Functional Performance as a Predictor of Injurious Falls in Older Adults

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OBJECTIVES: To determine whether a performance battery and its components aid in predicting injurious falls.

DESIGN: Longitudinal analysis; prospective cohort study.

SETTING: Clinical site.

PARTICIPANTS: Boston-area community-dwelling adults (N = 755; mean age ± SD 78.1 ± 5.4, 64.1% female, 77.6% white).

MEASUREMENTS: Baseline functional performance was determined according to the Short Physical Performance Battery (SPPB), measuring balance, gait speed, and five repeated chair stands. Fall history (past year) and efficacy in performing 10 daily activities without falling were assessed. Falls were assessed using a daily calendar over 4 years. Injurious falls were defined as resulting in fractures, sprains, dislocations, pulled or torn muscles, ligaments, or tendons or seeking medical attention.

RESULTS: Poorest chair stand performance (≥16.7 seconds) was associated with greater hazard of injurious falls than in all other chair stand performance groups (hazard ratio (HR) = 1.96, 95% confidence interval (CI) = 1.18–3.26 for ≥ 16.7 vs. 13.7–16.6 seconds; HR = 1.65, 95% CI = 1.07–2.55 for ≥ 16.7 vs. 11.2–13.6 seconds, HR = 1.60, 95% CI = 1.03–2.48 for ≥ 16.7 vs. <11.2 seconds). SPPB did not predict injurious falls. Fall history predicted injurious falls (HR = 1.82, 95% CI = 1.39–2.39); falls efficacy did not. Fall history and a slow chair stand (<16.7 seconds) had a 2-year cumulative incidence rate of an injurious fall of 46% (95% CI = 0.34–0.58), nearly the combined rate of a positive fall history (0.29, 95% CI = 0.25–0.34) and a slow chair stand alone (0.21, 95% CI = 0.13–0.30).

CONCLUSION: An easily administered chair stand test may be sufficient for evaluating performance as part of a risk stratification strategy for injurious falls. **J Am Geriatr Soc 63:315–320, 2015.**

Key words: falls; injury; aged; risk assessment

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Fall-related injuries in older adults are a major public health problem. Annually, 35% to 40% of community-dwelling adults aged 65 and older fall, with 10% of those who fall suffering serious injury.[1] Fall-related injuries are a major source of mortality, morbidity, and disability and can lead to loss of independence.[2,3] In 2000, $19.2 billion was spent on fall-related injuries in the United States.[4] This is expected to climb $32.4 billion by 2020.[5]

The Centers for Disease Control and Prevention has released an algorithm for Falls Risk Assessment and Interventions to aid in care planning and prevention.[6] This algorithm recommends assessing fall history, falls self-efficacy (e.g., worrying about falling), and functional performance, which may inform clinical decisions on patient education, referral to exercise or prevention programs, or conduct of multifactorial risk assessments and interventions. This algorithm was created to assess overall falls risk, although serious fall-related injuries have more direct consequences for health, function, and healthcare expenditures.

The algorithm evaluates three functional performance domains associated with falls[7] and fall-related injuries:[2] gait, lower-extremity strength or chair stand performance, and balance. Various tests assess these domains, although there is limited evidence regarding which test is most predictive of injurious falls. Few studies have investigated how these tests perform in combination with other brief assessments such as a falls history or self-efficacy.[8,9]

The Short Physical Performance Battery (SPPB) captures each of these functional domains with established cutpoints

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predictive of disability and mortality in older adults.[10,11] The SPPB is easily administered, requires little equipment, and can be completed in less than 10 minutes. Despite this, it has not been evaluated longitudinally as a predictor of fall-related injuries. Using the Centers for Disease Control and Prevention Falls Risk Assessment and Interventions algorithm as a guide, whether functional performance, combined with fall history and falls efficacy, predicts time to incident injurious falls was examined. It was hypothesized that, combined with fall history and falls efficacy, the SPPB and/or its components would predict injurious falls.

