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# Predictive value of functional disability scales among stroke survivors: A long-term mortality evaluation in a Brazilian stroke cohort

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ABSTRACT

*Objective:* To assess the influence of two functional scales- Modified Rankin Scale (m-RS) and Modified Katz Index (m-Katz Index) on long-term mortality in a stroke cohort.

*Material and methods:* Among 760 stroke survivors (median age: 66 (IQR:56–75), 56.4 % women) m-Katz Index and m-RS scales applied at 1 and 6 months after stroke, were investigated in relation to 12-years of all-cause mortality. Kaplan–Meier survival curves were computed, and time-varying covariate Cox regression models were fitted to calculate hazard ratios (HRs) with 95 % confidence intervals (CIs) in all sample and by sex. The prognostic ability of the fitted models was computed for each model by six different measures.

*Results:* After 12 years of follow-up (median survival time: 7.3 years), 311 participants died. Overall survival curves show lower survival rates among those with the highest levels of disability/dependence (all log-rank *p*-values <0.0001). These findings were confirmed in all regression models for both sexes, particularly in men who had higher levels of dependence on Activities of Daily Living (ADLs) by m-Katz Index and severe disability by m-RS and presented the highest HR of dying (HR: 3.34 (95 %CI: 2.27–4.92) and HR: 4.94 (95 % CI: 3.15–7.75), respectively).

*Conclusions:* Both the m-Katz Index and the m-RS scale were good predictors of long-term mortality, which is of importance for guiding the functional rehabilitation of stroke patients. Besides, high levels of disability and dependence were implicated with high mortality risks, regardless of sex.

## Introduction

Stroke burden related to disability and loss of independence in daily activities has a great impact on mortality.[1] This is particularly true in low-middle income countries (LMICs) where more than 70 % of strokes and post-stroke disabilities.[2] In Latin America, stroke is the second leading cause of death. Stroke represents a huge burden in Brazil which has one of the highest rates.[3,4] Since late 1960, ischemic heart disease and stroke have been the predominant causes of death in Brazil.[5] According to the National Health Survey ("Pesquisa Nacional de Saúde", PNS) 2013, there were 2,231,000 self-reported strokes and 568,000 stroke cases with severe disabilities in Brazil.[6] The prevalence of post-stroke disability was very impacting in both sexes (29.5 % for men and 21.5 % for women), regardless of the degree of disability.[6] Importantly, more recent data from PNS revealed a progressive increase in the prevalence of stroke from 2013 (prevalence ratio, PR= 1.53; 95 %CI: 1.35–1.70) to 2019 (PR=1.96; 95 % CI: 1,81–2.11), $p = 0{,}0003$.[7,8] PNS 2019 surveillance reported higher stroke prevalence among individuals

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aged 75 and over than people aged 18 to 29 years (9.5 % vs.0.3% , respectively).[8] Indeed, older survivors were the most afflicted by a greater post-stroke disability.[9,10]

Considering this scenario, it's imperative to put some effort into better-knowing stroke prognosis and disabilities faced by stroke survivors. Motor and functional deficits, such as decreased strength or paralysis on one side of the body (or both), loss of vision, confusion, and speech difficulty are the most disabling deficits and thus, can be associated with higher mortality.[11]

Many prospective studies have reported fatal and non-fatal outcomes, including poststroke functional disability.[10–18] One of the longest follow-up studies, the South London Stroke Register, a prospective population-based register, has described a poor range of non-fatal outcomes such as cognitive impairment, disability, and dependence between 20 % and 30 % 10 years after a stroke event.[12] However, few studies[14,15] have reported the predictive value of functional status and activities of daily living (ADL) scales on long-term mortality risk. In clinical practice, both the modified -Rankin Scale (m-RS)[19–21] and the m-Katz Index (m-Katz Index)[22–24] complement each other in the functional evaluation of a patient afflicted by stroke; however, the m-RS scale gives a broader functional status including additional items of instrumental activities of daily living (IADL) (for example, meal preparation and shopping). The scale also includes some items of basic ADLs (for example, walking and dressing).[22–24]

Given this context, the present study aims to assess the predictive value of these very well-known scales: the m-RS[19–21] and the m-Katz Index[22–24] in the long-term survival of stroke individuals living in deprived areas with scarce local resources for post-stroke rehabilitation. All individuals are participants from a stroke community cohort, the Brazilian Study of Stroke Mortality and Morbidity (EMMA).

## Materials and methods

### *Study design and population*

The original conception of the EMMA study was the investigation of stroke epidemiology according to the World Health Organization (WHO) STEPS Stroke,[25,26] in a population with low socioeconomic status in the region of Butantan, São Paulo, Brazil. The prospective cohort study was carried out at the University Hospital of the University of São Paulo (HU-USP) and started in 2006 with annual follow-up until 2018.

