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Current Cut Points of Three Falls Risk Assessment Tools Are Inferior to Calculated Cut Points in Geriatric Evaluation and Management Units

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Current Cut Points of Three Falls Risk Assessment Tools are Inferior to Calculated Cut Points in Geriatric Evaluation and Management Units

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Abstract: Background: Falls risk assessment tools are used in hospital inpatient settings to identify patients at increased risk of falls (which may be related to muscle loss/sarcopenia) to guide and target interventions for falls prevention. In 2022, Western Health, Melbourne, Australia, introduced a new falls risk assessment tool, the Western Health St. Thomas' Risk Assessment Tool (WH-STRATIFY), a modified version of The Northern Hospital's risk tool (TNH-STRATIFY), which replaced the Peninsula Health Risk Screening Tool (PH-FRAT). **Aims:** To determine the predictive accuracy of three falls risk assessment tools (PH-FRAT, TNH-STRATIFY and WH-STRATIFY) on admission to Geriatric Evaluation Management (GEM) units. **Method:** A retrospective observational study was conducted on four GEM units. Data was collected on 54 consecutive patients who fell during admission and 62 randomly sampled patients who did not fall between December 2020 and June 2021. Participants were scored against three falls risk assessment tools. The event rate Youden (Youden Index^{ER}) indices were calculated and compared using default and optimal cut points to determine which tool was most accurate for predicting falls. **Results:** Using default cut points to compare falls assessment tools, TNH-STRATIFY had the highest predictive accuracy (Youden Index^{ER} = 0.20, 95% confidence interval CI = 0.07, 0.34). The PH-FRAT (Youden Index^{ER} = 0.01 and 95% CI = -0.04, 0.05) and WH-STRATIFY (Youden Index^{ER} = 0.00 and 95% CI = -0.04, 0.03) were statistically equivalent and not predictive of falls compared to TNH-STRATIFY. When calculated optimal cut points were applied, predictive accuracy improved for PH-FRAT (Cut point 17, Youden Index^{ER} = 0.14 and 95% CI = 0.01, 0.29) and WH-STRATIFY (Cut point 7, Youden Index^{ER} = 0.18 and 95% CI = 0.00, 0.35). Overall, all tools had low predictive accuracy for falls. **Conclusion:** TNH-STRATIFY had the highest predictive accuracy for falls. The predictive accuracy of WH-STRATIFY improved and was significant when the calculated optimal cut point was applied. The optimal cut points of falls risk assessment tools should be determined and validated in different clinical settings to optimise local predictive accuracy, enabling targeted falls risk mitigation strategies and resource allocation.

Keywords: falls; falls risk assessment tools; GEM

1. Introduction

Inpatient falls are the most common reported incidents in many hospitals with higher risk in older adult sub-acute patients [1–5]. One Australian study reported over 40% of patients have experienced at least one fall during their admission [6]. As falls lead to health complications for patients (both physical and psychological) [7], and greater utilisation of hospital resources [8], falls risk assessment tools have been used as part of a broader plan to reduce the risk of falls for patients in sub-acute wards [9]. The major risk factors for inpatient falls include delirium, cognitive impairment, sarcopenia, previous falls, neurological disorders and sensory impairments [10–12]. The prevalence of sarcopenia (i.e., loss of muscle strength and mass) rises with age leading to increased risk of falls [10,12,13].

The term *falls risk assessment tool* has been used to describe a class of diagnostic processes to manage falls risk [3]. These include *risk-factor checklists* that prompt healthcare workers to identify common modifiable fall risk factors to reduce harm through targeted plan development. *Numerical risk prediction tools* have cut points on a scale designed to predict risk of future falls by calculating a score from a set of risk factors.

In 2022, a global multidisciplinary group presented consensus recommendations promoting the use of multifactorial falls risk assessments instead of numerical falls risk screening [14]. This included recommendations that assessments, interventions and strategies should consider local context and resources [14].

We conducted this retrospective observational study at Western Health, a metropolitan health network servicing the Western Suburbs of Melbourne, Australia. This study involved patients admitted to four Geriatric Evaluation and Management (GEM) units across the network [15]. Participants were older adults with acute deterioration in functional abilities due to illness, injury or cognitive decline and were at risk of falls. This study focused on assessing numerical risk falls prediction tools so targeted interventions and prevention strategies could be implemented to mitigate falls risk during hospitalisation [15].

Western Health previously used the Peninsula Health Falls Risk Screening Tool (PH-FRAT) (Appendix 1) first developed in 1999 by the Peninsula Health Falls Prevention Service. The PH-FRAT is used by approximately 400 agencies worldwide [15] in a variety of settings including sub-acute care [15–17]. However, its predictive performance for falls has been found to be poor [15]. The St. Thomas Risk Assessment Tool in Falling elderly inpatients (STRATIFY) is the most widely studied falls risk assessment tool and has the best diagnostic validity [15]. The Northern Hospital Modified St Thomas's Risk Assessment Tool (TNH-STRATIFY) was modified from STRATIFY based on local data, and included additional risk factors: age, impaired balance, drug and alcohol-related problems, and broadening of the agitation item to include confusion, intellectually challenged or impulsivity. These modifications resulted in statistically significant improvements to the predictive accuracy of TNH-STRATIFY compared to the original STRATIFY tool [18].

In 2021, the Western Health Falls Working Group modified the TNH-STRATIFY to form the WH-STRATIFY (Appendix A) by adding two additional risk factors: Non-English-Speaking Background (NESB) and medications affecting mobility (sedatives, antidepressants, anti-Parkinson's, diuretics, anti-hypertensives, hypnotics and opioids), based on evidence of these medications increasing falls risk [15,16]. The NESB category was added to the WH-STRATIFY [15] based on the expectation that NESB leads to greater disadvantage in communication and education on falls risk management [15,16]. A difference between WH-STRATIFY and its predecessors is the inclusion of suggested management strategies directly linked to each identified falls risk factor. In addition to numerical scoring, WH-STRATIFY promotes interventions tailored to the patient's individual risk, aligned with current guidelines [14]. In 2022, WH-STRATIFY was launched at Western Health.

Falls risk assessment tools should be tested in clinical practice for validity and feasibility prior to use [15]. This includes comparing predictive accuracy to other falls risk assessment tools [15–17,19] and establishing the optimal cut points (i.e., the threshold at which a falls risk assessment tool predicts a fall) [15,17,19,20]. In this study, a cut point is the minimum score required on a falls risk assessment tool to achieve the classification of someone predicted to have a fall during their GEM

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admission. Predictive accuracy varies with the cut point for different populations suggesting the cut point should be validated in the setting where the tool is applied [15].

Aims

This study of GEM unit inpatients compares the predictive accuracy for falls of the PH-FRAT, TNH-STRATIFY and WH-STRATIFY risk assessment tools using default and calculated optimal cut points.

