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ORIGINAL RESEARCH

Association Between Orthostatic Hypotension and Handgrip Strength With Successful Rehabilitation in Elderly Hip Fracture Patients

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Abstract

Objective: To investigate the relationship between orthostatic hypotension (OH) and muscle strength versus time to successful rehabilitation within elderly patients with hip fracture.

Design: A prospective, observational cohort study. Handgrip strength was measured at the day of admission and OH as soon as possible after surgery. Cox proportional hazard modeling was used to investigate the relationship between OH or handgrip strength (kg) and time to successful rehabilitation, expressed as hazard ratios (HRs). OH was defined as a decrease in systolic blood pressure of ≥20mmHg or diastolic blood pressure of ≥10mmHg after postural change (dichotomous). Handgrip strength was measured with a hand dynamometer (continuous).

Setting: General hospital.

Participants: Patients (N=116) aged ≥70 years with a hip fracture were recruited on the day of hospital admission.

Interventions: Not applicable.

Main Outcome Measures: Primary outcome was time to successful rehabilitation, which was defined as discharge to patients' own homes.

Results: During a median follow-up period of 36 days (interquartile range, 9−57d), 103 patients (89%) were successfully rehabilitated. No statistically significant relationships were found between OH and time to successful rehabilitation (HR=1.05; 95% confidence interval [CI], .67−1.66). Also, handgrip strength and successful rehabilitation were not statistically significantly related (HR=1.03; 95% CI, .99−1.06).

Conclusions: OH measured during the first days of hospitalization is not related to time to successful rehabilitation in patients with hip fracture who have undergone surgery. Although no significant relationship was seen in the present study, the width of the CIs does not exclude a relevant relationship between handgrip strength and time to successful rehabilitation.

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Hip fractures are a common cause of hospitalization and rehabilitation in elderly patients.[1,2] The main purpose of rehabilitation in these patients is to regain their prefracture health status as much as possible.[3,4] Dependence on medical care, decline in functional outcome, or admission to a nursing home may be the consequence when rehabilitation fails. The outcome of rehabilitation reflects the condition of the elderly patient and is a summation of many factors, including both physical and mental parameters.[3-11] The definition of successful rehabilitation or recovery varies widely, from regaining prior functional or mobility status, or both, to functional independence leading to discharge to the patient's own home.[4,7,9,10,12]

Examples of the numerous factors that negatively influence the response to rehabilitation are high age, the presence of cognitive impairment or coexisting diseases, and a high fear of falling (FOF).[3-5,9,13]

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Also, orthostatic hypotension (OH) and muscle strength are among the factors that have been found to influence rehabilitation in elderly patients.[7,8,10] Since the prevalence of OH and impaired muscle strength is high in elderly patients and are considered as important risk factors for falling and frailty, these variables are likely to negatively influence successful rehabilitation.[14-20]

A previous study[7] observed the counterintuitive finding that patients with OH had a higher hazard of successful rehabilitation compared with patients without OH. Another study[21] found no difference in functional outcome between stroke patients with and without OH. Muscle strength is considered to be a strong positive predictor for functional outcome after rehabilitation in elderly patients with hip fracture.[8,10] OH and muscle strength separately influence outcome, but it is likely that these factors are also interrelated. Several causes of OH, such as the use of different medications, hypovolemic disorders, and bed rest, are potentially related to muscle strength.[22-25]

Because muscle strength and OH are both related to successful rehabilitation, and possibly also interrelated, these factors should be combined (and adjusted for) in analyzing the association with rehabilitation. To our knowledge, no previous studies have investigated these combined associations. Therefore, we performed a study in which we aimed to investigate the relation of OH and muscle strength with time to successful rehabilitation in elderly patients with hip fracture. We hypothesized that the presence of OH or low muscle strength would negatively influence the time to successful rehabilitation. Furthermore, we hypothesized that the relationship between OH and time to successful rehabilitation would be influenced by muscle strength.

Methods

Study population

This prospective, observational cohort study was performed in a general hospital (Isala Hospital, Zwolle, The Netherlands). All patients aged ≥70 years who were admitted to the hospital with a hip fracture and treated with surgery were eligible, and most of them were recruited. Some patients could not be recruited because they were admitted during the night.

Recruitment and all study procedures took place between November 2014 and December 2015. Exclusion criteria were having a life expectancy of <3 months, being unable to mobilize before hospitalization, and being institutionalized in a nursing home facility before hospitalization. Because we only used a limited number of exclusion criteria, we tried to minimize the chance of selection bias.