We included all participants aged 18 years or older with hemorrhagic or ischemic stroke classified by the International Classification of Diseases (ICD)-10 such as HS (I61.X), IS (I63.X), respectively, who survived at least 1 month following the stroke and had data collected using both functional scales (m-RS and m-Katz Index).[19–24] Informed consent was signed by all study participants, either through the patient or a family member. This study was approved by the Ethics and Research Committee of the HU-USP 1963/21, São Paulo, Brazil.

### *EMMA data collection*

Data collection was carried out by trained researchers using the STEP 1 questionnaire according to the WHO STEPS Stroke.[25] All interview forms were double-checked with medical records by two independent researchers (Medical validation). After hospital discharge, survivors were followed up by telephone for 10 days, 1, and 6 months, and annually after the index event until 2018.[27]

### *Mortality*

Mortality data were confirmed by official death certificates in collaboration with the city of Sao Paulo's health statistics system (PRO-AIM, Program for Improvement of Mortality Information in the Municipality of Sao Paulo), State Health Offices (SEADE Foundation, São Paulo State Healthcare Data Analysis System) and the Brazilian Ministry of Health. All information gathered during the follow-up of the EMMA study was updated yearly.

### *Functional Status by modified Rankin scale (m-RS)*

The Rankin scale,[19] originally published in 1957, it was conceptualized to grade functionality in patients with cerebrovascular disease. The original scale was graded on five items from grade 1 (no significant disability) to grade 5 (severe disability). In 1988,[20] the Rankin (m-RS) was modified, one more category was added (Grade 0: "no symptoms'') and shortly afterwards Grade 6 (death) was added.[21] In the present study, we analyzed m-RS in the three following categories: 0-2 (without or mild disability), 3-4 (moderate disability), Category 5 (severe disability).

### *Activities of Daily Living (ADL) by modified Katz scale*

In the 1970 Katz e cols[22] published a more specific scale focusing on instrumental activities of daily living (ADL) that could be applied in chronically ill and elderly patients. The original Katz Index approaches self-care such as bathing, dressing, going to the toilet, transferring (mobilization), continence (maintaining control over elimination), and feeding.[23] For each domain, there are three options regarding the level of ADL, ranging from no supervision to total supervision (care 100 % of the time).[22] The shorter version of the Katz Index has the same six functions; however, 1 point is given for each type of independence, and 0 points for dependence.[24] This modified Katz Index considered a score of 6 as independent and 0 points as very dependent.[24] Here, m-Katz Index was evaluated in the following categories: Independence (6-5 points); Partial dependence (4-3 points) and Important dependence ($\leq$ 2).

### *Sociodemographic and clinical variables*

Sociodemographic collected were sex, age, self-reported race, and educational level. Clinical variables were previous medical history (such as stroke, alcoholism, smoking, hypertension, diabetes, dyslipidemia, and atrial fibrillation, medication conditions) and stroke characteristics during hospital stay and discharge.

### *Statistical analysis*

Continuous variables were analyzed using the Kruskal–Wallis test and presented as median values with their respective interquartile ranges (IQRs). Categorical variables were analyzed using the Chi-square test and presented as absolute and relative frequencies.

Long-term mortality risk (up to 12 years of follow-up) was evaluated according to m-Katz Index (6-5: Independence, 4-3: Partial dependence, $\geq$2: Important dependence) and m-RS (0-2: Without or mild disability, 3-4: Moderate disability, 5: Severe disability). For all-cause mortality, Kaplan–Meier survival curves were computed, and time-varying covariate Cox regression models were fitted to calculate hazard ratios (HRs) with their respective 95 % confidence intervals (CIs). Information on m-Katz Index and m-Rs were available at 1 month and approximately at 6 months after stroke, and the fitted model appropriately accounts for this update.[28–30] Regression models are presented as crude (Model 1), age- and sex adjusted (Model 2), and further adjusted by education attainment, marital status, hypertension, diabetes, dyslipidemia, atrial fibrillation, smoking, stroke subtype, recurrent stroke (at baseline) and medication use for the main cardiovascular risk factors (Model 3). All models were performed on the full sample and stratified by sex. To access and compare the prognostic ability of the fitted models, six different measures were computed for each model. The first three of them are: $R^2_D$,[31] $R^2_K$[32] and $R^2_{GH}$[33] They are called pseudo-R-squared measures and are computed based on the linear predictor only. The other measures are the Coefficient Of Determination (COD),[34] the Measure of Explained Randomness (MER)[35] and the Measure of explained variation (MEV),[36] which are computed based on the likelihood function. For all six indexes, a larger number indicates a better prognostic ability of the model. Statistical analyses were performed with the statistical software SPSS version 27.0, IBM Corp, Armonk, NY, and R version 4.0.2 for all analyses, P-values less than 0.05 were considered significant.