2. Results of the Study

Demographics

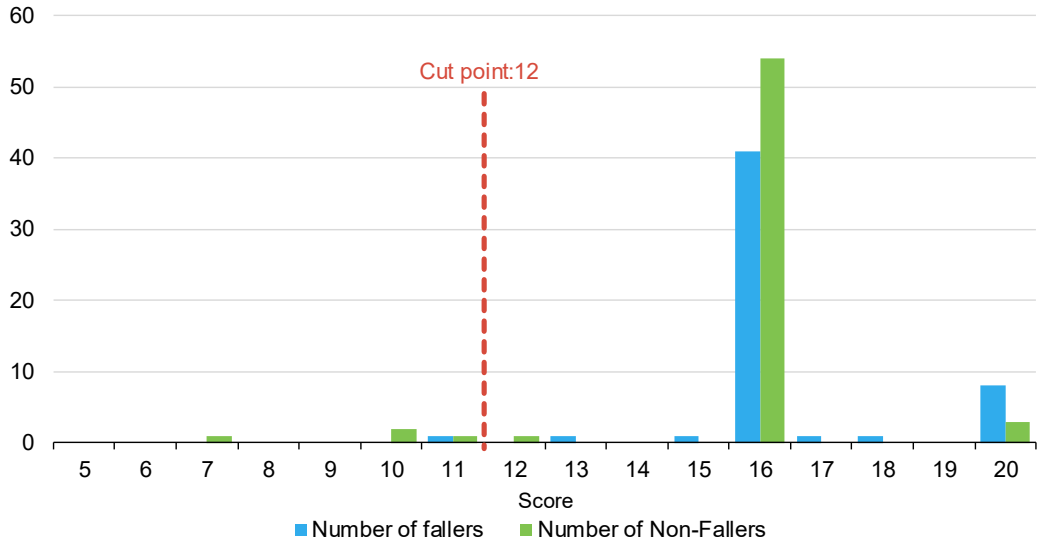
A total of 116 participants comprising 54 fallers and 62 non-fallers with mean age 81.0 years (fallers) and 79.3 years (non-fallers), p-value = .284. Fallers had a significantly higher average length of stay than non-fallers (28.0 days compared to 13.7 days, p-value < .0001 (Table 2).

Table 2. Patient profiles.

Profile	All	Fallers	Non-fallers	p-value
Number (%)	116 (100%)	54 (47%)	62 (53%)	.4576
Mean age years (SD)	80.1 (8.6)	81.0 (8.4)	79.3 (8.8)	.2839
Mean length of stay in days (SD)	20.3 (16.9)	28.0 (20.2)	13.7 (9.4)	.0000
Male (%)	50 (43%)	28 (52%)	22 (35%)	.0758

Comparing Predictive Accuracy using Default Cut Points

Figures 1–3 summarise the number of fallers and non-fallers for the three falls risk assessment tools using default cut points. Default cut points are the original scores for each tool that denote a patient as high or low falls risk (e.g., PH-FRAT = 12; TNH-STRATIFY = 3, and; WH-STRATIFY = 3).



Score	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of fallers	0	0	0	0	0	0	1	0	1	0	1	41	1	1	0	8
Number of Non-fallers	0	0	1	0	0	2	1	1	0	0	0	54	0	0	0	3

Figure 1. Number of fallers and non-fallers by PH-FRAT score.

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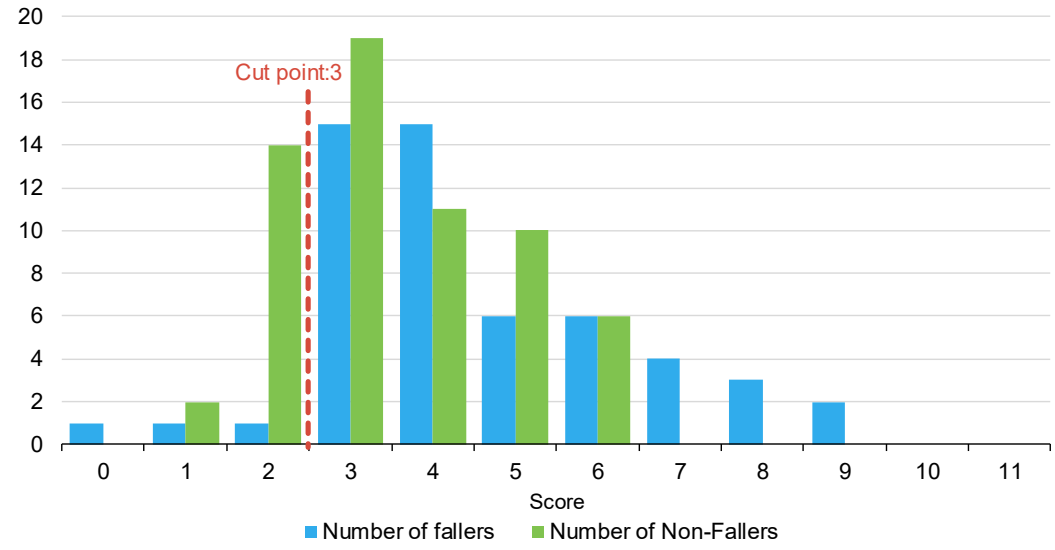
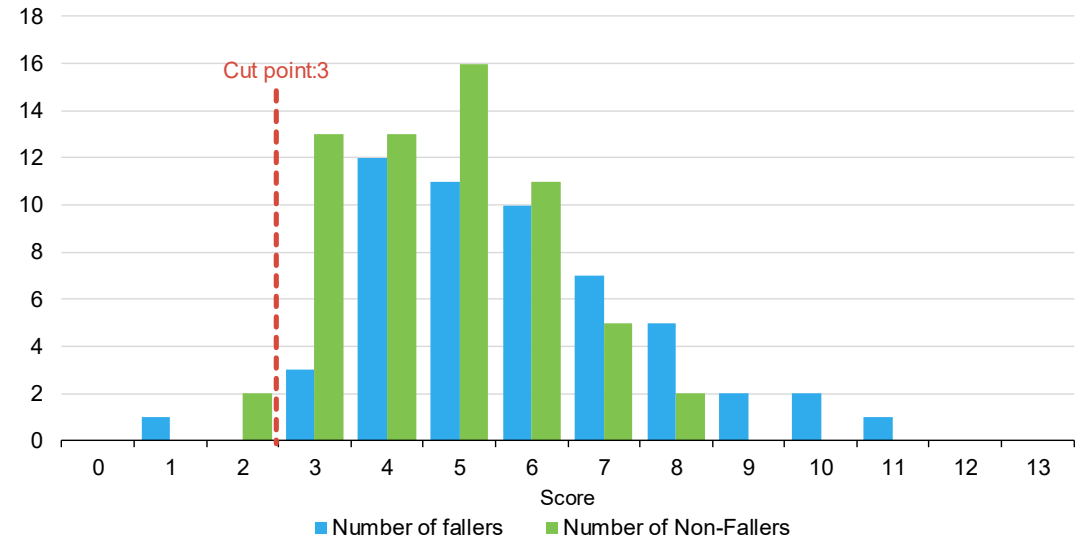


Score	0	1	2	3	4	5	6	7	8	9	10	11
Number of fallers	1	1	1	15	15	6	6	4	3	2	0	0
Number of Non-fallers	0	2	14	19	11	10	6	0	0	0	0	0

Figure 2. Number of fallers and non-fallers by TNH-STRATIFY score.