List of abbreviations:

BMI	**body mass index**
CI	**confidence interval**
DM	**diabetes mellitus**
FOF	**fear of falling**
HR	**hazard ratio**
IQR	**interquartile range**
OH	**orthostatic hypotension**
SBP	**systolic blood pressure**

Ethics approval and clinical trial registration

This study was performed in accordance with the Declaration of Helsinki. According to Dutch guidelines this study did not fall under the scope of the Medical Research Involving Human Subjects Act, and therefore this study did not need a formal approval of an accredited medical ethics committee. Written informed consent was obtained for all patients by the participating medical doctor or nurse. All data were analyzed anonymously. The study was registered on Trialregister.nl (NTR4940).

Data collection

Baseline data involved demographic characteristics and a full medical history, including a history of cardiovascular disease, diabetes mellitus (DM), hypertension, FOF, and medication use. Patients were considered to have cardiovascular disease when they had a history of angina pectoris, myocardial infarction, percutaneous transluminal coronary angioplasty, coronary artery bypass grafting, stroke, or transient ischemic attack.

Blood pressure was measured following a standardized protocol, using an automated sphygmomanometer.[26,a] If the automated sphygmomanometer displayed an error message, blood pressure was manually measured with a sphygmomanometer.[27,b] Blood pressure was measured 2 times in the supine position after 5 minutes of rest, and 2 times each at 1 and 3 minutes after postural change. The forearm of the patient was supported at heart level during the measurements in the upright position.[28] The postural change was from supine to standing position, or from supine to sitting position for patients who were unable to stand. Blood pressure was measured as soon as possible after surgery. OH was defined as a decrease in systolic blood pressure (SBP) of ≥20mmHg or diastolic blood pressure of ≥10mmHg after postural change compared with the mean value of the baseline measurements in the supine position.[29] Patients were asked whether they experienced any of the characteristic symptoms of OH, such as lightheadedness, syncope, or dizziness after postural change. The combination of OH and orthostatic complaints was described as symptomatic OH.

Handgrip strength was measured with a hand dynamometer[30,c] (in kilograms) within 2 days of hospital admission, preferably on the day of admission. When a patient underwent surgery on the day of admission, the handgrip strength was measured postoperatively, but always within 2 days after admission.

Testing was performed with the participant in a comfortable sitting position in the hospital bed. The forearms were resting with the elbow flexed at 90°, the forearm in a neutral position, and the thumbs facing up. Both the dominant and nondominant hands were tested, both 3 times. The best of 6 attempts of maximal voluntary contraction was used for statistical analysis.[30] OH was expressed as dichotomous (OH vs no OH), and handgrip strength was expressed as a continuous variable.

To measure FOF, a numeric scale (1−10) was used, with 1 representing no FOF and 10 representing an extreme FOF.[31] The FOF was measured on the day of admission.

Activities of daily living were measured with the Barthel-20 Index on the day of admission[32] to evaluate prefracture status.

Body mass index (BMI) was calculated by measuring body weight and height.

All tests were part of usual clinical care. Four trained medical staff members performed all tests to reduce the change on interobserver disagreement. The intent was that the same medical staff member should measure all variables for a particular patient.

Primary outcome

The primary outcome was the time to successful rehabilitation, which was defined as discharge to patients' own homes, where they functioned independently and lived by themselves. The time to successful rehabilitation started on the day of OH blood pressure measurements, which were performed as soon as possible after surgery. Patients were considered to be self-reliant if they regained their prefracture health status. As a consequence, patients with an already highly adapted home environment (eg, stairlift, home care, meal service) may be sent home earlier than others.

In the trial register, successful rehabilitation was predefined as having the same functional status as the prefracture status, evaluated by using the mobility component of the Barthel Index. Because all patients reached the prefracture mobility score on the Barthel Index in a few days after surgery (despite the fact they were not discharged home, but had to be admitted to a rehabilitation facility), we evaluated this definition and decided to change it to the current clinically more relevant definition.

Statistical analyses

Continuous variables are presented as mean and SD for normally distributed variables, or as median and interquartile range (IQR) for nonnormally distributed variables. Cox proportional hazard modeling was used to investigate the relationship between OH, orthostatic complaints, symptomatic OH, or handgrip strength and time to successful rehabilitation. Two separate Cox proportional hazard analyses were performed: one regarding the relationship between OH and successful rehabilitation, and one between muscle strength and successful rehabilitation. We used 3 different models. In model 1, unadjusted analyses were performed. In model 2, only age and sex were considered as possible confounders. In model 3, regarding the relationship between OH and rehabilitation, we additionally adjusted for the following variables: BMI, a history of DM, the score on the Barthel Index, previous macrovascular complications, mean SBP, the use of antihypertensive medication, and baseline handgrip strength. For the analyses regarding the relationship between handgrip strength and rehabilitation, we adjusted for age, sex, BMI, the score of the Barthel Index, previous macrovascular complications, and OH. These confounders were chosen based on clinical grounds, since all confounders were likely to be related to successful rehabilitation and OH or handgrip strength.[3-5,7-10,13,33] By adjusting for potential confounding factors, the risk of confounding bias was reduced.

