfaction [29]. Culturally, the daily activity patterns found in the present study are in line with that of Acehnese older adults, where physical activity is often embedded in household chores, community interactions, or religious practices rather than structured exercise. As outlined in the global consensus on optimal exercise for elderly population, regular light-to-moderate intensity activity is emphasized for its safety and overall health benefits, whereas vigorous-intensity exercise should be individualized based on functional capacity and health status [27]. Such culturally embedded forms of activity may provide not only physical benefits but also support social functioning [30]. The non-protective association of vigorous activity, in the present study, might be explained by its relative unfamiliarity and lower cultural acceptability in this population. Accordingly, interventions that rely on unfamiliar or technology-based exercise modalities, may require careful cultural adaptation to achieve meaningful QoL benefits in this setting, despite evidence of efficacy in other populations [31, 32].

It is worth noting that the study has cross-sectional design, which prevents establishing causal relationships between physical activity and reverse causality cannot be ruled out. Physical activity was self-reported using the QPAR, which may be subject to recall or social desirability bias. Functional status such as instrumental activities of daily living (IADL) was not assessed. Because IADL reflects independence and functional health, its inclusion in future study could clarify whether the observed associations between physical activity and QoL are mediated by functional capacity. The study was conducted in a semi-urban coastal area of Indonesia, and therefore the findings may not be generalizable to populations living in rural or metropolitan settings, or in countries with different cultural or environmental contexts. Moreover, the exclusion of indi-

viduals with severe hypertension or mobility impairments may limit generalizability to the broader hypertensive population. Additionally, the study did not measure objective activity intensity, such as through accelerometers, which could provide more precise quantification. Despite these limitations, the use of both logistic regression and PCA provided complementary insights into the complex relationship between different activity types and among older adults with hypertension.

Conclusions

Physical activity was associated with QoL among older adults with hypertension, primarily through moderate and light activities such as daily routines, walking, and household chores. After adjustment for sex and education and correction for multiple testing, the association remained significant only for the social QoL domain, suggesting that habitual activity in this population may contribute mainly through enhanced social participation and engagement. Vigorous activity was linked to poorer physical QoL, indicating that intensive exertion may not be well tolerated. The PCA showed that moderate and light, socially embedded activities represented the dominant behavioral patterns, highlighting their relevance as practical and sustainable forms of physical activity for hypertensive older adults. Future studies should adopt experimental or longitudinal designs to clarify the causal relationship between physical activity intensity and QoL. Interventions emphasizing culturally acceptable, moderate-intensity activities may represent an effective approach to preserving well-being and functional health in this population.

Declarations

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Author contributions: SA conceived the study, coordinated data collection, and drafted the manuscript. MZ contributed to data analysis and interpretation. AA contributed to study design and clinical interpretation of the findings. LW supervised the study and critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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