Score	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Number of fallers	0	1	0	3	12	11	10	7	5	2	2	1	0	0
Number of Non-fallers	0	0	2	13	13	16	11	5	2	0	0	0	0	0

Figure 3. Number of fallers and non-fallers by WH-STRATIFY score.

The PH-FRAT was poor at differentiating the falls risks of participants. The majority (82%) of participants were assigned a high score of 16 which overcalls fallers, noting a cut point of 12 (Appendix A2). In comparison, there is a larger spread of scores for TNH-STRATIFY and WH-STRATIFY (close to 90% of participants scored between 2 and 6 for TNH-STRATIFY and between 3 and 7 for WH-STRATIFY (Appendix A2).

Of the three falls risk assessment tools using default cut points, TNH-STRATIFY has the highest predictive accuracy with a Youden Index^{ER} of 0.20 and 95% Confidence Interval (CI) 0.07, 0.34). This

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difference was statistically significant (Table 3). PH-FRAT and WH-STRATIFY had similar predictive accuracy. PH-FRAT has a Youden Index^{ER} 0.01 and 95% CI -0.04, 0.05. WH-STRATIFY has a Youden Index$^{ER\ of}$ 0.00 and 95% CI -0.04, 0.03 (Table 3). Both PH-FRAT and WH-STRATIFY had sensitivity^{ER} of 0.98 and specificity^{ER} of 0.02.

Table 3. Diagnostic predictive accuracy metrics for PH-FRAT, TNH-STRATIFY and WH-STRATIFY using cut points for predicting a faller.

Metric	PH-FRAT		TNH-STRATIFY		WH-STRATIFY	
Sensitivity^{ER}	0.98	(0.95, 1.00)	0.95	(0.89, 1.00)	0.98	(0.94, 1.00)
Specificity^{ER}	0.02	(0.00, 0.06)	0.25	(0.13, 0.38)	0.02	(0.00, 0.04)
Youden Index^{ER}	0.01	(-0.04, 0.05)	0.20	(0.07, 0.34)	0.00	(-0.04, 0.03)

Note - Values in parenthesis are bootstrapped 95% confidence intervals based on 1,000 repetitions of original sample size. The event rate metrics also factors for patients who may have had multiple falls in the same admission and the patient's length of stay [21].

Predictive Accuracy using Optimal Cut Points

The default cut points for PH-FRAT and WH-STRATIFY were not optimal. The Youden Index^{ER} can be maximised to 0.143 (at optimal cut point 17 for PH-FRAT) and 0.183 (at optimal cut point score 7 for WH-STRATIFY) (Table 5). The optimal cut point for TNH-STRATIFY is the default cut point (3).

Table 5. Event rate diagnostics by varying the fall cut-off score for PH-FRAT, TNH-STRATIFY and WH-STRATIFY.

Cut-off score	Sensitivity^{ER}	Specificity^{ER}	Youden Index^{ER}
PH-FRAT			
6	1.000	0.000	0.000
7	1.000	0.000	0.000
8	1.000	0.002	0.002
9	1.000	0.002	0.002
10	1.000	0.002	0.002
11	1.000	0.018	0.018
12 (Default)	0.984	0.025	0.008
13	0.984	0.031	0.014
14	0.967	0.031	-0.002
15	0.967	0.031	-0.002
16	0.951	0.031	-0.019
17 (Optimal)	0.197	0.946	0.143
18	0.180	0.946	0.126
19	0.164	0.946	0.110
20	0.164	0.946	0.110
TNH-STRATIFY			
1	0.984	0.000	-0.016
2	0.984	0.000	-0.016
3 (Default, Optimal)	0.951	0.249	0.199
4	0.656	0.532	0.188
5	0.393	0.717	0.111
6	0.295	0.870	0.166
7	0.197	1.000	0.197
8	0.115	1.000	0.115
9	0.066	1.000	0.066
10	0.000	1.000	0.000

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11	0.000	1.000	0.000
WH-STRATIFY			
1	1.000	0.000	0.000
2	1.000	0.000	0.000
3 (Default)	0.984	0.016	0.000
4	0.934	0.219	0.154
5	0.689	0.399	0.088
6	0.492	0.688	0.180
7 (Optimal)	0.328	0.855	0.183
8	0.213	0.962	0.175
9	0.131	1.000	0.131
10	0.082	1.000	0.082
11	0.049	1.000	0.049
12	0.000	1.000	0.000
13	0.000	1.000	0.000

PH-FRAT-Peninsula Health Falls Risk Screening Tool, TNH-STRATIFY-The Northern Hospital Modified St Thomas's Risk Assessment Tool, WH-STRATIFY-Western Health St. Thomas' Risk Assessment Tool (See Appendix 4 for graphs which illustrate these results)

Using optimal cut points, TNH-STRATIFY has the highest Youden Index^{ER} (0.20) followed by WH-STRATIFY (0.18) and PH-FRAT (0.14) (Table 6). The Youden Index^{ER} confidence intervals for PH-FRAT (0.01 to 0.29), WH-STRATIFY (0.00 to 0.35) and TNH-STRATIFY (0.07 to 0.34) overlap. Therefore, TNH-STRATIFY no longer has predictive accuracy superiority using optimal cut points and the predictive accuracy for the three falls risk assessment tools is comparable.

Table 6. Diagnostic predictive accuracy metrics for PH-FRAT, TNH-STRATIFY and WH-STRATIFY using optimal cut points for predicting a faller.

Metric	PH-FRAT		TNH-STRATIFY		WH-STRATIFY	
Sensitivity^{ER}	0.20	(0.09, 0.32)	0.95	(0.89, 1.00)	0.33	(0.19, 0.47)
Specificity^{ER}	0.95	(0.87, 1.00)	0.25	(0.13, 0.38)	0.86	(0.72, 0.96)
Youden Index^{ER}	0.14	(0.01, 0.29)	0.20	(0.07, 0.34)	0.18	(0.00, 0.35)
Sensitivity	0.19	(0.09, 0.29)	0.94	(0.88, 1.00)	0.31	(0.19, 0.44)
Specificity	0.95	(0.89, 1.00)	0.26	(0.16, 0.37)	0.89	(0.81, 0.95)
Youden Index	0.14	(0.02, 0.26)	0.20	(0.08, 0.33)	0.20	(0.06, 0.33)

Values in parenthesis are bootstrapped 95% confidence intervals based on 1,000 repetitions of original sample size.