The confounding effect of FOF on the relationship between OH, handgrip strength, and successful rehabilitation was explored by adding FOF to model 3 in both analyses. FOF was added separately because of missing values (n=8). There were missing values of FOF (n=8), BMI (n=6), and the Barthel Index (n=2). The hazard ratios (HRs) regarding SBP refer to a pressure increase in steps of 10mmHg.

The Schoenfeld residual plots were inspected for each predictor variable to check the assumption of proportional hazards.

P values $<.05$ were considered statistically significant. Collinearity diagnostics were tested for each confounder; covariables are considered to be highly correlated with a variance inflation factor of ≥ 10.[34,35] When necessary, interaction was tested between different variables. Interaction was considered to be significant with a *P* value $<.05$.

All statistical analyses were performed using SPSS software[d] (version 22).

The Strengthening the Reporting of Observational Studies in Epidemiology statement was used to describe this observational cohort study.[36]

Results

A total of 116 patients were included in this cohort. The baseline characteristics are presented in table 1. The median age of the total study population was 82 years (IQR, 76–86y). Various surgical techniques were used to treat the hip fractures: 37% intramedullary nail, 50% hemi- or total hip arthroplasty, and 13% (sliding) hip screws. Thirty-nine patients (34%) were discharged to their own homes and 77 patients (66%)

Table 1 Baseline characteristics of total population

Characteristic	Baseline (N=116)
Demographics	
Age (y)	82 (76–86)
Sex: female	86 (74)
BMI (kg/m^2)	25 (23–28)
Hypertension	77 (66)
History of CVD	27 (23)
DM	23 (20)
Current smoker	17 (15)
Measurements	
Consumption meal or drink*	113 (97)
Days between surgery and BPM	2 (1–3)
SBP lying (mmHg)	130±22
DBP lying (mmHg)	65±11
Pulse frequency (beats/min)	81±18
OH	39 (34)
Orthostatic complaints	22 (19)
Symptomatic hypotension	16 (14)
Postoperative handgrip strength measurement	21 (18)
Handgrip strength (kg)	20 (15–26)
Barthel Index score	19 (17–20)
FOF†	1 (1–4)
Medication during admission	
No. of agents	6 (3–9)
Antihypertensive medication	70 (60)
Diuretics	40 (35)
Beta blockers	31 (27)
Calcium channel blockers	17 (15)
ACE inhibitors	44 (38)
Benzodiazepines	22 (19)
Antipsychotics	3 (3)
Antidepressants	12 (10)

NOTE. Values are median (interquartile range), n (%), mean ± SD, or as otherwise indicated.

Abbreviations: ACE, angiotensin-converting enzyme; BPM, blood pressure measurement; CVD, cardiovascular disease; DBP, diastolic blood pressure.

* Meal <2h or drink <1h before the measurements.

† Missing values in 8 patients.

to a nursing home facility for further rehabilitation. During a median follow-up period of 36 days (IQR, 9−57), 103 patients (89%) were successfully rehabilitated. Three patients died during rehabilitation. Ten patients could not return home and stayed at a long-term nursing home facility. Patients who did not successfully rehabilitate were found to have a higher prevalence of macrovascular disease and hypertension compared with patients who were successfully rehabilitated.

OH and successful rehabilitation

OH was present in 39 of 116 patients, a prevalence of 34% (95% confidence interval [CI], 25%−43%). The postural change was performed mostly from lying to sitting (n=114 [98%]) because of decreased mobility; only 2% of the tested population could perform postural change from lying to standing. Blood pressure measurement took place at a median of 2 days (IQR, 1−3d) after surgery.

Table 2 presents the results of the Cox regression analyses of the relationship between OH and successful rehabilitation. In the present study, no statistically significant relationships were seen between OH (HR=1.05; 95% CI, .67−1.66) and the time to successful rehabilitation. The confounders SBP (HR=1.01; 95% CI, 1.00−1.03), DM (HR=.47; 95% CI, .26−.85), and handgrip strength (HR=1.05; 95% CI, 1.01−1.08) were statistically significantly related to the time to successful rehabilitation. Adding FOF to the multivariable model did not change the association between OH and the time to successful rehabilitation. The HR of FOF was .87 (95% CI, .79−.97). Orthostatic complaints (HR=1.06; 95% CI, .62−1.83) and symptomatic OH (HR=1.15; 95% CI, .62−2.13) were also not related to the time to successful rehabilitation in the multivariable analyses.