METHODS

The Maintenance of Balance, Independent Living, Intellect and Zest in the Elderly (MOBILIZE) Boston Study was designed to assess risk factors and mechanisms of falls in a cohort of 765 community-dwelling older adults living in the Boston area.[12] Eligibility included age 70 and older, ability to walk 20 feet without the aid of another person, and intention to stay in the Boston area for 2 years or longer.[13] Exclusions were moderate to severe cognitive impairment (Mini-Mental State Examination (MMSE) score <18), severe visual or hearing deficits, and terminal illness. The analysis included 755 (98.7%) participants. Participants with less than 90 days of follow-up because of withdrawal (n = 8) from the study or death (n = 2) were excluded from the analysis.

Injurious Falls

Falls were defined as unintentionally coming to rest on the ground or another lower level not resulting from a major health event (e.g., myocardial infarction) or an overwhelming external hazard (e.g., vehicular accident).[14] Participants mailed daily falls calendars to the study site monthly.[15] Falls were assessed during a maximum follow-up of 4.3 years. Associated injuries were ascertained through structured interviews. Injurious falls were defined according to fractures; sprains; dislocations; pulled or torn muscles, ligaments, or tendons; or by seeking medical attention. Falls data were obtained for 98.5% of follow-up months in the first year, 90.8% in the second year, 88.2% in the third year, and 81.2% in the fourth year.[16]

The SPPB

The SPPB is a well-established, reliable, valid measure of lower-extremity performance.[10,11] It includes a test of standing balance, a timed 4-m usual-pace walk, and a timed test of five repeated chair stands. Each test is scored from 0 to 4, with a maximum summed score of 12 for the three tests and higher scores indicating better functioning. Scores were categorized based on previously validated cutpoints (Tables 1 and 2).[10] The SPPB is predictive of disability, hospitalization, and mortality in older populations.[10,11]

Baseline Characteristics

Baseline assessments included a home interview conducted by a trained research assistant, followed by a clinic assessment visit within approximately 2 weeks of the interview. Fall history (yes/no) within the past year was assessed according to self-report. Falls self-efficacy was measured using the Falls Efficacy Scale,[17] for which participants were asked to rate their level of confidence from 1 (not at all confident) to 10 (extremely confident) in performing 10 daily activities without falling.

Covariates such as age, sex, race, body mass index (BMI), and baseline health conditions known and hypothesized to be related to falls and fall-related injuries were considered in the analysis.[2,6] Psychotropic medication use (yes/no) included use of antidepressants, antipsychotics, hypnotics, benzodiazepines, and other sedatives. Cognitive impairment was defined as a score of less than 24 on the MMSE.[13] Depression was assessed using a modified Center for Epidemiologic Studies Depression Scale.[18,19] Vision was assessed using a light box at a 10-foot distance;[20] visual deficit was defined as scoring in the lowest quartile. Orthostatic hypotension was defined as a reduction of systolic blood pressure of 20 mmHg or more or of diastolic blood pressure of 10 mmHg or more within 3 minutes of standing.[21] Sensory impairment was defined as being unable to feel a 10-g Semmes-Weinstein monofilament on the dorsum of either great toe.[22]

Table 1. Risk of Injurious Falls According to Short Physical Performance Battery (SPPB) Score,[a] Fall History, and Falls Efficacy

Predictor	Model 1: Without SPPB (AIC = 2,696.4[b])	Model 2: With SPPB (AIC = 2,699.1[b])
	Hazard Ratio (95% Confidence Interval)	
Fall history (yes vs no)	1.82 (1.39–2.39)[c]	1.84 (1.40–2.42)[c]
Falls Efficacy Scale (per standard deviation)[d]	0.90 (0.80–1.02)	0.92 (0.81–1.04)
SPPB score (1–12)		
1–3 vs 4–6	—	0.63 (0.30–1.34)
1–3 vs 7–9	—	0.89 (0.44–1.79)
1–3 vs 10–12	—	0.98 (0.48–1.99)
4–6 vs 7–9	—	1.39 (0.87–2.22)
4–6 vs 10–12	—	1.53 (0.96–2.44)
7–9 vs 10–12	—	1.10 (0.80–1.52)
Age	1.03 (1.00–1.05)[c]	1.02 (1.00–1.05)
Male sex	0.77 (0.58–1.03)	0.77 (0.58–1.03)
White race	1.61 (1.11–2.33)[c]	1.61 (1.11–2.33)[c]
Psychoactive drug use	1.76 (1.11–2.80)[c]	1.76 (1.11–2.80)[c]
Depression	1.60 (1.03–2.74)[c]	1.60 (1.03–2.47)[c]

n = 32 (4.3%) for SPPB = 1–3, n = 68 (9.1%) for SPPB = 4–6, n = 204 (27.3%) for SPPB = 7–9, n = 443 (59.3%) for SPPB = 10–12.