3. Discussion

This study showed that calculating optimal cut points for three falls risk assessment tools (PH-FRAT, TNH-STRATIFY and WH-STRATIFY) is superior to default cut points in GEM inpatients. Using original cut points, PH-FRAT and WH-STRATIFY had no predictive accuracy for falls (Youden Index^{ER} of 0.01 and 0.00 respectively). This study indicated that using WH-STRATIFY instead of PH-FRAT did not improve the predictive accuracy of falls on admission to GEM. Of the three falls risk assessment tools, PH-FRAT had the lowest falls prediction accuracy compared to TNH-STRATIFY and WH-STRATIFY. These results are consistent with a previous large sample study on PH-FRAT [22]. This may be because the PH-FRAT assigns an automatic score of 16 is when there is 'a change in function' for the patient being considered. As 'change in function' is a predominant reason for patients admitted to GEM, there is a selection bias that automatically classifies patients as high-risk for falls. In clinical practice, the low predictive accuracy of falls risk reduces identification of patients at risk of falls thus misdirects appropriate falls prevention strategies [15].

This study included impact of adding two new risk factors (NESB and medications associated with falls) to TNH-STRATIFY to create a new falls risk assessment tool, WH-STRATIFY. These

additions did not improve the predictive accuracy of WH-STRATIFY even following cut point optimisation which suggests these categories could be removed. Other risk factors for falls, such as sarcopenia, are not captured in these risk assessment tools which should be considered in future. While there is evidence showing certain medications increase falls risk, there is limited evidence regarding whether patients with NESB have an increased risk of falls in hospital [23]. Although two additional risk factors were incorporated in WH-STRATIFY, the default cut point score remained at 3. We identified that this needs to be adjusted to 7 to maximise predictive accuracy (Youden Index^{ER} from 0.00 at the default cut point 3) to Youden Index ^{ER} of 0.183 at optimal cut point 7. Calculating optimal cut points optimises predictive accuracy of falls risk assessment tools to improve identification of falls risk in clinical settings and allows for improved allocation of hospital resources targeting falls mitigation.

The optimal cut point for WH-STRATIFY, however, reduces sensitivity and may not always be clinically desirable in a GEM population as this group is already at increased risk of falls given reduced muscle strength and decline in mobility [1]. A carefully balanced consideration of competing factors is required to achieve effective falls prevention strategies by finding acceptable sensitivity and specificity ranges to reduce of misclassification fallers or non-fallers. We have shown that falls risk assessment tools should undergo clinical validation and calculation of an optimal cut point before being incorporated into falls prevention program [20].

When comparing the three falls risk assessment tools, TNH-STRATIFY demonstrated the best predictive accuracy with statistically significant and highest Youden Index ^{ER} of 0.20 (see Table 6). Its predictive accuracy at the optimal cut-point (Youden Index of 0.20), however, is lower compared to the initial study where the calculated Youden Index for TNH-STRATIFY was 0.44 [18]. It is common in falls risk assessment tool studies to show poor results replication [15,16,21,22].This suggests that falls risk assessment tools' predictive accuracy may be affected by the patient sample and clinical setting. In other words, risk factors more predictive of fallers or non-fallers in the initial study setting are represented in the risk score, rather than in replicated studies [21,24]. Further studies are required to explore the underlying reasons in driving different predictive accuracies of falls risk assessment tools across different studies and whether this is due to certain changes in study population characteristics.

Limitations of the Study

This study had some strengths and limitations. This was an adaptation and validation study of a well-recognised risk assessment tool (TNH-STRATIFY) forming the WH-STRATIFY in a novel setting, as recommended in World Falls Guidelines [15]. In this retrospective study, only the numerical component of WH-STRATIFY could be assessed. The impact of WH-STRATIFY in its entirety requires future prospective evaluation of falls-risk management post-implementation to define how this tool performs in alignment with recent recommendations in favour of the use of multi-factorial risk assessment tools over numerical risk prediction tools [14].

Considerations when designing a clinical falls assessment tools include user variability, accuracy in scoring of the falls risk assessment tools, average time taken to use the tool and user satisfaction. These were not captured in this retrospective study. Furthermore, data depended on the quality of EMR documentation which was affected by incomplete data entry at point of care. Due to the retrospective nature of this study, there was no opportunity to clinically assess patients in real-time during their admission or gather any collateral history that would be helpful with calculating patients' falls risk beyond that which can be included in a numerical tool. When completing the falls risk assessment tools in clinical practice, staff may use alternate data sources rather than sole reliance on EMR data. However, the limitations of any missing data affected the collection of data for all three falls risk assessment tools similarly.

This study captures patients' falls risk on admission to GEM, however in clinical practice this risk may change during their admission which could alter the predictive ability of the tools. Regular re-scoring throughout a patient's admission using the WH-STRATIFY may lead to a more accurate

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score contemporaneous with the fall. Prospective studies and feedback surveys from users of these tools at different time periods could explore these limitations.

This study focused on a sample of GEM patients from different hospitals of a single health network which may reduce generalisability. This study minimised selection bias by randomisation, use of consistent criteria (Appendix A) when calculating the falls risk scores of each patient. Future studies across multiple hospital networks and patient groups in larger numbers would better determine generalisability of the findings.

4. Methods

Participants and Data Collection

All participants with inpatient falls admitted to GEM at Western Health between December 2020 and June 2021 were identified through mandatory reporting. This specific time window was selected to be outside the COVID-19 surge [25] to minimise changes to the typical patient profile and medical practices in GEM. A retrospective file review with data collection occurred in fifty-four consecutive patients who fell at least once during admission between December 2020 and June 2021. Sixty-two patients admitted to GEM within the same time period who did not fall during their GEM admission were randomly selected for comparison. As this study was performed before clinical launch of WH-STRATIFY only retrospective assessment was possible.

Data collection was completed between January 2022 and April 2022. The Electronic Medical Records (EMR) were reviewed to score each participant with PH-FRAT, TNH-STRATIFY and WH-STRATIFY (Appendix A). Data was stored in *REDCap*™. Only data available on EMR on the day of and day preceding GEM admission was used. To reduce observation bias, blind scoring was done by randomising the total sample so knowledge of patients' fall status was not known by the assessor. As there are no previous studies of WH-STRATIFY, sample sizes could not be statistically determined *a priori*. The sample size of 116 was based on the sample size used in a comparable study [21].