Because blood pressure may be a marker of frailty in old age,[37] we performed analyses in which we tested for the interaction between SBP and OH. No statistically significant interaction was seen.

The plots of the Schoenfeld residuals showed that the assumptions of proportional hazards were met (see supplemental appendix S1 for Schoenfeld residual plots, available online only at http://www.archives-pmr.org/). Collinearity was tested and no serious multicollinearity was seen, because the mean variance inflation factor value was 1.37 (range, 1.01−2.22).

Handgrip strength and successful rehabilitation

The median handgrip strength of the dominant arm was 20kg (IQR, 15−26kg). All handgrip strength measurements were performed within 2 days of admission. For most (82%) of the patients, the handgrip strength measurements were performed preoperatively.

Table 3 present the results of the Cox regression analyses of the relationship between muscle strength and time to successful rehabilitation. None of the models showed a significant relationship between handgrip strength and time to successful rehabilitation. The confounder cardiovascular disease was related to time to successful rehabilitation (HR=.57; 95% CI, .33−.99).

Adding FOF to the multivariable model did not change the association of handgrip strength with successful rehabilitation (HR=1.03; 95% CI, .99−1.06). As a confounder, FOF was significantly related to time to successful rehabilitation (HR=.87; 95% CI, .78−.97).

Discussion

OH, measured in the immediate postoperative phase, was not related to time to successful rehabilitation in hospitalized elderly with a hip fracture. Although increased muscle strength was not significantly related to time to successful rehabilitation in the present study, the width of the CI does not exclude a relevant relationship between handgrip strength and time to successful rehabilitation. Besides, muscle strength as a confounder, in the model with OH as the variable of interest, was significantly related to time to successful rehabilitation.

OH and successful rehabilitation

In contrast to the current study, a previous study[7] performed by the same authors showed that patients with OH were found to have a

Table 2 HRs of OH for successful rehabilitation (N=116)

Variable	Model 1	Model 2	Model 3
OH	1.35 (0.90−2.05)	1.28 (0.85−1.94)	1.05 (0.67−1.66)
Age	NA	0.96 (0.93−0.99)* (P=.02)	0.99 (0.96−1.03)
Sex: female vs male	NA	0.99 (0.63−1.54)	0.61 (0.31−1.18)
BMI	NA	NA	0.99 (0.95−1.05)
Barthel Index score	NA	NA	1.05 (0.94−1.18)
Antihypertensive medication	NA	NA	0.90 (0.58−1.40)
History of CVD disease	NA	NA	0.64 (0.37−1.11)
DM	NA	NA	0.47 (0.26−0.85)* (P=.01)
Mean SBP lying[†]	NA	NA	1.01 (1.00−1.03)* (P=.01)
Handgrip strength	NA	NA	1.05 (1.01−1.08)* (P<.01)

NOTE. Values are HR (95% CI) or as otherwise indicated. HRs for successful rehabilitation. Model 1 unadjusted. Model 2 adjusted for age and sex. Model 3 adjusted for age, sex, BMI, Barthel Index score, number of antihypertensive medications, previous macrovascular complications, DM, mean SBP lying, and handgrip strength.
Abbreviations: CVD, cardiovascular disease; NA, not applicable.
* A significant relationship.
† The HR refers to a pressure increase of 10mmHg.

higher hazard of successful rehabilitation compared with patients without OH. Although our previous study reported a positive relationship between OH and time to successful rehabilitation, we hypothesized before the present study that the presence of OH would negatively influence the time to successful rehabilitation. The prevalence of OH and successful rehabilitation was similar in both studies. When comparing both study populations, patients of the present study seemed to have less comorbidity, used less medication, and had lower baseline blood pressure, which reflects the setting of the previous study (nursing home).

The high prevalence of OH in the present study could be partially caused by hip fracture or hospital admission−related factors such as bed rest, surgery, effects of anesthesia, inadequate water intake, and blood loss. In these circumstances, OH may very well be a temporary phenomenon and therefore not a predictor for an outcome such as time to successful rehabilitation.[23] In the study by Weiss et al,[22] the effect of OH in hospitalized patients on mortality was described, and they advised to divide patients into 2 groups; patients with episodic OH, as is seen during hospitalization, and those with established OH (repeated measurements). Measuring OH in the first week of rehabilitation within a nursing home might possibly be a more accurate predictor for successful rehabilitation.

