Chapter 5

Clinical prediction rule for ambulation in children with cerebral palsy

Abstracted from:

Keeratisiroj O, Thawinchai N, Buntragulpoontawee M, Siritaratiwat W, Derivation of an ambulatory score chart for Thai children with cerebral palsy aged 2–18. J Med Assoc Thai. 2016;99: 1298-305.

1. Prognosis for gross motor function

Gross motor development in children with CP can be clarified and anticipated as far as development over the motor growth bends utilizing the GMFM and GMFCS together. Both measured by the GMFM and GMFCS order were observed to be a valid and reliable tools that has been generally utilized as a part of clinical work and research including children with CP.[1] A study of Beckung et al.,[1] they have analyzed motor growth in children with CP utilizing developmental curves. This study found that over 60% of children who can independently ambulation or in children were at GMFCS level I and II. In this study, gross motor development of children with CP will be developed until the age of 6 to 7 years, as well as Canadian[2] and an Israeli[3] study. Rosenbaum and colleagues[2] have created five distinct motor development curves at different levels of the GMFCS. They pointed to the trend of limitations, which is an increase in the severity of the impairment.

Gross motor development curves may help in estimating the nature of motor development in children with various types of CP by five distinctive GMFCS levels. The GMFM curve can also help physicians, physical therapists, and caregivers for the treatment plan and evaluate the intervention by comparing the development of children with the changes expected to occur over time.[1, 2]

2. Supporting research

The study entitled "Derivation of an ambulatory score chart for Thai children with cerebral palsy aged 2–18" by Keeratisiroj et al.[4] To my current knowledge, this is the first to develop clinical prediction rule for ambulation in Thai children with CP (Appendix D). Summaries of this study show the following.

Rationale of the study

When children are first diagnosed as having CP, most parents ask the following questions: "Will my child walk?" and "When will he/she walk?" The prognosis for their ambulation is very difficult because several factors can influence the ambulatory status of a child during his/her growth. Nonetheless, the identification of predictors for ambulation is most important in order to assist in formulating an appropriate plan of intervention.[5-7] This is especially so when the prognosis capacity with regard to walking tends to be poor: an appropriate treatment planning is the most effective way to prevent the loss of ambulatory capacity.[8]

Bleck[9] has also established a scoring system in the year 1975 to predict ambulatory children with CP in the first year of life or more, which is the problem of delayed primary walk. This scoring system has seven primitive reflexes and postural reactions as predictors, while there have also been other clinical predictors affecting walking prognosis.[5, 6, 10-14]

Performing a comparison between the different studies is difficult because of the variations in the definitions of ambulatory operational.[15] In the year 1997, Palisano and colleagues[16] created a five-level of GMFCS for children with CP and edited it in the year 2007.[17] Only the studies, recently, of Simard-Tremblay et al.[13] and Kułak et al.[14] used the GMFCS as a tool to classify ambulation. Many experts in clinical practice have developed their own specific criteria for predicting the ambulatory status in these children. These criteria may give sensible prognostic precision, however they are not really transferable to and appropriate in different settings.[5] Although the prognostic tools for gross motor function of children with CP have been developed,[2, 6, 9, 18] a simple tool to predict ambulatory status and one which uses GMFCS is still lacking.

Objectives of the study: To develop a simple prognostic score chart for predicting ambulatory status in Thai children with CP.

Study settings: Rajanagarindra Institute of Child Development Chiang Mai Province, Srisangwanchiangmai School, Srisangwankhonkaen School, Special Education Center Region 7, Special Education Center Region 8, and Special Education Center Region 9, Thailand.

Recruitment: All children with CP registered at the six special schools or hospitals for children with physical disabilities in northeastern and northern Thailand during the period from 2008 to 2013 were recruited. The children had to be 2 to 18 years old and diagnosed with CP by a physician or a physiotherapist, with the CP first appearing before age 2 were included. After eliminating duplicates and those not meeting the inclusion criteria, 630 participants were enrolled, and they provided informed consent. This number was subsequently reduced to 533 participants because some participants could not be evaluated using GMFCS (Figure 4.2).