Classification of Falls, Predicted Fallers and Non-Fallers

A *fall* was defined as "an event which results in a person coming to rest inadvertently on the ground or floor or other lower level," the definition widely accepted and used by the World Health Organisation [15–17,19]. For prediction purposes, participants were classified as *predicted fallers* if they scored at or above the cut points of the falls risk assessment tools. Similarly, participants classified as *predicted non-fallers* if they scored below the falls risk assessment tools' cut points.

Scoring of Falls Risk Assessment Tools

Using information available on the EMR on each patient's admission to GEM, falls risk factors were retrospectively identified and a score calculated for the three falls risk assessment tools (Table 1).

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Table 1. Summary of PH-FRAT, TNH-STRATIFY and WH-STRATIFY.

Tool	Scoring system	Risk factor assessed	Possible score
PH-FRAT	Total score range: 5-20	Recent falls	2, 4, 6 or 8
	Cut point: 12	Medication	1-4
	Weighting of one risk factor (recent falls)	Psychological	1-4
	If have one of change in functional	Cognitive status	1-4
	status/medication or dizziness/postural	Change in functional	16 or 20
	hypotension score is set to 16. If have both	status/medication	16 or 20
	conditions, score is set to 20.	Dizziness/postural hypotension	
TNH-	Total score range: 0-11	Age	0 or 1
STRATIFY	Cut point: 3	Falls history – current admission	0 or 3
	Weighting of one risk factor (falls history -	Falls history – previous 12	0 or 1
	current admission)	months	0 or 1
		Mental state	0 or 1
		Mobility	0 or 1
		Balance	0 or 1
		Toileting needs	0 or 1
		Vision impairment	0 or 1
		Drug/alcohol abuse	
WH-	Total score range: 0-13	Age	0 or 1
STRATIFY	Cut point: 3	Falls history – current admission	0 or 3
	Weighting of one risk factor (falls history -	Falls history – previous 12	0 or 1
	current admission)	months	0 or 1
		Mental state	0 or 1
		Mobility	0 or 1
		Balance	0 or 1
		Toileting needs	0 or 1
		Vision impairment	0 or 1
		Drug/alcohol abuse	0 or 1
		NESB	0 or 1
		Medications affecting mobility	

PH-FRAT-Peninsula Health Falls Risk Screening Tool, TNH-STRATIFY-The Northern Hospital Modified St Thomas's Risk Assessment Tool, WH-STRATIFY-Western Health St. Thomas' Risk Assessment Tool, NESB-Non-English Speaking Background. Please refer to Appendix 1 for further details of the falls risk assessment tools' scoring criteria

Participants with a score at or above the cut point were assessed by the falls risk assessment tool to be a predicted faller. The predictions were compared with the actual outcome during admission to assess each tool's predictive accuracy.

Ethics

Ethics approval was obtained from Western Health Office for Research (ERM ID 81444).

Statistical Analysis

Due to variability of participants falls' frequency and admission length, the fall *event rate (ER)* (defined as the frequency of falls during the patient's admission) was used. *Sensitivity*^{ER} is the number of falls during the patient's GEM admission correctly predicted by the falls risk assessment tool divided by the total number of falls. *Specificity*^{ER} is the length of hospital stay for non-fallers accurately predicted to have low falls risk by the falls risk assessment tool divided by the total length of hospital stay for all non-fallers. The event rate *Youden Index (Youden Index*^{ER}*)* [15] measured predictive accuracy of the falls risk assessment tools. The *Youden Index*^{ER} is the sum of the event rate sensitivity

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(sensitivity^{ER}) and event rate specificity (specificity^{ER}) less 1 and produces a value between -1 and 1, with a higher value indicating greater predictive accuracy.

The *Youden Index^{ER}* is preferred [26] as it provides a measure of accuracy by equally weighing sensitivity (i.e., the tool correctly predicts patient is at high risk of fall) and specificity (i.e., the tool correctly predicts patient is at low risk of fall). It adjusts for patients who had multiple falls and GEM length of stay. Statistical significance was assessed using bootstrapped 95% confidence intervals. *Bootstrapping* is a statistical method that resamples a single data set of the current study to create many simulated samples. This process allows the construction of the confidence intervals [15] and other studies have also used this method to derive 95% confidence intervals for the Youden Index^{ER} [26]. If the 95% confidence intervals for two falls risk assessment tools overlap, this implies that the two tools do not differ significantly at a 5% level.

The optimal cut point is the score that maximises the predictive accuracy of the three falls risk assessment tools (WH-STRATIFY, PH-FRAT and TNH-STRATIFY). Using optimal cut points reduces misclassification of those who are likely or not to fall during GEM admission. Microsoft Excel was used in the statistical implementation.

Deriving Optimal Cut Points

Cut points were modified to demonstrate impact on the sensitivity^{ER}, specificity^{ER} and Youden Index^{ER}. We selected the optimal cut point as the score where the Youden Index^{ER} is at its highest calculated value.

5. Conclusion

Of the three falls risk assessment tools (TNH-STRATIFY, WH-STRATIFY and PH-FRAT) using the default cut points, TNH-STRATIFY offered the highest predictive accuracy. PH-FRAT and WH-STRATIFY at default cut points had negligible predictive accuracy which improved when using calculated optimal cut points. Future prospective research is required to assess the utility of WH-STRATIFY as part of a falls risk management program. The optimal cut points of falls risk assessment tools should be determined and validated in different clinical settings to optimise predictive accuracy, support targeted falls risk mitigation and improve resource allocation.

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Appendix A. Falls Risk Assessment Tool data definition

Table A1 shows the data collection table used to collect all of the patient data and calculate a score with respect to each of the three falls risk assessment tools.

Table A1. Falls Risk Assessment Tool data definition.