## Results

Overall, 1,863 participants were included in the EMMA between April 2006 and September 2014. Of these, 1,378 were confirmed by medical researchers as ischemic stroke (IS) (1,183 cases) or hemorrhagic stroke (HS) (195 cases). We excluded 36 unspecific strokes (I64), 160 stroke sequalae (I69.X), 128 transitory ischemic attacks (TIA, G45.X), 17 subarachnoid hemorrhages (I60), 25 (I67.X) with other cerebrovascular diseases, 118 with other non-neurological diagnoses such as hypoglycemic crisis and two had missing information on clinical data or imaging to confirm or exclude a stroke diagnosis. From the remaining 894 participants, 134 were excluded due to missing information on functional scales: m-RS and/or m-Katz Index at 1- or 6 months after hospital discharge. Thus, the final study sample was comprised of 760 participants who were survivors after one month of acute events (56 % of men).

### *Clinical and demographical characteristics*

Baseline demographic and clinical characteristics by gender are presented in Table 1. Most stroke cases were first-ever event (72.8 %) and IS subtype (86.3 %). Women were more afflicted by IS while more men had HS ($p < 0.0001$). Overall, men had a higher burden of stroke risk factors at baseline, while women reported higher use of medications for most traditional cardiovascular risk factors (hypertension, dyslipidemia, diabetes, and atrial fibrillation) up to a month after stroke (48 % vs. 42 %, $p = 0.003$).

### *Post-stroke Activities of Daily Living (ADL) and functional status*

Post-stroke disability at 1- and 6 months after stroke is described in Table 2. One month after stroke, more than 60 % of participants were independent, having no or mild disability. In the same period, it was observed higher levels of partial and important dependence based on m-Katz Index among women compared to men (13 % vs. 8.2 % and 24.8 % vs. 21.7 %, respectively, $p = 0.03$), without statistically significant differences in the functional status by m-RS according to sex. Six months after the acute event, however, the significant differences were noticed only in the m-RS evaluation but not in the m-Katz Index. The main findings revealed women with a higher frequency of moderate post-stroke disability than men (24.4 % vs. 17 %) based on m-RS, $p = 0.04$.

### *Mortality*

After 12-years of follow-up (median survival time: 7.3 years), 311 stroke participants died. Survival probability curves according to m-Katz Index and m-RS for all sample and by sex are demonstrated in Figs. 1–3. For all scenarios, stroke survivors who had the highest levels of dependence and disability had the poorest survival rates, all log-rank $p$ values <0.0001. Among participants with moderate (3-4 points in the m-RS) and severe disability (5 points in the m-RS), we found a median survival time of 2132 days (95 %CI: 1756–2508 days) and 1001 days (95 %CI: 465–1537 days), respectively. For those with higher levels of dependence, the median days of survival were as follows: partial dependence (4-3 points in the m-Katz Index): 2678 days (95 %CI: 1831–3525 days) and important dependence (≤ 2 n the m-Katz Index): 1866 days (95 %CI: 1435–2297 days).

These findings were confirmed in all Cox regression models for both sexes, particularly in men with higher level of dependence on ADL and

**Table 1**
Baseline characteristics of the 760 participants from the EMMA study.

| | Women n=331 | Men n=429 | Total n=760 | p-value |
|---|---|---|---|---|
| Sociodemographic | | | | |
| Median age, years (IQR) | 70 (58–78) | 65 (56–75) | 66 (56–75) | <0.0001 |
| Race (skin color), % | | | | 0.15 |
| White | 195 (58.9) | 265 (62.2) | 460 (60.8) | |
| Brown | 114 (34.4) | 121 (28.4) | 235 (31.0) | |
| Black | 19 (5.7) | 30 (7.0) | 49 (6.5) | |
| Yellow | 3 (0.9) | 10 (2.3) | 13 (1.7) | |
| Education, % | | | | <0.0001 |
| Illiterate | 79 (23.9) | 46 (10.7) | 125 (16.4) | |
| 1–7 years | 155 (46.8) | 203 (47.3) | 358 (47.1) | |
| ≥ 8 years | 97 (29.3) | 180 (42.0) | 277 (36.4) | |
| Marital status, % | | | | <0.0001 |
| Single | 60 (18.2) | 41 (9.6) | 101 (13.3) | |
| Married | 135 (41.0) | 304 (71.0) | 439 (58.0) | |
| Divorced | 23 (7.0) | 35 (8.2) | 58 (7.7) | |
| Widowed | 109 (33.1) | 45 (10.5) | 154 (20.3) | |
| Ignored | 2 (0.6) | 3 (0.7) | 5 (0.7) | |
| Stroke characteristics at hospital admission | | | | |
| Stroke subtype, % | | | | <0.0001 |
| Ischemic | 305 (92.1) | 351 (81.8) | 656 (86.3) | |
| Hemorrhagic | 26 (7.9) | 78 (18.2) | 104 (13.7) | |
| First-ever stroke, % | 250 (75.5) | 303 (70.6) | 553 (72.8) | 0.13 |
| NIHSS within 24 h at hospital admission | 7 (3–11) | 6 (3–11) | 6 (3–11) | 0.82 |
| Onset symptoms, % | | | | 0.66 |
| Less than 24 h | 262 (79.2) | 334 (77.9) | 596 (78.4) | |
| More than 24 h | 69 (20.8) | 95 (22.1) | 164 (21.6) | |
| Length of hospital stay, days (IQR) | 3 (1–7) | 3 (2–8) | 3 (2–7) | 0.17 |
| Comorbidities | | | | |
| Number of chronic comorbidities, % | | | | 0.89 |
| 0 | 4 (1.2) | 7 (1.6) | 11 (1.4) | |
| 1–2 | 147 (44.4) | 191 (44.5) | 338 (44.5) | |
| ≥ 3 | 180 (54.4) | 231 (53.8) | 411 (54.1) | |
| Hypertension, % | 315 (95.2) | 404 (94.2) | 719 (94.6) | 0.55 |
| Atrial fibrillation, % | 54 (17.3) | 48 (11.9) | 102 (14.3) | 0.04 |
| Diabetes, % | 178 (53.8) | 240 (55.9) | 418 (55.0) | 0.55 |
| Dyslipidemia, % | 196 (59.2) | 236 (55.0) | 432 (56.8) | 0,25 |
| Heart failure, % | 69 (20.8) | 98 (22.8) | 167 (22.0) | 0.51 |
| Chronic kidney disease, % | 42 (12.7) | 101 (23.5) | 143 (18.8) | <0.0001 |
| Coronary artery disease, % | 60 (18.1) | 80 (18.7) | 140 (18.4) | 0.84 |
| COPD, % | 14 (4.2) | 19 (4.4) | 33 (4.3) | 0.89 |
| Alcohol consumption, % | 29 (8.8) | 122 (28.4) | 151 (19.9) | <0.0001 |
| Smoking, % | | | | <0.0001 |
| Never | 232 (70.1) | 220 (51.3) | 452 (59.5) | |