Outcome variable: The GMFCS was used to describe walking ability[17]. The subjects were assessed using the GMFCS—Expanded and Revised family and self-report questionnaires, which have been allowed to be translated into the Thai language[19]. The ambulatory status were classified as three levels: independent ambulation (GMFCS I-II), assisted ambulation (GMFCS III), and non-ambulation (GMFCS IV-V).

Explanatory variables: The patient data that had to be included for the study were as follows: prognostic predictors (age, type of CP, sitting independently at age two, and eating independently) and other variables (gender, body mass index, caregivers, gestational age, birth weight, hyperbilirubinemia, epilepsy or seizure, intellectual impairment, visual impairment, hearing impairment, hand function, speech, medication, history of orthopedic surgery, and orthotics use). These variables were confirmed and the GMFCS was assessed using interviews on site, telephone, or mail.

Statistical analysis

Total of 471 cases which had complete significant predictors' values for analyses. Then, the subjects were categorized into three groups by their GMFCS: independent ambulation, assisted ambulation, and non-ambulation (criterion-classified ambulatory status). Baseline characteristics and clinical history data were described by descriptive statistics. The different data between the three groups were tested using the nonparametric test for trends across the ordered groups.

Multivariable ordinal continuation ratio logistic regression was used to analyze after the candidate predictors (*p*-value ≤0.20) were selected through univariable analysis. Coefficients of the significant predictors from multivariable models were converted into scores by division of the lowest coefficient, and they were rounded off to the nearest integer or half. The items and the total scores for each subject were created and used to represent the summary measure for predicting the ambulatory status in children with CP, and these were categorized into three levels (score-classified ambulatory status).

The discriminative and predictive abilities of the ambulatory status scores were presented with probability curves. The receiver operating characteristic (ROC) curve which was used to assess the probability of the total score showed ambulation. The Hosmer and Lemeshow chi-square goodness-of-fit test[20] was made use of to compare how well the predicted probabilities fit with the actual probabilities. Score-classified ambulatory statuses were compared to criterion-classified ambulatory statuses to indicate the estimation validity by percentage of agreement.

Results and discussion

The subjects were classified into three groups according to their GMFCS levels: non-ambulation (n=264), assisted ambulation (n=57), and independent ambulation (n=150). In multivariable analysis, the significant predictors were age, type of CP, sitting independently at age two, and eating independently. The significant predictors of this score chart have been mentioned in the author's previous study.[21] It is well known that age or maturation is associated with different aspects of child development including walking.[15] The type of CP and gross motor skills (sitting independently) were found to have a strong association with ambulation in several previous studies for a long time.[5, 6, 10, 11, 14, 15, 22, 23] In addition, it has been recently found that eating independently is associated with ambulation in two previous studies.[6, 14] Nevertheless, strong predictors such as primitive reflexes and postural reactions were excluded from this study because we took into consideration predictors from routine data to clinical usefulness.

Item scores for the significant predictors of the ambulatory status were derived from the coefficients. They varied from 0 to 6, and the total scores ranged from 0 to 12, as illustrated in Table 5.1. Figure 5.1 demonstrates a simple score chart for predicting the ambulatory status, in which the subjects were classified into three groups according to their total scores: non-ambulation (scores <7), assisted ambulation (scores 7–8), and independent ambulation (scores >8). The ambulatory scores predicted the non-ambulation group correctly in 244 out of 264, assisted ambulation in 10 out of 57, and independent ambulation in 113 out of 150. The prognostic estimation validity of the subjects into their original levels had a correctness percentage of 77.9%, underestimation had a correctness percentage of 12.1%, and overestimation had a correctness percentage of 10%, as illustrated in Table 5.2.