[a]Higher scores indicate better physical functioning.

[b]Lower values indicate better model performance.

[c]$P < .05$.

[d]Falls Efficacy Scale range 1 (not at all confident) to 10 (extremely confident).

AIC = Akaike information criterion.

Statistical Analysis

Multivariable Cox proportional hazards models were built to predict incident injurious falls. Covariates univariately related to injurious falls ($\alpha = 0.1$) were included in the models to prevent overfitting. The predictors fall history

Table 2. Risk of Injurious Falls According to Short Physical Performance Battery (SPPB) Component Scores, Fall History, and Falls Efficacy

Predictor	Model 1: Gait Speed[a] (AIC = 2,697.7[b])	Model 2: Chair Stands[c] (AIC = 2,309.5[b])	Model 3: Balance[d] (AIC = 2,670.4[b])
	Hazard Ratio (95% Confidence Interval)		
Fall history (yes vs no)	1.80 (1.37–2.36)[e]	1.79 (1.33–2.40)[e]	1.79 (1.36–2.35)[e]
Falls Efficacy Scale (per standard deviation)[f]	0.93 (0.82–1.06)	0.93 (0.79–1.08)	0.91 (0.79–1.03)
SPPB Component Scores (1–4)[g]			
1 vs 2	0.61 (0.25–1.50)	1.96 (1.18–3.26)[e]	1.54 (0.87–2.75)
1 vs 3	0.85 (0.35–2.06)	1.65 (1.07–2.55)[e]	1.08 (0.64–1.81)
1 vs 4	1.01 (0.41–2.47)	1.60 (1.03–2.48)[e]	1.35 (0.82–2.22)
2 vs 3	1.40 (0.87–2.26)	0.84 (0.54–1.31)	0.70 (0.43–1.15)
2 vs 4	1.66 (1.05–2.63)[e]	0.81 (0.52–1.27)	0.88 (0.56–1.39)
3 vs 4	1.19 (0.83–1.69)	0.97 (0.68–1.37)	1.26 (0.90–1.75)
Age	1.02 (1.00–1.05)	1.03 (1.01–1.06)[e]	1.03 (1.00–1.05)
Male	0.80 (0.60–1.07)	0.69 (0.50–0.94)	0.80 (0.60–1.07)
White	1.67 (1.15–2.42)[e]	1.59 (1.07–2.38)[e]	1.50 (1.04–2.17)[e]
Psychoactive drug use	1.75 (1.10–2.79)[e]	1.87 (1.16–3.01)[e]	1.66 (1.04–2.64)[e]
Depression	1.58 (1.02–2.44)[e]	1.57 (0.93–2.64)	1.59 (1.03–2.47)[e]

[a]1 = <0.46 m/s (n = 21, 2.8%); 2 = 0.46–0.64 m/s (n = 70, 9.4%); 3 = 0.65–0.82 m/s (n = 140, 18.7%); and 4 = ≥0.83 (n = 516, 69.1%).
[b]Lower scores indicate better model performance.
[c]1 = completed 5 in ≥16.7 seconds (n = 85, 12.8%); 2 = completed 5 in 13.7–16.6 seconds (n = 129, 19.5%); 3 = completed 5 in 11.2–13.6 seconds (n = 232, 32.7%), and 4 = completed 5 in <11.2 seconds (n = 217, 32.7%).
[d]1 = held side-by-side stand for 10.0 seconds and semitandem stand for <10.0 seconds (n = 57, 7.7%), 2 = held semitandem stand for 10.0 seconds and full tandem stand for ≤3.0 seconds (n = 96, 13.0%), 3 = held full-tandem for 3.1–9.9 seconds (n = 156, 21.1%), and 4 = held full tandem for 10.0 seconds (n = 430, 58.2%).
[e]$P < .05$.
[f]Range 1 (not at all confident) to 10 (extremely confident).
[g]Higher scores indicate better physical function.
AIC = Akaike information criterion.

