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Predicting Recovery of Independent Walking After Stroke

A Systematic Review

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Abstract: Patients recovering from a stroke experience reduced participation, especially when they are limited in daily activities involving walking. Understanding the recovery of independent walking, can be used by clinicians in the decision-making process during rehabilitation, resulting in more personalized stroke rehabilitation. Therefore, it is necessary to gain insight in predicting the recovery of independent walking in patients after stroke. This systematic review provided an overview of current evidence about prognostic models and its performance to predict recovery of independent walking after stroke. Therefore, MEDLINE, CINAHL, and Embase were searched for all relevant studies in English and Dutch. Descriptive statistics, study methods, and model performance were extracted and divided into two categories: subacute phase and chronic phase. This resulted in 16 articles that fulfilled all the search criteria, which included 30 prognostic models. Six prognostic models showed an excellent performance (area under the curve value and/or overall accuracy ≥0.90). The model of Smith et al. (2017) showed highest overall accuracy (100%) in predicting independent walking in the subacute phase after stroke (*Neurorehabil Neural Repair* 2017;31(10–11):955–64.). Recovery of independent walking can be predicted in the subacute and chronic phase after stroke. However, proper external validation and the applicability in clinical practice of identified prognostic models are still lacking.

Key Words: Stroke, Prognosis, Ambulation, Independency

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Stroke often causes long-term disability, due to considerable impairment of functional mobility.[1] Because of improved acute stroke care, such as thrombolysis and thrombectomy, mortality rates improved in the last decades.[2,3] However, a considerable part of the stroke survivors still experience difficulties in walking independently in the chronic phase after stroke.[4,5]

Ambulation is an essential aspect of independency in activities of daily living, social participation, overall autonomy, and quality of life.[6] Even though motor function of the lower limbs improves most in the first 30 days after stroke,[7] the extent to which a patient after stroke recovers is variable and depends on the patient-specific spontaneous neurological recovery. This also hinders participation in daily life, because reduced participation is especially experienced when patients are limited in daily activities involving walking, like housekeeping, mobility, and physical exercise.[8] It is therefore not surprising that being able to walk independently is one of the primary goals in stroke rehabilitation.[9,10] Besides that, clinicians should be facilitated to inform patients and their relatives about the recovery potential and enhance the decision-making process during stroke rehabilitation. Therefore, it is important to gain insight in the prognosis of walking ability after stroke.

Many models for predicting motor outcome after stroke have been developed, but it lacks of an overview and synthesis of all models focusing on independence of walking. Preston and colleagues[11] recently published their review about the prediction of independent walking in patients who are not ambulatory within the first month after stroke. However, such a prognostic model only suits this specific group of stroke patients who experience severe consequences after stroke. It is therefore less applicable in stroke units and rehabilitation centers, where also patients with minor to moderate impairments after stroke are admitted.

Besides the applicability in stroke units and rehabilitation centers, also the performance of the developed prognostic model should be taken into account before implementing in clinical practice. Clinicians are facilitated by prognostic models with excellent performance to objectively and more accurately inform patients and their relatives about the recovery potential and discharge destination.[12,13] It also supports clinicians in their

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decision-making process at stroke units and rehabilitation centers[14] and gives direction to further personalize therapies during rehabilitation.[15]

In view of this, the current systematic review focuses on providing an overview of current evidence about prognostic models and its performance to predict recovery of independent walking in patients after stroke, for the purpose of improving personalized stroke rehabilitation. In addition, we explore the potential gaps in current literature and determine whether future research in the area of predicting independent walking is required.

METHODS

Search Strategy

A systematic review was conducted to summarize evidence about the performance of prognostic models to predict the recovery of independent walking in patients with stroke. This study was registered with the international prospective register of systematic reviews (registration number: CRD42021271629) and conforms all Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and reports the required information accordingly (see Supplementary Checklist, http://links.lww.com/PHM/C289).