The distributions of the ambulatory status are presented with mean total scores: 3.4±2.5 in non-ambulation, 7.5±2.0 in assisted ambulation, and 9.2±1.8 in independent ambulation, as shown in Table 5.2 and Figure 5.2. Figure 5.3 illustrates the probability curves of the ambulatory status scores, which discriminate the non-ambulation group from the other groups (area under the receiver operating characteristic curve; AuROC=0.9391, Figure 5.4), and discriminate the independent ambulation group from the other groups (AuROC=0.9205, Figure 5.5).

Table 5.1 Item score for significant predictors of ambulatory status (n = 471)

Predictors	OR (95% CI)*	*p*-value*	Coefficient*	Scores
Age (year)				
2 to less than 6	Reference		Reference	0
6 to less than 12	2.07 (1.07–3.98)	0.030	0.73	1
12 to 18	3.26 (1.59–6.72)	0.001	1.18	1.5
Type of CP				
Spastic quadriplegia	Reference		Reference	0
Mixed	3.94 (1.09–14.25)	0.037	1.37	2
Hypotonia	9.76 (1.89–50.39)	0.007	2.28	3
Spastic diplegia	8.07 (3.27–19.95)	<0.001	2.09	3
Dyskinesia	12.09 (4.42–33.04)	<0.001	2.49	3.5
Spastic hemiplegia	40.47 (15.37–106.56)	<0.001	3.70	5
Ataxia	91.49 (15.26–548.58)	<0.001	4.52	6
Sitting independently at age 2				
No	Reference		Reference	0
Yes	7.74 (4.85–12.34)	<0.001	2.05	3
Eating independently				
No	Reference		Reference	0
Yes	2.95 (1.65–5.24)	<0.001	1.08	1.5

Note: *Analysis using multivariable ordinal continuation ratio logistic regression.

Abbreviations: CI = confidence interval; CP = cerebral palsy; OR = odds ratio.

Ambulatory prognostic score chart

Predictors		Scores	
Age (year)	2 to less than 6	0	....
	6 to less than 12	1	
	12 to 18	1.5	
Type of CP	Spastic quadriplegia	0	....
	Mixed	2	
	Hypotonia	3	
	Spastic diplegia	3	
	Dyskinesia	3.5	
	Spastic hemiplegia	5	
	Ataxia	6	
Sitting independently at age 2		3	....
Eating independently		1.5	.... +
	Total scores	0-12	....

Total scores	Ambulatory status
<7	Non-ambulation
7–8	Assisted ambulation
>8	Independent ambulation

Figure 5.1 The ambulatory prognostic score chart for children with cerebral palsy

Table 5.2 Score-classified ambulatory Status and criterion-classified ambulatory status, and prognostic estimation validity

Score-classified ambulatory status	Total score	Criterion-classified ambulatory status			validity*		
		Non-ambulation	Assisted ambulation	Independent ambulation	% Over	% Correct	% Under
Mean±SD		3.4±2.5	7.5±2.0	9.2±1.8			
IQR		1–5.5	6–9	8.5–10.5			
Non-ambulation (n=284)	<7	244	20	20	-	51.8	8.5
Assisted ambulation (n=34)	7–8	7	10	17	1.5	2.1	3.6
Independent ambulation (n=153)	>8	13	27	113	8.5	24.0	-
Total (n=471)	0–12	264	57	150	10.0	77.9	12.1

Note: *Percentage of total subjects.

Abbreviations: IQR = interquartile range; SD = standard deviation.