and falls efficacy score were adjusted for age, sex, race, psychotropic medication use, and depression,[2,6] and SPPB or SPPB component scores were added as ordinal predictors in separate models. The Akaike information criterion was used to determine goodness of fit. The proportional hazards assumption was checked by testing the relationship between injurious falls and the interaction between the predictors or covariates and the log of survival time ($\alpha = 0.05$). Cumulative incidence was calculated according to risk group and plotted against follow-up time. Two sensitivity analyses were performed, one assessing the relationships between continuous functional performance (gait speed and chair rise time) and injurious falls using Cox proportional hazards regression and one using classification and regression tree (CART) analysis in R statistical software (R Foundation for Statistical Computing, Vienna, Austria)[23] to determine the cutpoint or threshold of continuous performance most predictive of injurious falls. Analyses other than CART were performed using SAS version 9.3 (SAS Institute, Inc., Cary, NC).

RESULTS

The proportional hazards assumption was met. Participants had a median follow-up time of 2.43 years (interquartile range 1.40–3.23). Over the follow-up, 221 participants (29%) experienced one or more injurious falls. The mean age of the 755 participants was 78.1 ± 5.4; 64.1% were female, and 77.6% were white.

Adjusting for covariates, fall history predicted incident injurious falls (hazard ratio (HR) = 1.82, 95% confidence interval (CI) = 1.39–2.39), whereas falls efficacy and SPPB score did not (Table 1). Participants with the poorest chair stand performance (≥16.7 seconds) had a greater hazard of injurious falls than all other groups (HR = 1.96, 95% CI = 1.18–3.26 for ≥ 16.7 vs. 13.7–16.6 seconds, HR = 1.65, 95% CI = 1.07–2.55 for ≥ 16.7 vs. 11.2–13.6 seconds, HR = 1.60, 95% CI = 1.03–2.48 for ≥ 16.7 vs. <11.2 seconds) (Table 2). Inability to complete the chair stand (n = 64) was not associated with greater hazard of injurious fall (HR = 1.07, 95% CI = 0.66–1.73 vs all other participants). The second-poorest-performing gait speed group had a greater hazard of injurious fall than the highest-performing group (HR = 1.66, 95% CI = 1.05–2.63).

Because the worst-performing chair stand group had the highest hazard of injurious falls, and the chair stand model had the best goodness of fit, the interaction between chair stand performance and fall history, which was not significantly associated with injurious falls was tested. The cumulative incidence of an injurious falls when having a slow chair stand (score = 1; ≥16.7 seconds) and a fall history were assessed together and separately was also assessed (Figure 1). A positive fall history and slow chair stand were associated with a 2-year cumulative incidence of 46% (95% CI = 0.34–0.58) for an injurious fall, compared with 12% (95% CI = 0.10–0.15) for neither risk factor, 29% (95% CI = 0.25–0.34) for a fall history alone, and 21% (95% CI = 0.13–0.30) for a slow chair