Questions/Risk Factors	Descriptions
1. Demographics Age (years) Gender: Female, Male	**Source: (including time frame of when search is for)** • Electronic Medical Record (EMR) Patient information on admission **Definition:** • Age (rounded to nearest whole year) • Gender- what is documented on patient information on EMR
2. Is the patient aged 80 or older? Yes / No	**Source: (including time frame of when search is for)** • EMR Patient information on admission **Definition:** Age (to the whole year)
3. Length of stay	**Source: (including time frame of when search is for)**

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Days	• EMR inpatient recorded date of admission to and date of discharge from GEM **Definition:** • Length of inpatient stay from day of admission to day of discharge from GEM to any other location (including home, residential care or another inpatient unit) • Rounded to nearest whole day
4. Was there a recent fall? • None in the last 12 months One or more • Within the last 0-3 months, Within the last 3-12 months, Patient is in hospital primarily due to fall • Fall during current admission (interval from day of admission to day of fall (in days)	**Source: (including time frame of when search is for)** • EMR Medical GEM admission note (including any past medical history of falls or if fall was a reason for admission to hospital), nursing admission note • EMR Initial patient assessment completed by nursing on admission • EMR Adults risk assessment on day of admission to GEM à Falls Assessment • EMR date of admission and date of patient's fall in GEM • RiskMan data to correlate patients who fell in GEM at Williamstown, Footscray and Sunshine Hospitals from February to May 2021 **Definition:** Search for key words "Fall" or "Falls" on EMR on the patient's GEM admission
5. Is the patient taking of the following medications- sedatives, antidepressants, anti-parkinson's, diuretics, anti-hypertensives, hypnotics, opioids? No/Taking one/Taking two/Taking more than two Class(es): Sedatives, Antidepressant, Anti-Parkinson's, Diuretics, Anti-hypertensives, Hypnotics, Opioids	**Source: (including time frame of when search is for)** • Medical admission medication list • Medication Administration Record (MAR) medications charted on day of admission to GEM • Pharmacy medication reconciliation list on admission to GEM **Definition:** Medication classes which are charted or documented on admission to GEM unit including both regular and as required medications: • Sedatives • Anti-depressants • Anti-Parkinson's • Diuretics • Hypnotics • Opioids
6. Is the patient affected by psychological condition including: anxiety, depression, reduced cooperation, reduced insight, reduced judgment? • No • Appears mildly affected by one or more • Appears moderately affected by one or more • Appears severely affected by one or more	**Source: (including time frame of when search is for)** • EMR Behaviours of concern • EMR Mental Status- Orientation, Affect/Behaviour, Hallucinations present • EMR Medical GEM admission note (including any past medical history of psychological condition • EMR Interactive view→ Adult Systems Assessment à Mental Status→ Affect/Behaviour, Hallucinations present **Source: (including time frame of when search is for)** • EMR Initial patient assessment completed by nursing on admission • EMR Adults risk assessment on admission to GEM à Falls Assessment • EMR date of admission and date of patient's fall in GEM **Definition:** • EMR search for key words including: a. Depression b. Anxiety c. Feeling down d. Affect e. Reduced insight

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	f. Poor judgment • Grading severity a. Mildly affected b. Psychological condition has not impacted on daily ADLs c. No change to antipsychotic or antidepressant on GEM admission medication list d. Moderately affected e. Psychological condition is an active issue as per medical team on GEM admission f. As required antipsychotic or benzodiazepine on GEM admission medication list g. Severely affected h. Psychological condition is reason for patient's acute hospitalisation prior to transfer to GEM i. Code grey or requiring IM antipsychotic Psychological condition led to patient needing 1:1 special on admission to GEM
7. What is the patient's cognition? • Cognitively intact • Mildly cognitive impairment If mildly cognitive impaired, does it include any of: • Confused • Impulsive • Agitated • Moderate cognitive impairment • Severe cognitive impairment **Note: Moderate to severe cognitive impairment will already automatically include confused, impulsive and/or agitated behaviours.*	**Source: (including time frame of when search is for)** • EMR Medical GEM admission note • EMR nursing admission note • EMR OT admission note • EMR Initial patient assessment à Premorbid Information • EMR Interactive View à Adult Risk assessment à Cognition – Abbreviated Mental Test (4AT-Delirium screening test) on admission **Definition:** • EMR search for key words including: a. Dementia b. Delirium c. Cognitive impairment • Mild cognitive impairment a. Cognitive impairment has not affected independence with Activities of Daily Living (ADLs), or b. 4AT score 1-3 (delirium screening test) • Moderate cognitive impairment a. Cognitive impairment has led to needing assistance with domestic ADLs from others, or b. 4AT score 4-7 (Abbreviated Mental Test delirium screening test) • Severe cognitive impairment a. Requires full assistance with ADLs, or **b.** 4AT score 8-12
8. What is the patient's level of mobility? supervision or assistance when mobilising? • Independent • Supervision • Assistance • Impaired balance • Hemiplegia • Gait aid	**Source: (including time frame of when search is for)** • EMR Medical GEM admission note • EMR nursing admission note • EMR Physiotherapist admission note • EMR Initial patient assessment à premorbid information completed by nursing on admission • EMR Interactive view→Adult Systems Assessment→ Neurological Gait, Upper limb movement/Strength, Lower limb movement/Strength **Definition:** • Review documentation to see if on admission to GEM, does the patient need supervision or assistance (a person to help i.e. not just mobility aid) when mobilising • Search for words on the patient's GEM medical admission including: a. Impaired balance or poor balance or balance issues b. Unsteadiness or unsteady Hemiplegia – unilateral arm +/- leg weakness
9. Does the patient require frequent toileting of bowels +/- bladder? Yes/No	**Source: (including time frame of when search is for)** • EMR Medical GEM admission note, nursing admission note • EMR Initial patient assessment completed by nursing on admission • EMR Adults risk assessment on admission to GEM (nursing note)→ Continence Assessment→Incontinent of Urine, Incontinent of faeces, Urgency • EMR Interactive view à Adult Systems Assessment→Activities of Daily Living- Hygiene-Incontinence Aid **Definition:** • Review the nursing and medical notes on patient's admission about urgency, urinary incontinence and bowel incontinence • Look for terms on GEM admission notes including: a. Urinary incontinence

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	b. Faecal incontinence c. Incontinent Urgency (difficulty toileting in time)
10. Does the patient have vision impairment which affects every day functioning? Yes/No	**Source: (including time frame of when search is for)** • EMR Medical GEM admission note • EMR nursing admission note • EMR Initial patient assessment completed by nursing on admission à look at Speech and Sensory deficits and check for Visual impairment, glasses/contact lenses • EMR Interactive View→Adult Systems Assessment→Mobility status **Definition:** • On patient's GEM admission, does the patient have/described with the following: a. Glasses b. Contact lenses c. Visually impaired Legally blind
11. Does the patient present with drug/alcohol related issues? Yes/No	**Source: (including time frame of when search is for)** • EMR Initial patient assessment completed by nursing on admission→ Social history→Substance Use, Alcohol • EMR Medical GEM admission note social history • EMR nursing admission note **Definition:** • On the patient's admission to GEM, look for key words including: a. Illicit Drugs b. Recreational drugs c. Substance Use d. Drug abuse e. Addiction (relating to illicit drugs and/or alcohol) f. Alcohol g. Etoh h. AWS (Alcohol Withdrawal Scale) Alcohol withdrawal
12. Does the patient require a language interpreter? Yes/No	**Source: (including time frame of when search is for)** • EMR Patient information→ Interpreter Required • EMR Medical GEM admission notes • EMR Nursing GEM admission notes **Definition:** EMR search term for "Interpreter"
13. Does the patient have any recent change in functional status or medications that affect safety of mobility? • No • Yes • Medications • Functional status change	**Source: (including time frame of when search is for)** • EMR Medical GEM admission notes • EMR Nursing GEM admission notes **Definition:** • Medication that had led to sedation or affected mobility including dizziness, postural instability, postural hypotension. Change in functional status that led to change to safety with mobility including needing a new gait aid, needing supervision with mobility/transfers, needing assistance with mobility/ transfers
14. Does the patient experience dizziness or postural hypotension? • No • Yes • Dizziness • Postural hypotension	**Source: (including time frame of when search is for)** • EMR Medical GEM admission notes • EMR Nursing GEM admission notes **Definition:** • Terms including: "Dizziness" or "Dizzy" • Postural BP on day of admission or documented on the patient's GEM admission note that it occurred during acute admission. Significant postural hypotension is postural drop of at least 20mmHg systolic or 10mmHg diastolic from sitting or supine position to standing
PH-FRAT score Low Risk: 5-11 Medium: Risk: 12-15 High Risk: 16-20	