We searched up to January 2022 for all relevant studies in English and Dutch. Key words were as follows: (1) stroke, (2) independent walking, (3) multivariate prognostic model, and (4) accuracy and all terms related to these. MEDLINE (PubMed), CINAHL, and Embase were searched to find studies that met these and other criteria: for example, patients ≥18 yrs of age and model performance reported in terms of discrimination and/or calibration. The outcome of interest of this review is "the ability to walk independently," which is defined according to several published articles[11,16,17]: "the independence of walking with or without the use of some form of assistive device, but without any physical assistance." Only studies in which the outcome meets this description were included. Baseline measures and outcomes could be obtained at any time point after stroke. The full search strategies are available from the author.

Title and abstract were screened by two independent reviewers (BK and NCW) to identify relevant studies. Full article copies of these relevant studies were retrieved and were read independently by the two reviewers. Based on the previously mentioned criteria, the studies were included or excluded. A conflict of opinion was resolved by consensus after discussion. If no agreement was reached, it was resolved by an independent third reviewer (MFP). The reference lists of the studies were screened for potential relevant articles.

Quality Assessment

The QUIPS (Quality In Prognosis Studies) tool[18] was used to assess the quality of the included studies. The QUIPS tool is recommended by the Cochrane Prognosis Methods Group to determine the risk of bias across six domains (i.e., study participation, study attrition, prognostic factor measurement, outcome measurement, adjustment for other prognostic factors, statistical analysis, and reporting), and, with that, the methodological quality of each paper. The risk of bias of each domain was expressed on a three-grade scale: high, moderate, or low.

Two researchers assessed independently each of the included studies (BK and NCW). Disagreements were resolved with discussion between the two reviewers. If no agreement was reached, it was resolved by an independent third reviewer (MFP).

Data Synthesis

Data were extracted by one reviewer (NCW) and cross-checked by the second reviewer (BK). The outcomes were, based on the recommendations by the Stroke Recovery and Rehabilitation taskforce,[19] ordered according to the following phases after stroke:

- Acute phase: <7 days after stroke
- Subacute phase: ≥7 days <6 mos after stroke
- Chronic phase: ≥6 mos after stroke

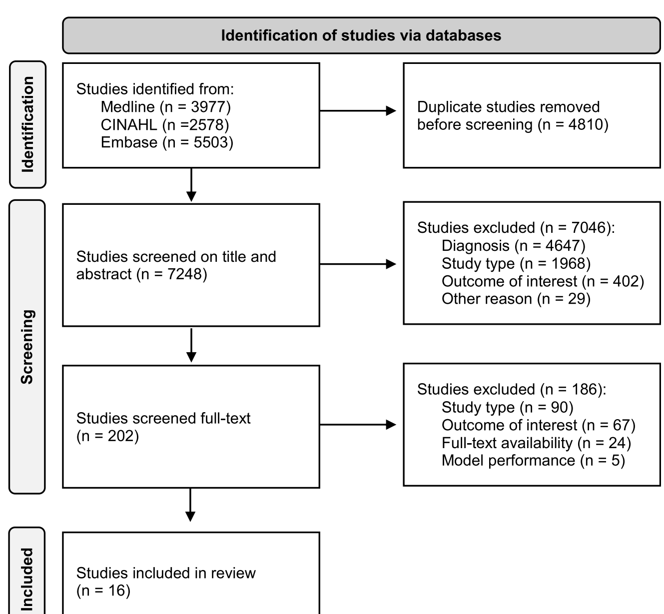

FIGURE 1. Identification of studies via databases.

These phases were used to order prognostic models in which independent walking was predicted in that particular time frame.

The reviewers also extracted descriptive statistics (e.g., year of publication, number of included stroke patients), information about the method of the prognostic model, and model performance reported in terms of discrimination (i.e., area under the curve [AUC] values, accuracy in terms of overall accuracy, sensitivity, specificity). When available, also calibration measures were reported (i.e., significance of the Hosmer-Lemeshow test or the line/shape of calibration plots/slopes).

When the performance of the prognostic models was described in AUC values, the following threshold according to Hosmer and Lemeshow[20] was used: no discrimination (AUC ≤ 0.50), poor (>0.50 AUC < 0.70), fair (≥0.70 AUC < 0.80), good (≥0.80 AUC < 0.90), and excellent (AUC ≥ 0.90). The same threshold was used for overall accuracy values. Prognostic models with an overall accuracy and/or AUC value of ≥0.90 were considered to be excellent and considered acceptable for use in clinical practice.