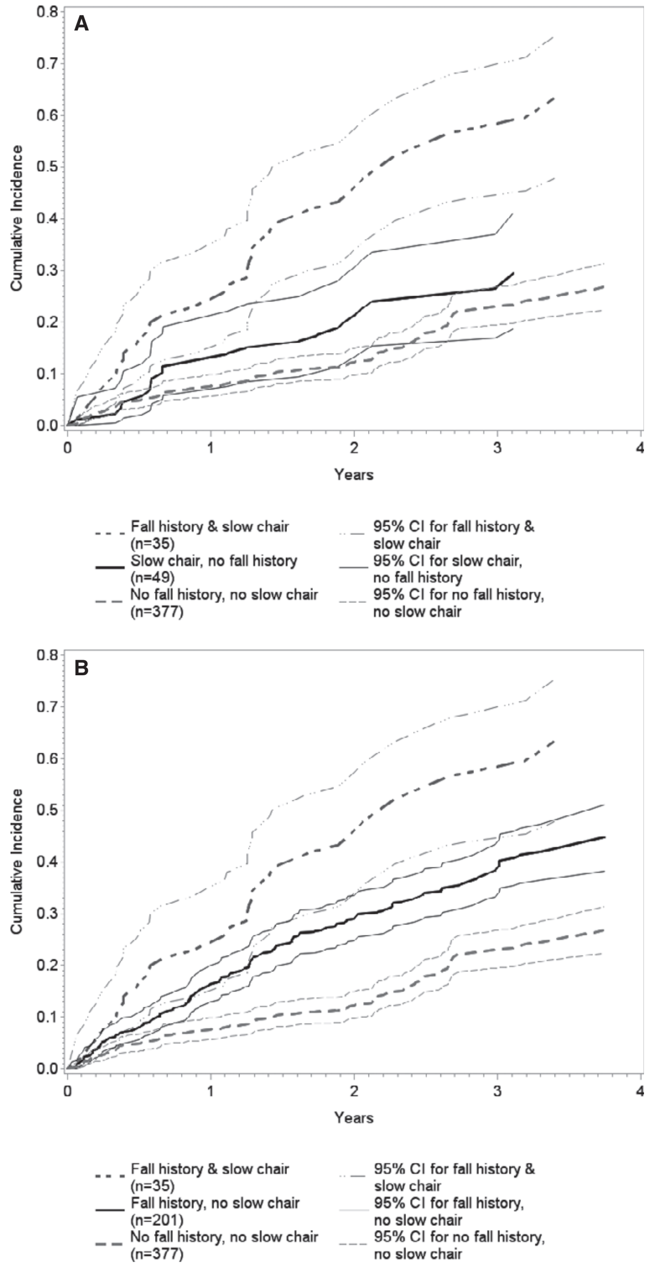

Figure 1. Cumulative incidence of injurious falls according to risk group. (A) Cumulative incidence rates of injurious falls across 4 years for the slow-chair-stand, no-fall-history risk group. (B) Cumulative incidence rates for the fall-history, no-slow-chair-stand risk group. Both figures also show the cumulative incidence rates of the fall-history, slow-chair-stand risk group and the no-fall history, no-slow-chair-stand risk group for comparison. Bold lines represent cumulative incident rates, and fine lines represent upper and lower bounds for 95% confidence intervals (CIs) of the cumulative incidence rates.

stand alone. Neither gait speed (HR = 0.63, 95% CI = 0.33–1.20) nor chair rise time (HR = 1.02, 95% CI = 0.99–1.02) was significant as a continuous predictor of injurious falls. Using CART, the most-predictive cutpoint of injurious falls in chair stand time was 15.5 seconds or longer.

DISCUSSION

The utility of a lower-extremity function measure as part of an injurious falls risk assessment strategy in older adults was determined. Although SPPB score was not predictive of injurious falls in this cohort, a 16.7-second cutpoint for the five-repetition chair stand test was an independent predictor. Performing slower than this threshold and reporting one or more falls in the preceding year was associated with a compounded risk of injurious falls over 4 years. These findings inform fall risk assessment recommendations and stratification guidelines and extend them to include fall-related injuries.

Multiple components of functional performance were assessed separately and in combination using the SPPB to evaluate injurious falls risk. The chair stand component of the SPPB performed better than the combined score, which includes balance and gait speed. This has important clinical implications, suggesting that a short, simple chair stand test, which may identify lower-extremity weakness, poor muscle power, and limitations in dynamic balance, may be sufficient for evaluating performance as part of a risk stratification strategy for injurious falls.

Although the SPPB has not been assessed to the authors' knowledge as a predictor of injurious falls using prospective data, the chair stand test was retrospectively evaluated as a predictor of falls and fall-related fractures.[24] The test was predictive of falls but not fall-related factures, although because 10 of 101 participants experienced fractures, lack of statistical power could account for this negative finding. In addition, previous studies have found that chair stand performance has been associated with recurrent falls,[3,25,26] with one study reporting that chair stand performance was a better predictor of multiple falls than the one-leg standing balance test and the Timed Up and Go Test[26] and another study reporting that it had predictive validity similar to that of the alternate-step test and the 6-m-walk test.[25] None of these studies evaluated the association of these tests with injurious falls.