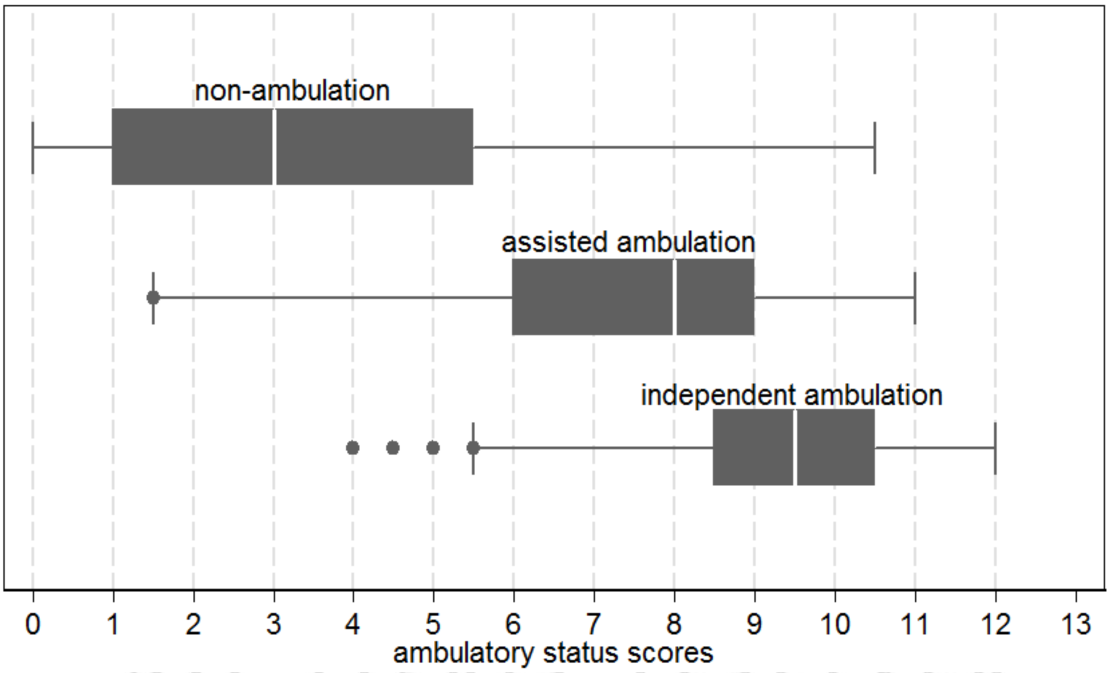

Figure 5.2 The distribution of the ambulatory status scores

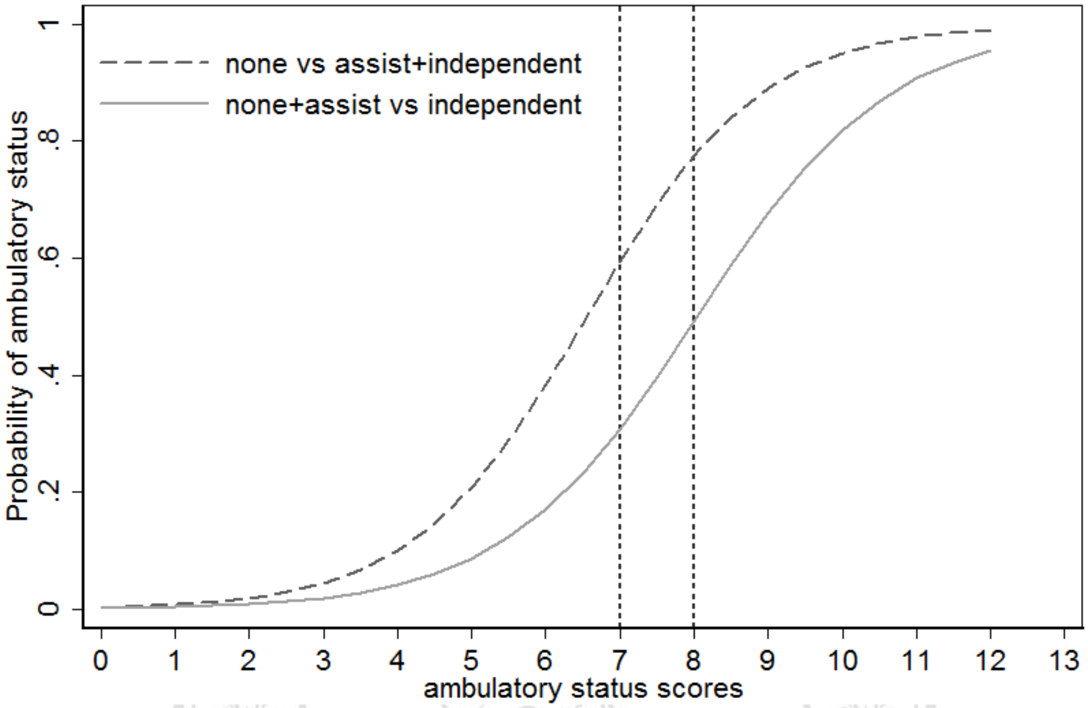

Figure 5.3 The discrimination