RESULTS

Figure 1 outlines the flow of studies through the review. From the initially identified 12,058 studies, only 16 articles fulfilled all the search criteria.

Quality Assessment

The quality of the 16 studies was assessed by using the QUIPS tool. Table 1 shows the results of this assessment. Hiraoka et al.,[25] Jenkin et al.,[26] and Pournajaf et al.[32] showed low risk of biases on all domains. Studies with highest risk of bias were Hirano et al.[24] and Kollen et al.,[16] due to their scores of “high” and “moderate” on two domains (respectively, study attrition and prognostic factor measurement; study confounding and study attrition). However, the risk of bias of the studies overall was good to excellent, and therefore all 16 remained included for analyses.

Study Characteristics

Of the 16 studies, respectively, nine and six studies had a prospective and retrospective design. Only one study had a combined design of prospective and retrospective data.[23] In three of the 16 articles, the authors developed more than one prognostic model, with 30 prognostic models in total. Various types of modeling were used to predict independent walking: multivariate logistic regression models, stepwise discriminant analysis, decision tree model, classification and regression tree analyses, multivariate backwards prognostic model, and multivariate survival analysis.

Participants

The studies included between 41 and 577 patients with stroke, involving 2727 participants in total. In Table 2, the sample characteristics of each study are shown. The patients were mainly men with an average age of 56.9–75.0 yrs and experience an ischemic stroke in either the right or left hemisphere.

Outcome of Interest

The prognostic models were categorized into being able to walk independently in the several phases after stroke, according to the recommendations by the Stroke Recovery and Rehabilitation taskforce.[19] None of the included prognostic models predicted independent walking in the acute phase after stroke. In Table 3, the results of the prognostic models of each study in these categories are shown. Detailed information about these included prognostic models was shown in a table in the Supplemental Digital Content (SDC, http://links.lww.com/PHM/C290).

The 30 prognostic models were identified from 16 different studies. Eight of these 30 models showed fair performance (AUC value and/or overall accuracy ≥0.70 to <0.80). Sixteen

TABLE 1. Risk of bias assessment

	Study Participation	Study Attrition	Prognostic Factor Measurement	Outcome Measurement	Study Confounding	Statistical Analysis and Reporting
Ferreira[21] (2015)	L	M	L	M	L	L
Gianella[22] (2019)	L	M	L	L	L	L
Henderson[23] (2022)	M	L	L	L	L	L
Hirano[24] (2016)	L	H	M	L	L	L
Hiraoka[25] (2017)	L	L	L	L	L	L
Jenkin[26] (2021)	L	L	L	L	L	L
Kim[27] (2021)	L	L	L	L	H	L
Kollen[16] (2006)	L	M	L	L	H	L
Kwah[28] (2013)	L	M	L	L	L	L
Louie[29] (2018)	L	M	L	L	L	L
Masiero[30] (2007)	L	H	L	L	L	L
Mulder[31] (2019)	L	H	L	L	L	L
Pournajaf[32] (2019)	L	L	L	L	L	L
Sánchez[33] (1999)	L	H	L	L	L	L
Smith[34] (2017)	M	M	L	L	L	L
Veerbeek[5] (2011)	L	M	L	L	L	L

H, high risk of bias; L, low; M, moderate.