(*continued on next page*)

**Table 1** (*continued*)

| | Women n=331 | Men n=429 | Total n=760 | p-value |
|---|---|---|---|---|
| Current | 72 (21.8) | 148 (34.5) | 220 (28.9) | |
| Past | 27 (8.2) | 61 (14.2) | 88 (11.6) | |
| Medication use, % | | | | 0.003 |
| Never | 39 (11.8) | 52 (12.1) | 91 (12.0) | |
| Pre-stroke | 59 (17.8) | 52 (12.1) | 111 (14.6) | |
| Post-stroke | 74 (22.4) | 145 (33.8) | 219 (28.8) | |
| Continuous use | 159 (48.0) | 180 (42.0) | 339 (44.6) | |

Never used: Patients who never used pre- and post-stroke medications for chronic clinical conditions (hypertensives and/or antidiabetic and/or, lipid lowering drugs and/or antiplatelets and/or anticoagulants), Pre-stroke: Patients who only used pre- stroke medications for chronic clinical conditions (hypertensives and/or antidiabetic and/or, lipid lowering drugs and/or antiplatelets and/or anticoagulants), Post-stroke: Patients who only used post-stroke medications for chronic clinical conditions (hypertensives and/or antidiabetic and/or, lipid lowering drugs and/or antiplatelets and/or anticoagulants), Continuous used: Patients kept using medications (pre- and post-stroke) for chronic clinical conditions (hypertensives and/or antidiabetic and/or, lipid lowering drugs and/or antiplatelets and/or anticoagulants).
IQR: Interquartile range.
Chronic obstructive pulmonary disease: COPD.
National Institutes of Health Stroke Scale: NIHSS.

**Table 2**
Levels of Activities Daily Living (ADL) by modified Katz index and functional status by modified Rankin scale 1 month and 6 months after stroke among 760 EMMA participants.

| | Women n=331 | Men n=429 | Total n=760 | p-value |
|---|---|---|---|---|
| 1 –month disability | | | | |
| Modified Rankin scale | | | | 0.20 |
| Without or mild disability | 195 (58.9 %) | 273 (63.6 %) | 468 (61,6 %) | |
| Moderate disability | 97 (29.3 %) | 121 (28.2 %) | 218 (28.7 %) | |
| Severe disability | 39 (11.8 %) | 35 (8.2 %) | 74 (9,7 %) | |
| Activities Daily Living (modified Katz index) | | | | 0.03 |
| Independence | 206 (62.2 %) | 301 (70.1 %) | 507 (66.8 %) | |
| Partial dependence | 43 (13 %) | 35 (8.2 %) | 78 (10.2 %) | |
| Important dependence | 82 (24.8 %) | 93 (21.7 %) | 175 (23.0 %) | |
| 6 –month disability | | | | |
| Modified Rankin scale | | | | |
| Without or mild disability | 224 (67.6 %) | 321 (74.8 %) | 545 (71.8 %) | 0.04 |
| Moderate disability | 81 (24.4 %) | 73 (17.0 %) | 154 (20.2 %) | |
| Severe disability | 26 (8.0 %) | 35 (8.2 %) | 61 (8.0 %) | |
| Activities Daily Living (modified Katz index) | | | | |
| Independence | 241 (72.8 %) | 330 (77.0 %) | 571 (75.1 %) | 0.35 |
| Partial dependence | 33 (10.0 %) | 32 (7.4 %) | 65 (8.6 %) | |
| Important dependence | 57 (17.2 %) | 67 (15.6 %) | 124 (16.3 %) | |