of the ambulatory status scores

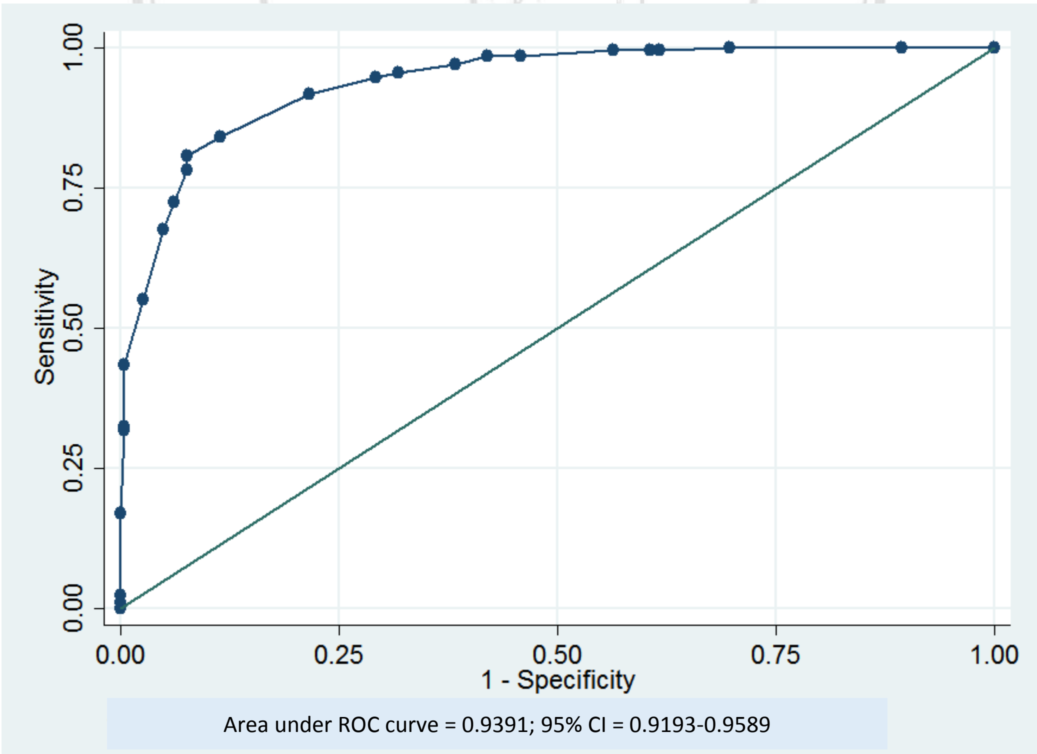

Figure 5.4 The Receiver operating characteristic (ROC) curve of non-ambulation group and other groups