TABLE 2. Patient characteristics

Study	N	Inclusion Criteria	Age, Mean ± SD (Range) or Median (IQR)	Gender, Male, %	Stroke Type, Ischemic, %	Lesion Side, Right, %
Ferreira[21] (2015)	201_{DV}	[a] <5 yrs poststroke; moderate disability (mRS = 3 or 4)	56.9 (21.0–90.0)	49.0	76.1	50.5
Gianella[22] (2019)	185	[a] <90 d after unilateral hemispheric stroke; ≥18 yrs of age; FAC ≤ 2 at admission	65.0 (54.5–74.5)	60.0	67.6	45.9
Henderson[23] (2022)	257	[a] <6 mos after stroke; 18–89 yrs of age; FAC ≤ 2 at admission	62.0 (52.0–71.0)	61.0	64.0	42.0
Hirano[24] (2016)	72	[a] Severe hemiplegia at admission (BRS of II or I in lower extremity)	63.2 ± 11.3 (39.0–87.0)	62.5	20.8	58.3
Hiraoka[25] (2017)	128	[a] Thalamic hemorrhage	67.6 ± 10.3 (40.0–93.0)	58.6	0.0	49.2
Jenkin[26] (2021)	68	unilateral impairments; nonambulatory at admission	57 (16)	72.0	82.0	65.0
Kim[27] (2021)	$577_{D}/173_{V}$	[a] Hemiplegia or hemiparesis; >20 yrs of age; FAC of ≤3 within 7–30 d	$60.8 \pm 13.2_{DV}$	57.6_{DV}	N/A	N/A
Kollen[16] (2006)	101	[a] MCA ischemic stroke; 30–80 yrs of age; impaired motor function of lower limbs; MMSE ≥24	65.9 ± 10.6	57.4	100.0	58.4
Kwah[28] (2013)	114	stroke or TIA; ≥18 yrs of age	78 (16)	47.0	68.0	46.0
Louie[29] (2018)	84	<4 wks after stroke; nonambulation at admission; MMSE ≥20	68.6 ± 14.1	52.4	81.0	N/A
Masiero[30] (2007)	$100_{D}/50_{V}$	[a] <8 wks after hemispheric stroke; FAC ≤ 1; MMSE ≥21	$69\ (12)_{D}/68\ (11)_{V}$	$51.0_{D}/58.0_{V}$	$74.0_{D}/84.0_{V}$	$37.0_{D}/46.0_{V}$
Mulder[31] (2019)	243	Discharged home after completing inpatient care; FAC ≥ 3; MMSE ≥24	57.1 ± 10.3	65.0	81.5	N/A
Pournajaf[32] (2019)	310	[a] >3 mos after stroke; could walk ≥6 m; ≥18 yrs of age	75.0 (65.0–81.0)	50.0	78.7	50.6
Sánchez[33] (1999)	92	[a] Unilateral hemispheric stroke; MI-leg <75 during first month after stroke	67.0 ± 10.0	64.1	76.1	48.5
Smith[34] (2017)	41	MI-leg <100 and FAC ≤ 3 within first 3 d after stroke; ≥18 yrs of age	72.0 (43.0–96.0)	41.0	85.0	49.0
Veerbeek[5] (2011)	154	[a] Ischemic stroke; ≥18 yrs of age; premorbid BI >19; hemiparesis and FAC ≤ 3 within 72 hrs after stroke	67.5 ± 14.2	39.6	100.0	56.5

[a] First-ever stroke.

BI, Barthel Index; BRS, Brunnstrom Recovery Stage; D, development study; DV, development + validation dataset; MCA, middle cerebral artery; MMSE, Mini-Mental State Examination; MRS, modified Rankin scale; N, sample size; N/A, data are not applicable; TIA, transient ischemic attack; V, validation study.

prognostic models showed good performance (AUC value and/or overall accuracy ≥0.80 to <0.90) and six of these models showed an excellent performance (AUC value and/or overall accuracy ≥0.90). The highest overall accuracy (100%) was found by Smith et al.[34]

Subacute Phase

In eight studies, nine models were conducted for predicting independent walking in the subacute phase after stroke.[22–26,29,30,34] In this category, Smith et al.[34] found highest overall accuracy values. With their Time to Walking Independently after Stroke (TWIST) algorithm, they conducted a classification and regression tree analysis in which they found that a Trunk Control Test (TCT) score of >40 in the first week poststroke was able to predict the ability of independent walking 6 wks after stroke accurate (overall accuracy = 0.91). They also predicted independent walking 12 wks after stroke. They found that patients with hip extension against gravity (measured with Medical Research Council scale ≥ 3) in the first week after stroke were able to walk independently 12 weeks after stroke with a 100% accuracy. Their models were not validated afterward.