*P*-value was derived from Chi-square.
Modified Rankin scale categories: without or mild disability: 0–2 points, Moderate disability: 3-4; Severe disability: 5.
Modified Katz (Independence in Activities of Daily Living) categories: Independence: 6-5 points, Partial dependence: 4-3; Important dependence ≤ 2.

severe disability by m-RS who presented the highest HR for death on multivariate models (HR: 3.34 (95 %CI: 2.27–4.92) and HR: 4.94 (95 % CI: 3.15–7.75), respectively). (Table 3). Analyzing all six measures used to evaluate the prognostic ability of the m-RS and m-Katz Index, we noted no difference in performance, regardless of sex (Supplementary Table 1).

## Discussion

ADL measured by the modified Katz index and functional status by m-RS scale were significant predictors of long-term survival after a stroke. The six R2 measures considered have shown that the abilities of ADL and m-RS to predict mortality were similar. Although, our rates of severe/very severe disability at 6 months were lower than those reported in Brazilian populational data (PNS, 2013)[6] (7.9 % men and 8.2 % women in the EMMA vs. 29.5 % men and 21.5 % in the PNS), mortality risks (HR) related to severe disability and important dependence were very high for both sexes. There was more than 3-fold higher risk of dying for women, and almost 5-fold for men with severe disability after stroke compared to those without disability in long-term follow-up. Also, among those with important dependence was above three for women and men (Table 3).

In the full models adjusted for multiple confounders, we verified that men had a higher mortality risk when we considered functionality by m-RS. This fact is true since men had a slightly higher prevalence of severe disability compared to women in this analysis of the EMMA cohort.

Previous analyses of the EMMA cohort have described the predictive value of several risk factors related to poor long-term survival such as low education, multimorbidities, continuous use of medications for main cerebrovascular risk factors (hypertension, dyslipidemia, diabetes, and atrial fibrillation),[37–41] as well as non-conventional risk factors such as major depression.[42] We also previously verified low educational levels influencing functional dependence (moderate-severe m-RS) among ischemic stroke survivors.[43] Here, all these potential risks were considered in the regression models to evaluate the prognostic role of ADL and functional status in more than 10 years of follow-up of the EMMA cohort.

Both the Katz Index and the m-Rankin scale complement each other in clinical practice, and they were implicated with high mortality when higher levels of disability and/or dependence were present after a stroke. Besides the functionality, m-RS has additional information on IADL and ADL items, while the m-Katz index focuses only on ADL. These small differences in the items evaluated by each scale could justify the differences verified in terms of mortality risk that were slightly higher when we used m-RS. However, the six items used to evaluate the prognostic value of these scales showed no significant differences between them.

The novelty of the present study is depicting the predictive value of well-known scales used in clinical practice to evaluate functional status and instrumental activities. We considered the influence of functionality by m-RS[19–21] and ADL by modified Katz[22–24] applied in one and six months after an acute event on the long-term mortality.

Few studies have investigated post-stroke disability and long-term mortality.[14,15] A multicentric hospital-based study ($n = 134$) retrospectively evaluated very old patients (aged ≥ 80) with IS followed by 5 ± 1.9 years (range, 2–9 years) regarding mortality and several risk factors that could influence the mortality risk, including functionality by in the m-RS at hospital discharge (median hospital stay: 10 days).[14] The main findings of this study revealed functional status, mild-moderate (2-3), and moderate-severe disability (4-5) as the most significant predictors of long-term mortality. Like our study, moderate disability was associated with the risk of dying by more than 3-fold, and severe disability was highly related to mortality risk (nearly 8-fold), probably because individuals in this study were 16 older than ours (88 vs. 66 years old) and we did not consider mild and moderate cases together in one category as Minn et al did.[14]