Analogous to the association with mortality, as assessed in the study by Weiss, one may hypothesize that episodic and sustained OH have different associations with rehabilitation. Episodic OH may have no consequences for chances of rehabilitation, whereas sustained OH may be much more relevant.

The confounders DM, SBP, handgrip strength, and FOF were significantly related to time to successful rehabilitation. The hazard of successful rehabilitation in patients with DM was lower than in patients without DM, as was also seen in our previous study.[7] The hazard of successful rehabilitation increased by 15% (95% CI, 3%−28%) for every 10-mmHg increase in SBP. In a previous study,[38] higher blood pressure in frail patients was related to lower all-cause mortality, while the opposite relationship was seen in nonfrail patients. Therefore, it was not unexpected that higher SBP is associated with a higher hazard of successful rehabilitation.

Poor muscle strength and FOF are frequently seen in elderly patients, and these factors are also related with the level of frailty.[14-16] Successful rehabilitation increased by 5% (95% CI, 1%−8%) for every 1-kg increase in handgrip strength measurement. The relationship between handgrip strength and rehabilitation will be discussed in the next section (Handgrip strength and successful rehabilitation).

The time to successful rehabilitation decreased by 13% (95% CI, 3%−22%) for every 1-point increase on the visual analog scale for FOF. These results support previous studies[11,39] regarding the impact of FOF on functional outcomes, which describe an association of FOF with negative outcomes such as falling and functional impairment (eg, instrumental activities of daily living). In the study by Oude Voshaar et al,[9] FOF seems to be an important predictor for functional recovery after hip fracture surgery. Previous studies[40,41] described that fear after falling may restrict physical activity, which causes immobility and further loss of functional independence and risk of falling. FOF can be divided into 3 components: physiological, behavioral, and cognitive.[11] Prevention and treatment of FOF by intervening in all 3 of these components are important clinical treatment goals.

Handgrip strength and successful rehabilitation

Although increased muscle strength was not significantly related to time to successful rehabilitation in the present study, a relationship cannot be excluded based on the width of the CI. In the model with OH as the variable of interest, a statistically significant association was observed. Previous studies[8,42] also observed positive relationships between handgrip strength and rehabilitation. Di Monaco et al[8] described a significant relationship between handgrip strength and functional outcomes in patients with hip fracture. Another study[42] showed a relationship between handgrip strength during hospital admission and walking independently. An important difference between the study by Di Monaco and the present study is the timing of the handgrip strength measurement—at the rehabilitation department after discharge from the hospital versus preoperatively in the present study. Measuring handgrip strength preoperatively reflects the baseline condition of a patient and is a predictor for complications or length of stay.[43,44] Therefore, the handgrip strength measurement can be used to identify those patients who are frailer and need a different approach during hospitalization.[43]

Study strengths

Since the present study took place in a general hospital and only a few exclusion criteria were used, our study population is a representative group of elderly patients with a hip fracture. The timing of inclusion and the homogenous study population of the present study were major strengths compared with our previous study.[7] Recruitment and testing took place within 2 days after admission to the hospital, preferably on the day of admission.

Table 3 HRs of handgrip strength for successful rehabilitation (N=116)

Variable	Model 1	Model 2	Model 3
Handgrip strength	1.02 (1.00−1.04)*	1.02 (0.99−1.05)	1.03 (0.99−1.06)
Age	NA	0.97 (0.94−1.00)	0.99 (0.95−1.02)
Sex: female vs male	NA	0.72 (0.39−1.33)	0.83 (0.44−1.57)
BMI	NA	NA	0.97 (0.93−1.02)
Barthel Index score	NA	NA	1.09 (0.98−1.21)
History of CVD disease	NA	NA	0.57 (0.33−0.99)
OH	NA	NA	1.09 (0.71−1.68)

NOTE. Values are HR (95% CI). HRs for successful rehabilitation. Model 1 unadjusted. Model 2 adjusted for age and sex. Model 3 adjusted for age, sex, BMI, Barthel Index score, previous macrovascular complications, and OH.
Abbreviations: CVD, cardiovascular disease; NA, not applicable.
* $P=.054$.