The multivariate logistic regression model of Masiero et al.[30] including age, TCT, and Functional Independence Measure within 24 hrs after admission to rehabilitation showed excellent AUC values in predicting independent walking at discharge. Even in their validation dataset (N = 50), they found excellent accuracy values (AUC = 0.94 [95% CI = 0.86–0.96]).

Gianella et al.[22] included five prognostic factors in their multivariate logistic regression model (age, gender, time between stroke and hospitalization, Berg Balance Scale, Fugl-Meyer Assessment score for Lower Extremity) with excellent accuracy (AUC = 0.93 [95% CI = 0.90–0.97]). Thereby, the Hosmer-Lemeshow test was not statistically significant, which indicates that there was no evidence of a failure of fit.

The last model for predicting independent walking in the subacute phase after stroke was conducted by Hirano et al.[24] They used age and knee extension strength/body weight ratio on the unaffected side at admission to predict independent

TABLE 3. Results by category

	Accuracy	AUC	Sensitivity	Specificity
Subacute phase				
Gianella[22] (2019)		0.93 (95% CI = 0.90–0.97)		
Henderson[23] (2022)		0.86 (95% CI = 0.81–0.90)		
Hirano[24] (2016)	0.92		0.98	0.81
Hiraoka[25] (2017)	0.85			
Jenkin[26] (2021)		0.81 (95% CI = 0.71–0.92)	0.73 (95% CI = 0.63–0.82)	0.89 (95% CI = 0.81–0.94)
Louie[29] (2018)		0.73 (95% CI = 0.62–0.84)	0.74 (95% CI = 0.59–0.84)	0.68 (95% CI = 0.49–0.83)
Masiero[30] (2007)	$0.86_D/0.76_V$	$0.94\ (95\%\ CI = 0.86–0.96)_D/0.90_V$	0.87 (95% CI = 0.77–0.96)	0.96 (95% CI = 0.75–0.95)
Smith[34] (2017)	0.91		1.0 (95% CI = 0.84–1.0)	0.90 (95% CI = 0.68–0.99)
	1.0		0.80 (95% CI = 0.28–0.99)	1.0 (95% CI = 0.90–1.0)
Chronic phase				
Ferreira[21] (2015)		$0.87\ (95\%\ CI = 0.82–0.92)_V$		
Kim[27] (2021)	$0.81_D/0.82_V$	$0.82\ (95\%\ CI = 0.77–0.88)_V$		
	$0.81_D/0.77_V$	$0.77\ (95\%\ CI = 0.71–0.83)_V$		
	$0.74_D/0.80_V$	$0.80\ (95\%\ CI = 0.74–0.86)_V$		
Kollen[16] (2006)	0.86		0.96	0.60
	0.75		0.90	0.53
	0.80		0.89	0.61
	0.79		0.92	0.59
	0.78		0.91	0.58
	0.83		0.94	0.62
	0.80		0.91	0.59
	0.80		0.92	0.61
	0.79		0.92	0.58
	0.81		0.92	0.63
Kwah[28] (2013)		0.84 (95% CI = 0.77–0.92)		
Mulder[31] (2019)	0.86 (95% CI = 0.81–0.90)		0.94 (95% CI = 0.89–0.97)	0.54 (95% CI = 0.39–0.68)
Pournajaf[32] (2019)	0.75	0.81	0.71	0.79
Sánchez[33] (1999)	0.77		0.85 (95% CI = 0.72–0.93)	0.64 (95% CI = 0.47–0.79)
Veerbeek[5] (2011)	0.89		0.93 (95% CI = 0.86–0.96)	0.75
	0.88		0.94	0.63 (95% CI = 0.43–0.78)
	0.92		0.96 (95% CI = 0.90–0.98)	0.75 (95% CI = 0.56–0.88)

D, development study; V, validation study

walking at discharge from rehabilitation, which was accurate in 92% of the cases.