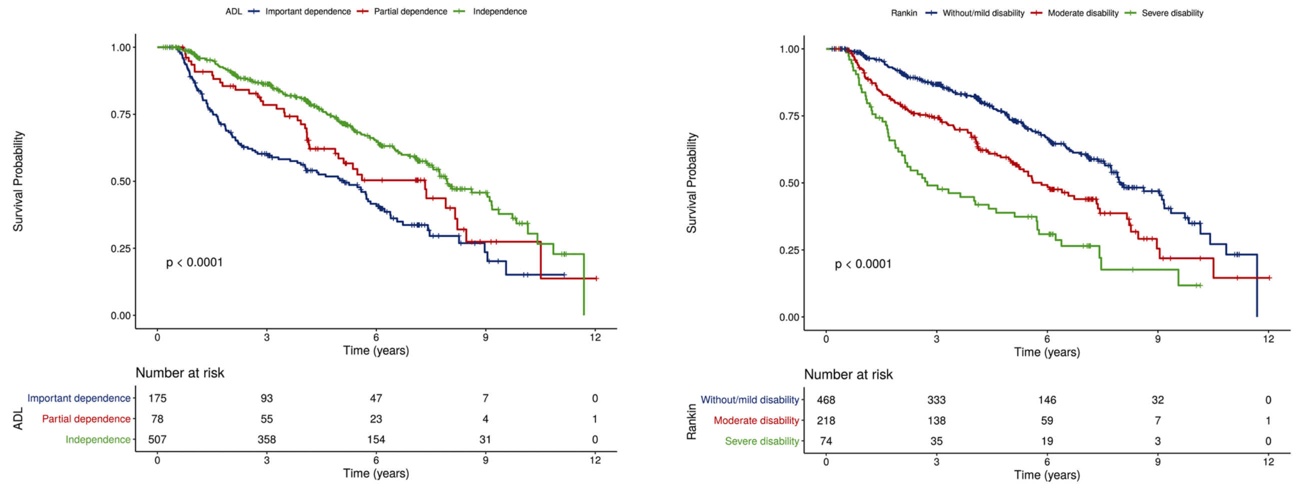


**Fig. 1.** Kaplan Meyer survival curves for 12-year all-cause mortality according to Levels of Activities of Daily Living (ADL) by modified Katz index and functional status by modified Rankin scale (m-RS) 1 month after stroke among total sample from EMMA study.

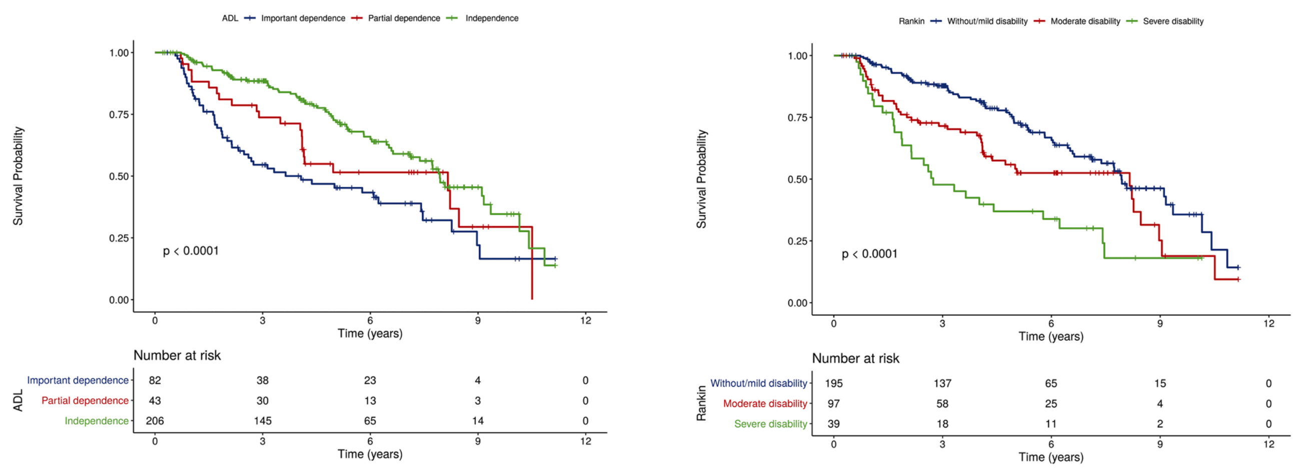


**Fig. 2.** Kaplan Meyer survival curves for 12-year all-cause mortality according to Levels of Activities of Daily Living (ADL) by modified Katz index and functional status by modified Rankin scale (m-RS) 1 month after stroke among women from EMMA study.