Study limitations

The current study also has some limitations. The main limitation was that 18% of the handgrip strength measurements were not measured preoperatively. However, we performed the same analyses in the group of patients with preoperatively measured handgrip strength, and the results did not relevantly change (data not shown). Although OH should be measured from lying to standing, this was not possible in 98% of patients. It is very likely that the actual number of patients with OH was higher. Furthermore, OH was only measured once during the follow-up period, which probably biased the results. If repeated OH measurements had been obtained, not only episodic OH but also established OH would have been diagnosed. Future studies are needed to evaluate the clinical implications of sustained OH on rehabilitation.

Another limitation is the definition of successful rehabilitation; in our study, this was defined as discharge to patients' own homes. Patients with a worse outcome after rehabilitation but with a highly adapted home environment may be sent home earlier than others.

Conclusions

In conclusion, this study showed that OH measured during the first days of hospitalization was not related to time to successful rehabilitation. Although no significant relationship was seen in the present study, the width of the CI does not exclude a relevant relationship between handgrip strength and time to successful rehabilitation.

Suppliers

a. A&D UA-767 Plus; A&D Company.
b. Heine Gamma XXL-T sphygmomanometer; Heine Optotechnik.
c. Jamar hand dynamometer; Patterson Medical.
d. SPSS software (version 22); IBM Corp.

Keywords

Blood pressure; Hypotension, orthostatic; Rehabilitation

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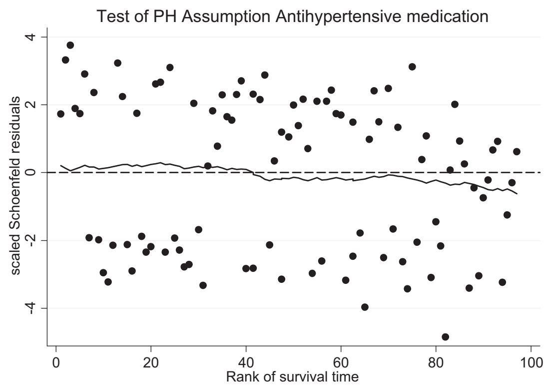
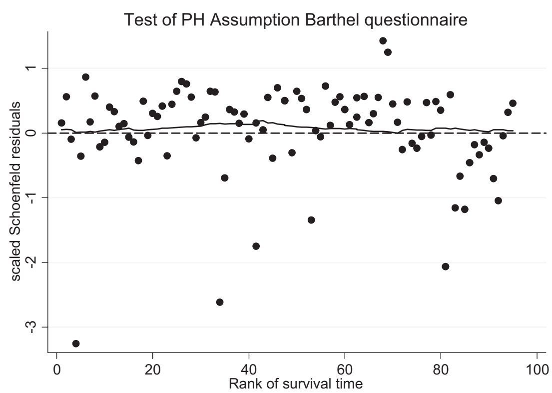
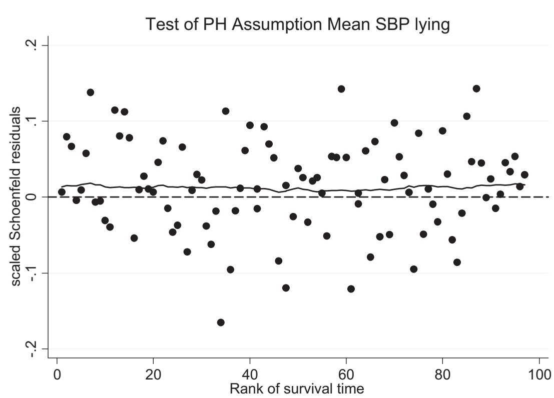
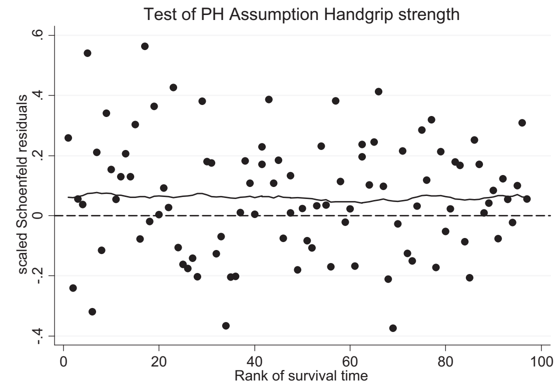
Supplemental Appendix S1 Schoenfeld Residual Plots