Risk factor	Level	Risk score
Recent Falls	none in last 12 months	2
(To score this, complete	one or more between 3 and 12 months ago	4
history of falls, overleaf)	one or more in last 3 months	6

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Score of 12 or above suggests increased risk of falls Automatic High risk Recent change in functional status and / or medications affecting safety of mobility (or anticipated) Dizziness / postural hypotension		one or more in last 3 months whilst inpatient / resident	8
	Medications *(Sedatives, Anti-Depressants Anti-Parkinson's, Diuretics Anti-hypertensives, hypnotics)*	not taking any of these taking one taking two taking more than two	1 2 3 4
	Psychological *(Anxiety, Depression ¯Cooperation, ¯Insight or ¯Judgement esp. re mobility)*	does not appear to have any of these appears mildly affected by one or more appears moderately affected by one or more appears severely affected by one or more	1 2 3 4
	Cognitive status *(AMTS: Hodkinson Abbreviated Mental Test Score)*	AMTS 9 or 10 / 10 OR intact AMTS 7-8 mildly impaired AMTS 5-6 moderately impaired AMTS 4 or less severely impaired	1 2 3 4
	Risk Score (Low Risk: 5-11 Medium: Risk: 12-15 High Risk: 16-20)		/20
	Automatic High-Risk Status: *(if ticked then circle* HIGH *risk below)* • Recent change in functional status and / or medications affecting safe mobility (or anticipated) • Dizziness / postural hypotension		

NH-STRATIFY score Score of 3 or more is considered High Risk	**Risk factors**	**Risk score**
	Fall: During current Admission	Yes = 3, No = 0
	Fall: Within 12 months	Yes = 1, No = 0
	Mental State-Current cognition- confused, impulsive, agitated or cognitively impaired	Yes = 1, No = 0
	Mobility: Patient needs supervision or assistance when mobilising	Yes = 1, No = 0
	Impaired Balance and/or hemiplegia	Yes = 1, No = 0
	Age 80 or older	Yes = 1, No = 0
	Frequent toileting bowels +/- bladder	Yes = 1, No = 0
	Vision impairment- that affects every day functioning	Yes = 1, No = 0
	Drug and alcohol: patient presents with drug/alcohol related issues	Yes = 1, No = 0

WH-STRATIFY score Score of 3 or above is considered High falls risk	**Risk factors**	**Risk score**
	Fall: During current Admission	Yes = 3, No = 0
	Fall: Within 12 months	Yes = 1, No = 0
	Language: patient is NESB	Yes = 1, No = 0
	Current cognition- confused, impulsive, agitated or cognitively impaired	Yes = 1, No = 0
	Vision impairment- that affects every day functioning	Yes = 1, No = 0
	Mobility: Patient needs supervision or assistance when mobilising	Yes = 1, No = 0
	Impaired Balance and/or hemiplegia	Yes = 1, No = 0

 doi:10.20944/preprints202304.0361.v1

	Age 80 or older	Yes = 1, No = 0
	Frequent toileting bowels +/- bladder	Yes = 1, No = 0
	Medications affecting mobility: anti-hypertensives, diuretics, sedatives, opioids or S11	Yes = 1, No = 0
	Drug and alcohol: patient presents with drug/alcohol related issues	Yes = 1, No = 0

Appendix B. Summary statistics by falls risk assessment tool

Table A2 compared three falls risk assessment tools (PH-FRAT, TNH-STRATIFY and WH-STRATIFY) and looked the number of patients who were classified into each of the numerical score according each tool. It also looked patients' length of stay, number of patients who fell and total number of falls.

Table A2. Number of patients, fallers, patient-days, and falls by scores produced under PH-FRAT, TNH-STRATIFY and WH-STRATIFY.

Score	Number of patients (%)	Number of fallers (%)	Length of stay, days (%)	Number of falls
PH-FRAT				
5	0 (0%)	0 (0%)	0 (0%)	0 (0%)
6	0 (0%)	0 (0%)	0 (0%)	0 (0%)
7	1 (1%)	0 (0%)	2 (0%)	0 (0%)
8	0 (0%)	0 (0%)	0 (0%)	0 (0%)
9	0 (0%)	0 (0%)	0 (0%)	0 (0%)
10	2 (2%)	0 (0%)	13 (1%)	0 (0%)
11	2 (2%)	1 (2%)	36 (2%)	1 (2%)
12	1 (1%)	0 (0%)	5 (0%)	0 (0%)
13	1 (1%)	1 (2%)	31 (1%)	1 (2%)
14	0 (0%)	0 (0%)	0 (0%)	0 (0%)
15	1 (1%)	1 (2%)	24 (1%)	1 (2%)
16	95 (82%)	41 (76%)	1,896 (80%)	46 (75%)
17	1 (1%)	1 (2%)	56 (2%)	1 (2%)
18	1 (1%)	1 (2%)	32 (1%)	1 (2%)
19	0 (0%)	0 (0%)	0 (0%)	0 (0%)
20	11 (9%)	8 (15%)	264 (11%)	10 (16%)
TNH-STRATIFY				
0	1 (1%)	1 (2%)	35 (1%)	1 (2%)
1	3 (3%)	1 (2%)	31 (1%)	1 (2%)
2	15 (13%)	1 (2%)	205 (9%)	1 (2%)
3	34 (29%)	15 (28%)	624 (26%)	18 (30%)
4	26 (22%)	15 (28%)	722 (31%)	16 (26%)
5	16 (14%)	6 (11%)	247 (10%)	6 (10%)
6	12 (10%)	6 (11%)	274 (12%)	6 (10%)
7	4 (3%)	4 (7%)	89 (4%)	5 (8%)
8	3 (3%)	3 (6%)	65 (3%)	3 (5%)
9	2 (2%)	2 (4%)	67 (3%)	4 (7%)
10	0 (0%)	0 (0%)	0 (0%)	0 (0%)
11	0 (0%)	0 (0%)	0 (0%)	0 (0%)
WH-STRATIFY				
0	0 (0%)	0 (0%)	0 (0%)	0 (0%)
1	1 (1%)	1 (2%)	35 (1%)	1 (2%)
2	2 (2%)	0 (0%)	14 (1%)	0 (0%)