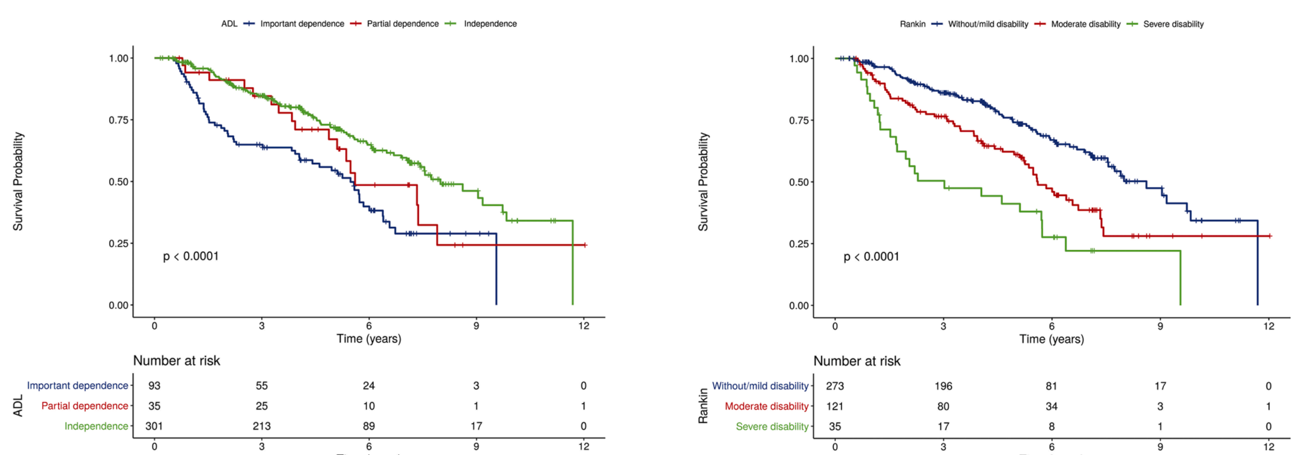


**Fig. 3.** Kaplan Meyer survival curves for 12-year all-cause mortality according to Levels of Activities of Daily Living (ADL) by modified Katz index and functional status by modified Rankin scale (m-RS) 1 month after stroke among men from EMMA study.

Few studies have investigated post-stroke disability and long-term mortality.[14,15] A multicentric hospital-based study ($n$ = 134) retrospectively evaluated very old patients (aged ≥ 80) with IS followed by 5 ± 1.9 years (range, 2- 9 years) regarding mortality and several risk factors that could influence the mortality risk, including functionality by in the m-RS at hospital discharge (median hospital stay: 10 days).[14] The

**Table 3**
Hazard ratios of all-cause mortality according to functional status by Modified Rankin scale and by levels of Activities Daily Living (ADL) by modified-Katz index along 12-y follow-up in the EMMA cohort.

| | Total=760 HR (CI 95 %), *p*-value | Women=331 HR (CI 95 %), *p*-value | Men=429 HR (CI 95 %), *p*-value |
|---|---|---|---|
| Modified Rankin scale | | | |
| Model 1 | | | |
| Without or mild disability | Reference (1.00) | Reference (1.00) | Reference (1.00) |
| Moderate disability | 2.36 (1.56–2.65), $p<0.001$ | 1.70 (1.17–2.49), $p=0.006$ | 2.39 (1.65–3.46), $p<0.001$ |
| Severe disability | 5.54 (4.07–7.54), $p<0.001$ | 5.56 (3.46–8.92), $p<0.001$ | 5.74 (3.81–8.64), $p<0.001$ |
| Model 2 | | | |
| Without or mild disability | Reference (1.00) | Reference (1.00) | Reference (1.00) |
| Moderate disability | 1.79 (1.37–2.34), $p<0.001$ | 1.36 (0.93–2.00), $p=0.111$ | 2.34 (1.61–3.39), $p<0.001$ |
| Severe disability | 4.28 (3.12–5.87), $p<0.001$ | 4.06 (2.50–6.59), $p<0.001$ | 4.55 (2.99–6.93), $p<0.001$ |
| Model 3 | | | |
| Without or mild disability | Reference (1.00) | Reference (1.00) | Reference (1.00) |
| Moderate disability | 1.85 (1.41–2.44), $p<0.001$ | 1.49 (1.00–2.21), $p=0.045$ | 2.40 (1.63–3.54), $p<0.001$ |
| Severe disability | 3.94 (2.81–5.50), $p<0.001$ | 3.54 (2.05–6.10), $p<0.001$ | 4.94 (3.15–7.75), $p<0.001$ |
| Activities Daily Living (modified Katz index) | | | |
| Model 1 | | | |
| Independence | Reference (1.00) | Reference (1.00) | Reference (1.00) |
| Partial dependence | 1.69 (1.16–2.47), $p<0.001$ | 1.71 (1.01–2.89), $p=0.045$ | 1.61 (0.93–2.78), $p=0.085$ |
| Important dependence | 4.55 (3.54–5.84), $p<0.001$ | 4.88 (3.35–7.11), $p<0.001$ | 4.30 (3.07–6.02), $p<0.001$ |
| Model 2 | | | |
| Independence | Reference (1.00) | Reference (1.00) | Reference (1.00) |
| Partial dependence | 1.50 (1.03–2.19), $p=0.034$ | 1.30 (0.76–2.21), $p=0.324$ | 1.70 (0.98–2.94), $p=0.060$ |
| Important dependence | 3.46 (2.67–4.48), $p<0.001$ | 3.53 (2.40–5.20), $p<0.001$ | 3.37 (2.37–4.78), $p<0.001$ |
| Model 3 | | | |
| Independence | Reference (1.00) | Reference (1.00) | Reference (1.00) |
| Partial dependence | 1.59 (1.08–2.35), $p=0.017$ | 1.49 (0.84–2.63), $p=0.167$ | 1.78 (1.01–3.14), $p=0.045$ |
| Important dependence | 3.03 (2.31–3.99), $p<0.001$ | 3.13 (2.05–4.79), $p<0.001$ | 3.34 (2.27–4.92), $p<0.001$ |