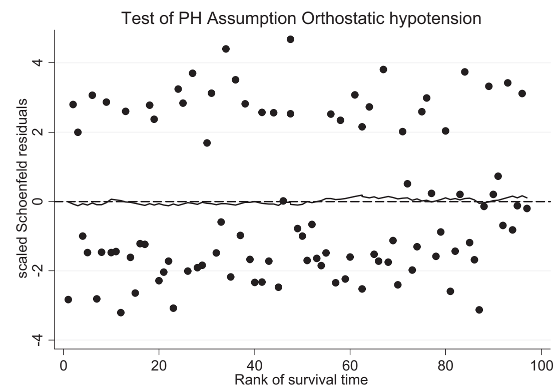
Schoenfeld residuals for table 2

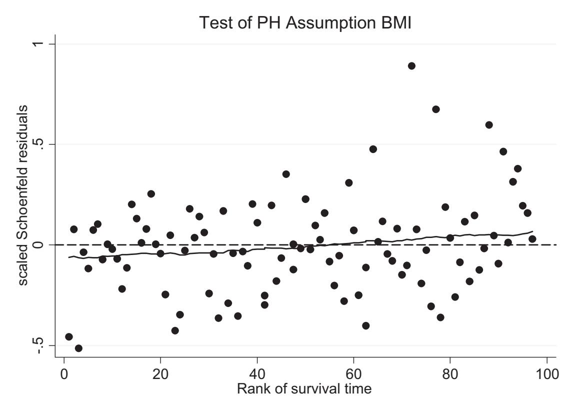


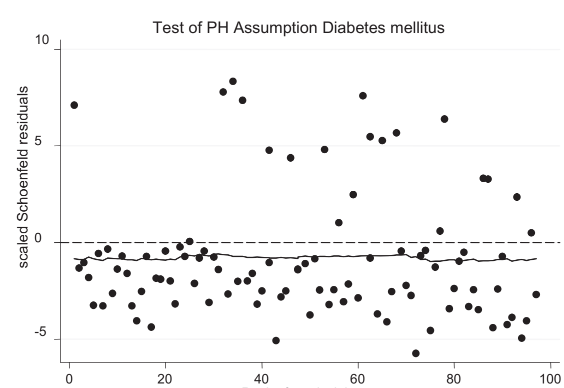












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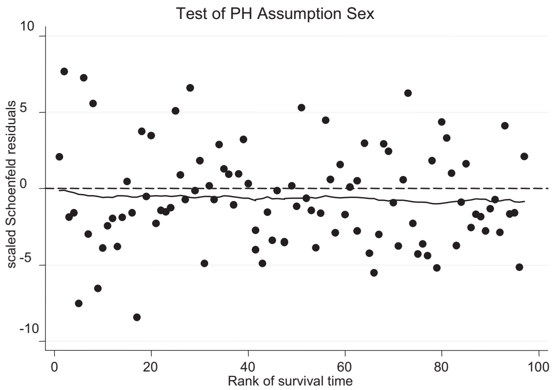
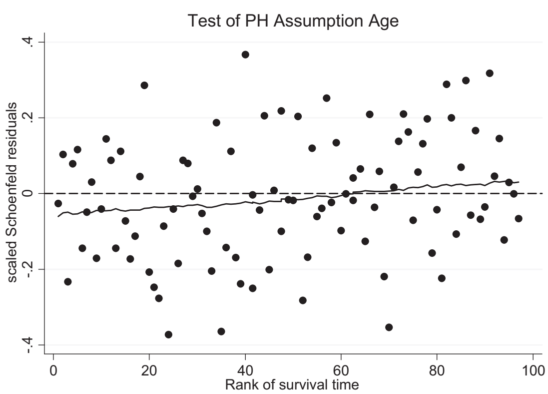
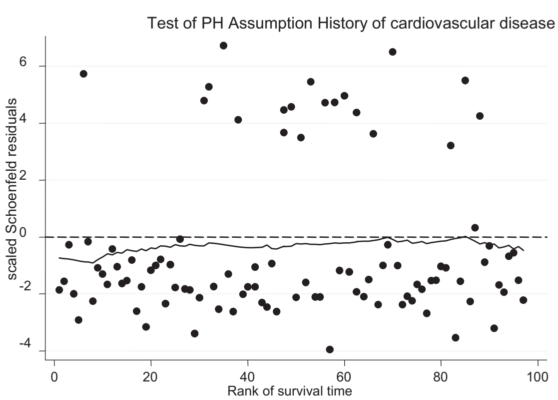
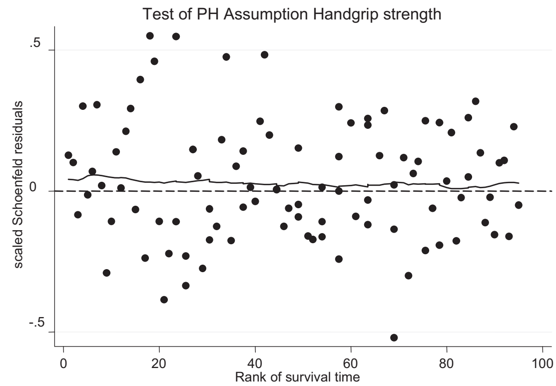
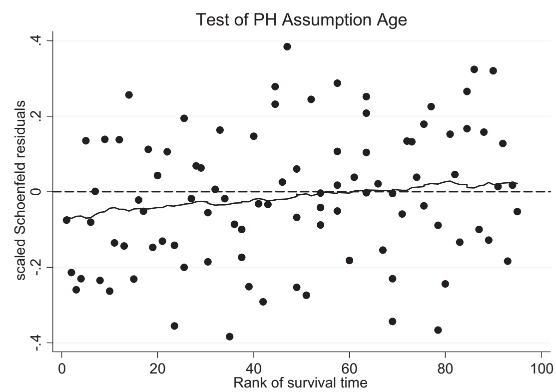