Chronic Phase

In eight studies, 21 prognostic models were presented to predict independent walking in the chronic phase after stroke.[5,16,21,27,28,31–33] In this category, only one prognostic model showed excellent performance: one of the three multivariate logistic regression models of the Early Prediction of Functional Outcome After Stroke (EPOS) study of Veerbeek et al.[5] The TCT score for item 3 "sitting" (TCT-3) and the Motricity Index (MI) leg score at the ninth day after stroke predicted independent walking 6 mos after stroke with 92% accuracy. This model is also recommended to use in Dutch clinical practice, by the stroke guidelines of the Royal Dutch Society for Physical Therapy (in Dutch: "KNGF").[35]

DISCUSSION

This systematic review provides an overview of current evidence about prognostic models and its performance to predict recovery of independent walking in patients after stroke, aiming to expose the potential gaps in current literature and define future research areas. We found 16 studies in which 30 prognostic models were developed, concluding that recovery of independent walking can be accurately predicted in the subacute and chronic phase after stroke. However, besides accuracy, the applicability of prognostic models in clinical practice is important for implementation in clinical care in people after stroke.

Applicability

During admission to a stroke unit or inpatient rehabilitation, clinicians have limited time for measuring the impairment of functional mobility repeatedly after stroke. Considering the limited time to perform tests, it is important to use a prognostic model that is easy to perform in clinical practice. Moreover, a test set which is brief and simple will most likely be performed more frequently, which may help in more accurate estimation of the outcome.

Six of the 30 prognostic models were able to predict independent walking with excellent accuracy. However, besides the accuracy of these prognostic models, also the applicability in stroke units and rehabilitation centers should thus be considered. In other words, the prognostic models should be easy to apply in clinical practice, regardless of limited time and the physical level of the patient after stroke. The studies of Hirano et al.,[24] Masiero et al.,[30] and Gianella et al.[22] do not match this condition, because the test sets used in their prognostic models were extensive and time consuming. For instance, Hirano et al.[24] measured knee extension strength and body weight on the unaffected side to calculate a ratio on which they build their predictions for independency of walking. Furthermore, performing the test set was needed within 1 day after admission to the rehabilitation center.[22,30] With such extensive test sets, it is hard to meet this deadline of less than 24 hours after admission, especially when you take into account the medical examination, an overload of new information on the first day, and fatigue of the patient with stroke.

More appropriate and feasible is the applicability of the EPOS study of Veerbeek et al.[5] and the TWIST algorithm of Smith et al.[34] Their test sets consist of, respectively, the TCT-3 and MI leg score on the ninth day, and the TCT and hip extension (measured with Medical Research Council) at the seventh day after stroke. Both test sets are brief and simple to perform in clinical practice, but one drawback is that it both should be performed exactly on the ninth or ninth day after stroke. Therefore, it is not always feasible to perform, which hampers the applicability of these prognostic models in clinical practice.

Validation

Many prognostic models are prone to overfitting due to a lack of external and cross-validation. Only two of the included studies have controlled for overfitting by applying a cross-validation procedure. In the study of Mulder et al.,[31] this 10-fold cross-validation resulted in an adjusted overall accuracy of 79%. The study of Hiraoka et al.[25] found an error rate by cross-validation of only 0.042. Besides that, three of the 16 included studies validated their model(s) immediately.[21,27,30] Only Masiero et al.[30] found excellent accuracy values in their external validation dataset: they found excellent performance values of 94%.

Moreover, Veerbeek et al.[36] recently published an article about the external validation of their EPOS study. An important difference with the development study of 2011 was that the outcome of interest was measured 3 mos after stroke (subacute phase) instead of 6 mos after stroke (chronic phase). In the development study,[5] they found that the TCT-3 and the MI leg score on the ninth day could predict independent walking at 6 mos poststroke with 92% accuracy. However, as expected, these values decreased in the validation cohort[36]: TCT-3 and the MI leg score on the ninth day poststroke, could predict independent walking at 3 mos after stroke with 86% accuracy (overall accuracy = 0.86, sensitivity = 0.93, specificity = 0.65).

In the TWIST model of Smith et al.,[34] independent walking could be predicted with excellent accuracy (100%) and their model is easy applicable in clinical practice. However, their model is not validated yet, causing difficulty in concluding which prognostic model is best in predicting independent walking after stroke. Veerbeek[37] proposed to validate the TWIST model of Smith et al.[34] in the upcoming years. Validation of the TWIST model will result in insight in the actual accuracy of their model, which positively contributes to the comparison between the prognostic models with excellent accuracy and easy applicability.