Model 1: crude.
Model 2: age, sex (except for the models stratified by sex).
Model 3: age, sex (except for the models stratified by sex) educational level, marital status, stroke subtype, stroke episode, number of comorbidities, hypertension, dyslipidemia, diabetes, atrial fibrillation, smoking, medications for chronic clinical conditions (hypertensives and/or antidiabetic and/or, lipid lowering drugs and/or antiplatelet and/or anticoagulants).
Hazard ratio, CI 95 %: 95 % confidence interval.
Modified Rankin scale categories: without or mild disability: 0–2 points, Moderate disability: 3–4; Severe disability: 5.
Modified Katz (Independence in Activities of Daily Living) categories: Independence: 6-5 points, Partial dependence: 4-3; Important dependence ≤ 2.

main findings of this study revealed functional status, mild-moderate (2-3), and moderate-severe disability (4-5) as the most significant predictors of long-term mortality. Like our study, moderate disability was associated with the risk of dying by more than 3-fold, and severe disability was much more related to mortality risk (nearly 8-fold), probably because individuals in this study were older than ours (88 vs. 66 years old)[14]].

A large Swedish population-based register that included 15,959 stroke patients investigated the influence of disability by m-RS applied three months after stroke on one-year survival.[15] Among all other potential predictors associated with the risk of dying in this study, such as aging, male sex, diabetes, hypertension, treatment, AF, current smoking, and depressive mood, the degree of disability was the most impacting risk factor for long-term mortality, being the risk progressively higher with increasing m-RS: category.[15] Like our study, more disabled stroke cases had higher mortality risk considering multivariate adjustments in the Cox model in the Swedish study.

### *Strengths and limitations*

To the best of our knowledge, this is the first study that brings information about the prognostic value of two functional scales in long-term mortality in individuals with stroke. No previous study has used an ADL instrument such as the Katz index to predict stroke mortality. Both are well-known scales, easily applicable in clinical practice, that can better elucidate and guide the functional rehabilitation of these populations. Our study brings additional information besides the utility of functional scales, considering their impact on long-term mortality risk. One significant methodologic difference between the previous studies and ours, was regarding the evaluation of the time-dependent effect of both scales applied at one and six months after an acute event in long-term mortality risk considering the possible differences between sexes. Applying these statistical strategies, we observed that either functional status by the m-RS or the ADL by the modified Katz Index had the same utility to predict long-term mortality.

This study has some limitations. We cannot rule out the possibility of selection bias because data from the EMMA cohort is based in a single center, a community hospital that mainly attends individuals with low-middle SES. Thus, we should be cautious regarding the generalization of our findings. We did not have complete information on the NIH scale at hospital admission, and information about stroke recurrence was lacking during the follow-up of the study.

## Conclusion

Both the m-Katz Index and the m-RS scale were good predictors of long-term mortality, which is of importance for guiding the functional rehabilitation of stroke patients. Besides, high levels of disability and dependence were implicated with high mortality risks, regardless of sex.

## Statement of ethics

Written informed consent was obtained from all EMMA participants or from their advocate (usually a close family member). The study was approved by the Research Ethics Committee of the Hospital Universitário linked to the Universidade de São Paulo (HU-USP), São Paulo, Brazil.

## Data available on request

The data underlying this article will be shared on reasonable request to the corresponding author.

## CRediT authorship contribution statement

**Ana Cristina G de Goes:** Data curation, Writing – review & editing, Supervision. **Karla A S Souza:** Writing – review & editing. **Gisela Tunes:** Conceptualization, Formal analysis, Writing – review & editing. **Airlane P Alencar:** Conceptualization, Formal analysis, Writing – review & editing. **Ana C. Varella:** Writing – review & editing. **Tiffany E Gooden:** Writing – review & editing. **Neil G Thomas:** Writing – review & editing. **Gregoy YH Lip:** Writing – review & editing. **Itamar S Santos:** Writing – review & editing. **Paulo A Lotufo:** Writing – review & editing. **Isabela M Benseñor:** Writing – review & editing. **Alessandra C Goulart:** Conceptualization, Data curation, Writing – review & editing.

## Declaration of Competing Interest

ACGG, KASS, GT, APA, ACV, TEG, NGT, ISS, PAL, IMB, ACG: Declare no conflict of interest.

GYHL: Consultant and speaker for BMS/Pfizer, Boehringer Ingelheim, Anthos and Daiichi-Sankyo. No fees are directly received personally. He is co-principal investigator of the AFFIRMO project on multimorbidity in AF, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 899871.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jstrokecerebrovasdis.2023.107487.

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