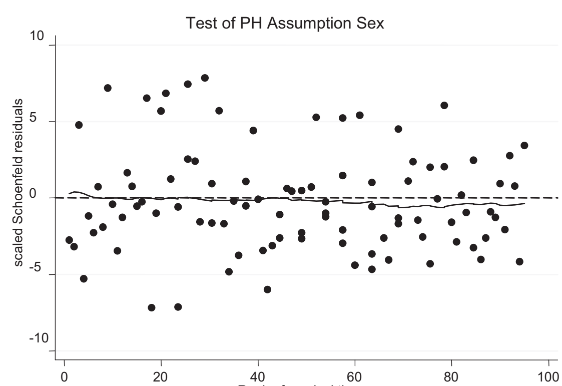




Schoenfeld residuals for table 3







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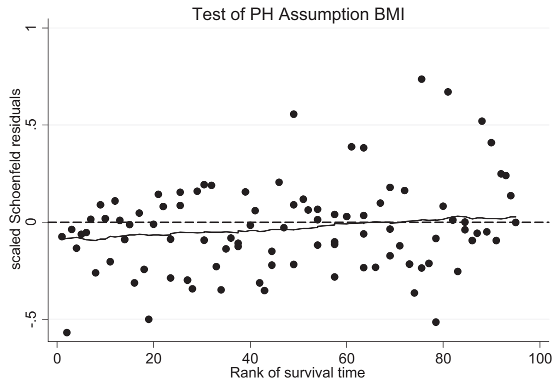

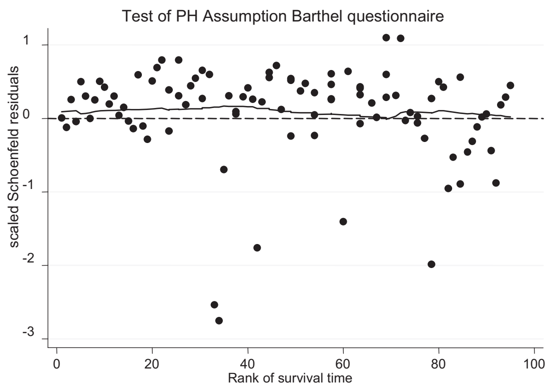

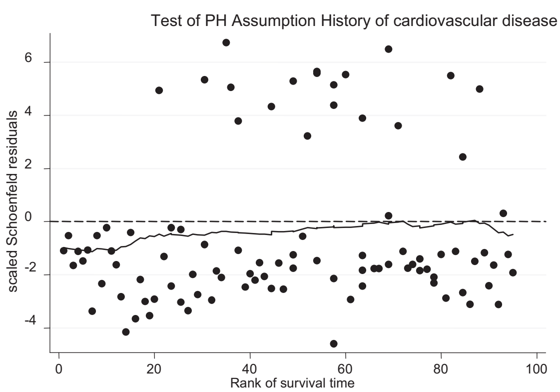

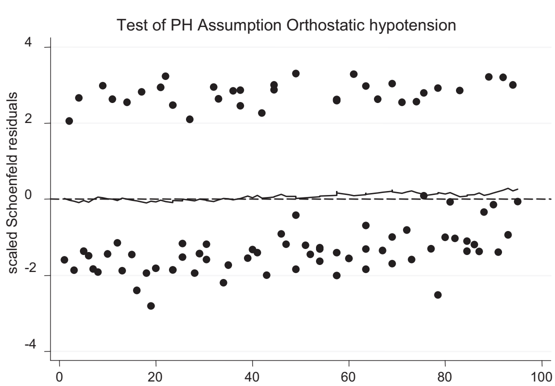

Abbreviation: PH, proportional hazard.