When the magnitude of the HRs for chair stand performance predicting injurious falls was examined, a HR closer to 1 was noted in the comparison between the poorest- and the best-performing group (1 vs 4) than in the comparison between the poorest- and the second-poorest-performing group (1 vs 2). Previous findings from this study show that individuals with high and low performance have higher rates of falls than those in the middle categories,[27] suggesting that higher functioning may contribute to falls due to greater exposure to activities that may precipitate falls. It may be that individuals with poorer function are driving the significant relationship observed, whereas those with higher function are responsible for the unexpected trend in magnitude of the HRs. In addition, participants who were unable to complete the chair stand test did not have a greater hazard of fall-related injury, which was unexpected because it is likely that this group was the most impaired. One potential explanation is that this group's impairment may have decreased their mobility, which could have led to less exposure to situations in which falls might occur. Further investigation of fall-related injury risk is needed in these groups.

Having a slow chair stand and a fall history together was not only associated with a greater incidence of injurious falls than having neither risk factor, but also resulted in nearly the combined risk of having either risk factor alone. This emphasizes the importance of assessing fall history and functional performance when estimating risk of fall-related injury. Although there was some overlap in the CIs for cumulative incidence in these risk groups, this is probably due to the small number of participants in the slow-chair-stand, fall-history risk group (n = 35). Having only a positive fall history was also associated with a higher cumulative incidence of having an injurious fall than having neither risk factor. A slow chair stand without a positive fall history was associated with a marginally higher incidence and was not significantly different from that of the low-risk group, although this group may include older adults with poor function who may be at future risk of injurious falls and other unfavorable outcomes. This group also had large CIs, probably due to fewer participants (n = 49).

Once individuals are stratified according to basic risk factors, those identified as high risk should undergo a more-comprehensive multifactorial risk assessment and treatment, if needed.[6,28] Multifactorial assessments and treatment of individuals identified as being at high risk of falling can lead to a 30% to 40% reduction in falls.[29] Consistent with this multifactorial approach, additional risk factors for fall-related injury were included in the analysis, and it was found that psychoactive medication use and depression were predictive, although they did not attenuate the effects of functional performance. More research is needed to evaluate whether multifactorial treatment strategies are similarly effective at preventing fall-related injuries.

A major strength of this study is the collection of longitudinal falls data through monthly calendars over a maximum follow-up of 4.3 years. For functional performance, previously defined cutpoints were used that have been validated in large populations of older adults, which may make them more generalizable.[10] Sensitivity analyses were performed to test whether continuous chair rise time and gait speed predicted injurious falls, which they did not, supporting the findings of a threshold effect with chair rise time. A CART analysis, which determines the most-predictive cutpoint from a continuous measure, was also performed, resulting in a similar cutpoint of 15.5 seconds in chair rise time. A potential future direction is to determine the predictive validity of each of these cutpoints in a separate study population.

Given its direct relationship with poor health and function and greater healthcare expenditures, the outcome of serious fall-related injury is particularly salient to older adults, the healthcare system, and the economy at large. Much of the literature focuses solely on falls, ignoring resulting injuries. Risk factors that are specific to or have greater importance for fall-related injuries are crucial to include in studies focusing on risk assessment and treatment.

Limitations of this study include that specific findings may be limited to community-dwelling older adults and may not be generalizable to other populations, such as institutionalized or frail older adults or those with significant cognitive impairments. Because of the small number of participants in the slow-chair-stand, fall-history group and the slow-chair-stand, no-fall-history group, there may have been insufficient power to fully detect differences in cumulative incidence of injurious falls between these and other groups. In addition, injurious falls risk was assessed only at baseline, and individuals' functional status can fluctuate over time, but the baseline assessment may help shed light on what can be predicted from a one-time medical assessment anywhere from 0 to 4 years later, as Figure 1 illustrates. Finally, the analysis was designed to assess time to first injurious fall. An important future direction is to assess whether the SPPB or its components can stratify individuals at risk for multiple future injurious falls.

CONCLUSION

The chair stand assessment predicts injurious falls and may have clinical utility when implementing a risk assessment and treatment strategies. This assessment is easy and quick to use in a busy clinical practice. These findings support the use of current algorithms including measures of fall history and functional performance and extend the use of these tools to risk estimation of fall-related injury. Estimation of injurious falls risk has particularly important implications for prevention of disability and mortality in older adults[30] and reducing healthcare use and expenditures.[4] Future studies should investigate the effectiveness of intervening on groups stratified according to injurious falls risk and how treatment strategies should differ based on results from risk assessment.

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