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3	16	(14%)	3	(6%)	222	(9%)	3	(5%)
4	25	(22%)	12	(22%)	469	(20%)	15	(25%)
5	27	(23%)	11	(20%)	587	(25%)	12	(20%)
6	21	(18%)	10	(19%)	461	(20%)	10	(16%)
7	12	(10%)	7	(13%)	307	(13%)	7	(11%)
8	7	(6%)	5	(9%)	134	(6%)	5	(8%)
9	2	(2%)	2	(4%)	43	(2%)	3	(5%)
10	2	(2%)	2	(4%)	44	(2%)	2	(3%)
11	1	(1%)	1	(2%)	43	(2%)	3	(5%)
12	0	(0%)	0	(0%)	0	(0%)	0	(0%)
13	0	(0%)	0	(0%)	0	(0%)	0	(0%)

Percentages in parenthesis represents the proportion of the column total for each falls risk assessment tool.

Table A3 and Figure A1 show the impact on the predictive accuracy diagnostics by varying the falls cut-off score. This table compared the three falls risk assessment tools (PH-FRAT, WH-STRATIFY and TNH-STRATIFY) with regards to their cut-off scores demonstrated their respective Youden Index[ER]

Table A3. Event rate diagnostics by varying the fall cut-off score for PH-FRAT, TNH-STRATIFY and WH-STRATIFY.

Cut-off score	Sensitivity[ER]	Specificity[ER]	Youden Index[ER]
PH-FRAT			
6	1.000	0.000	0.000
7	1.000	0.000	0.000
8	1.000	0.002	0.002
9	1.000	0.002	0.002
10	1.000	0.002	0.002
11	1.000	0.018	0.018
12 (Cut-off)	0.984	0.025	0.008
13	0.984	0.031	0.014
14	0.967	0.031	-0.002
15	0.967	0.031	-0.002
16	0.951	0.031	-0.019
17	0.197	0.946	0.143
18	0.180	0.946	0.126
19	0.164	0.946	0.110
20	0.164	0.946	0.110
TNH-STRATIFY			
1	0.984	0.000	-0.016
2	0.984	0.000	-0.016
3 (Cut-off)	0.951	0.249	0.199
4	0.656	0.532	0.188
5	0.393	0.717	0.111
6	0.295	0.870	0.166
7	0.197	1.000	0.197
8	0.115	1.000	0.115
9	0.066	1.000	0.066
10	0.000	1.000	0.000
11	0.000	1.000	0.000
WH-STRATIFY			
1	1.000	0.000	0.000
2	1.000	0.000	0.000

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3 (Cut-off)	0.984	0.016	0.000
4	0.934	0.219	0.154
5	0.689	0.399	0.088
6	0.492	0.688	0.180
7	0.328	0.855	0.183
8	0.213	0.962	0.175
9	0.131	1.000	0.131
10	0.082	1.000	0.082
11	0.049	1.000	0.049
12	0.000	1.000	0.000
13	0.000	1.000	0.000

Figure A1. Graph of event rate diagnostics by varying the fall cut-off score for PH-FRAT, TNH-STRATIFY and WH-STRATIFY.

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Appendix C. WH STRATIFY Interventions

Table A4 shows the suggested interventions for the WH STRATIFY.

Table A4. WH STRATIFY falls risk assessment tool and its suggested interventions.

Questions	Optional answer	Optional answer	If yes - drop down multi choice options
Fall: Current Admission	No (score 0)	Yes patient has had a fall during current admission (score 3)	Bathroom Supervision at all times Ensure Physiotherapy are involved in care Consider referral to OT Handover History of falls to oncoming shift Monitor postural BP for 48/24. Report drop of 20mmHg
Fall: Within 12 months	No (0)	Yes patient has had fall/s in last 12 months (1)	Provide falls prevention education Monitor postural BP for 48/24. Report drop of 20mmHg
Language:	Speaks and understands English	Patient does not speak or understand English (1)	Phone interpreter-falls education/orientation/4AT Write common word translation on patient whiteboard Ask family to assist with orientation/falls education
Current cognition	No Cognitive impairment (0)	Confused, impulsive, agitated or cognitively impaired (1)	Lolo bed with crash mats Bathroom supervision at all times Falls Mat alarm Locate patient closer to nurses' station Portable Video Monitoring Overnight Request family stay with patient Assess for constipation/overflow/bowel sounds Complete 4AT and report score 4+ to HMO Pain assessment Toilet regime pre+post meals Review About Me form Mobilise regularly Update patient whiteboard each shift
Vision impairment	No Visual impairment (0)	Yes visual impairment that affects every day functioning (1)	Vision impaired sign above bed Consider using manual hand bell Ensure glasses within reach co-locate with other patient if suitable
Mobility Impaired	No Mobility Impairment (0)	Yes patient needs supervision or assistance when mobilising (1)	Refer to Physiotherapy if change in baseline function Ensure gait aid within reach at all times
Impaired Balance:	No Balance Impairment (0)	Yes Patient has impaired balance and/or hemiplegia (1)	Refer to Physiotherapy Reinforce PT mobility instructions Ensure gait aid within reach at all times Bathroom supervision at all times
Age, over 80:	No (0)	Yes patient is 80 years or older (1)	Educate on increased falls risk
Frequent toileting/urgency:	No (0)	yes patient requires frequent toileting: bladder +/- bowels (1)	Bedside commode or access to bottle Consider proximity to toilet Check urine - FWT or MSU Toileting regime Monitor for constipation and overflow Educate on suitable continence aids Consider bladder scan for retention
Medications affecting mobility:	One or none (0)	2 or more: antihypertensives, diuretics, sedatives, opioids or S11 (1)	Educate patient - increased falls risk due to meds
Drug and alcohol issues	No (0)	Yes patient presents with drug/alcohol related issues (1)	Consider referral to addiction medicine
Patient falls risk:	Low Risk= less than 3	High Risk- 3 or more	

Standard Falls risk strategies - All Patients	Focus is on identifying risk factors and implementing prevention strategies regardless of risk rating.	Discuss strategies to keep patient safe in hospital Reduce all clutter Call bell always within reach Gait aid always within reach Use non slip footwear during daytime - not socks Dress in day clothes if available

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