Inclusion Criteria

The extent to which independent walking poststroke is predictable depends on several aspects of which patient selection as a limitation of the prognostic models should be addressed. In contrast to the results of other prognostic models in the subacute phase after stroke (49%–68.2%), Gianella et al.[22] found that only 10.27% of the patients could walk independently (Functional Ambulation Categories [FAC] ≥ 4) at discharge. An argumentative explanation seems to be the inclusion criteria of Gianella et al.[22]: they included adult patients with "first-ever unilateral hemispheric stroke" and FAC ≤ 2 at admission, which indicates that the included patients suffered from severe consequences after stroke. This causes less recovery potential at discharge and that is why such prognostic model is not easy to apply in clinical practice.

Prognostic Factors

Personalized stroke rehabilitation requires insight in the prognosis of physical recovery after stroke. Clinicians should be facilitated with such predictions to inform patients and their relatives about the recovery potential. Interestingly, modifiable prognostic factors such as balance,[22,23,26,29] trunk stability,[5,16,30,34] leg strength of the affected side,[5,31,33] and hip extension strength[34] seem to have a role in the prediction of independent walking after stroke. Based on the current study, we cannot prove the causality of modifiable prognostic factors on the recovery of independent walking, but further research should examine their influence on the ability to walk independently in the subacute and chronic phase after stroke. This could result in enhancing the decision-making process at stroke units and therefore improve personalized stroke rehabilitation.[38,39]

Limitations

As shown in Table 1 of the Supplemental Digital Content, http://links.lww.com/PHM/C290, in the 30 included prognostic models nine different outcome measures were used to define independent walking (i.e., FAC, Functional Independence Measure, Barthel Index, clinical observation, Five-Meter Walk Test, modified Ashworth scale, Hoffer classification, Community Ambulation Questionnaire, and Walking Handicap Scale). In 28 of the 30 prognostic models, the categorical outcome of interest was divided into a dichotomized value (e.g., "FAC ≥ 4 = independent walking"), which caused simplification of the data. In some cases, the outcome measures were created by the authors (e.g., a scoring scale by Ferreira et al.[21]) and different cutoff values were used. For instance, either the FAC score of ≥3 or a score of ≥4 was used to indicate "independent walking." However, these cutoff points have considerable different meanings: a FAC score of 3 means a patient walks with supervision of another person, while a score of 4 means the patient is able to walk without the need of assistance of others. This even more indicates that it is difficult to compare the included prognostic models. The divergence in outcome measures is one of the main limitations of the current study. As described previously, another limitation of this study is that not every included prognostic model is validated yet, as a result of which we encountered difficulty in defining the best prognostic model to predict independent walking after stroke.

Future

Considering the applicability of prognostic models in clinical practice, the existing well-performing models could be further improved on several aspects. Many of the currently used test sets involve the physical assessment of motor function, but these are often time-consuming and unsuitable to perform within several days after stroke. Therefore, we suggest to conduct further research on the use of feasible and less time-consuming assessments to predict independent walking in patients with stroke. The physical assessments could possibly be replaced by upcoming technologies like wearable motion sensors.[40,41] Using these kind of measures to assess physical recovery would be easy to apply in clinical practice. It also would result in more objective and feasible monitoring of physical recovery, because we would be able to derive objective biomarkers with a continuous level of measurement (e.g., walking speed and distance). The current technical improvements and the growing urge to focus on individuals rather than population averages strengthen our expectation that the use of biomarkers for developing prognostic models will increase in the upcoming years. Developing prognostic models based on patient-specific biomarker data might improve the accuracy of outcome predictions. This will encourage precision medicine, resulting in an improvement of personalized stroke rehabilitation.[38,39]

CONCLUSIONS

This systematic review provided an overview of current evidence about prognostic models to predict the recovery of independent walking in the subacute and chronic phase after stroke. Six prognostic models with excellent accuracy were identified. However, proper external validation and/or the applicability in clinical practice of identified prognostic models is still lacking because of the time-consuming and burdensome test sets.

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