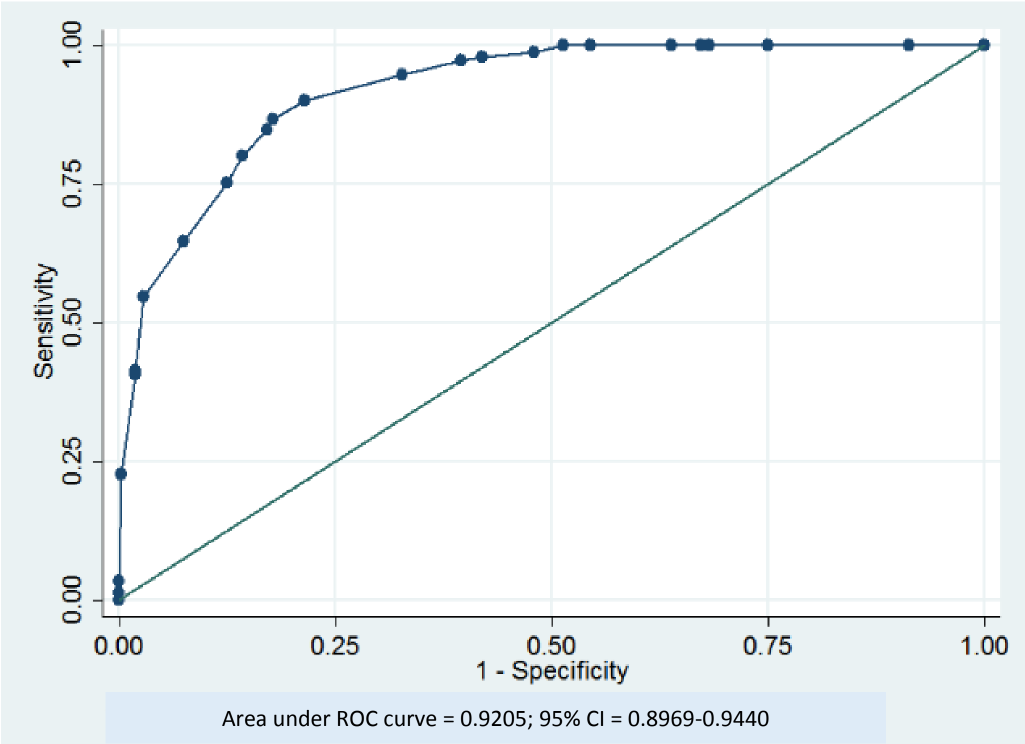

Figure 5.5 The Receiver operating characteristic (ROC) curve of independent ambulation group and other groups

The scoring method for the prognosis for walking in children with CP has been previously established by Bleck.[9] However, he examined only seven primitive reflexes and postural reactions. This scoring method was discriminated into good prognosis, watched prognosis, and bad prognosis. He stated that it appears simple, easy to understand, and easy to apply. It may be inappropriate for use in some context; however, a recent correlational study in Japan[24] demonstrated that there was no distinction in Bleck's scores between the ambulation children and the non-ambulation children. A large retrospective study conducted by Wu et al.[6] created a simple tool for predicting the probability of ambulatory outcome from various levels in children with CP aged 2 to 14. This tool was divided into four ambulatory charts according to gross motor function achieved at age two, utilizing Aalen-Johansen estimators of long-term transition probabilities. Additionally, there were also prognostic tools of gross motor function.[2, 18] The gross motor function curves among the 5-level GMFCS were constructed to inform regarding the prognosis of children with CP at the age. All of the above show that our prognostic tool is different from the previous tools in both outcome and predictors, including techniques and applications.

The ambulatory score chart was developed for the simple use of clinicians and therapists. The ambulatory outcome was divided into three groups, which may be useful for clinical practice. The first group, of children scoring <7, was classified as the “non-ambulation” group. The health care team should inform the parents that the children could not walk in the first age range, and the team should have a treatment plan chalked out with the parents to improve the walking ability of the children to bring it to its full potential. If the children are more likely to continue as having non-ambulation in the next age, their parents should plan to adjust the environmental context and the daily life of the children with assistive devices. The second group, with the children scoring from 7 to 8, was classified as the “assisted ambulation” group. In the first stage, these children are assisted to walk with aids such as wheel walkers, but when they grow up, there might be a possibility that the children will walk independently. Thus the health care team should plan for parents to emphasize the enhancement of the children’s walking ability. The last group, of children scoring >8, was classified as the ‘independent ambulation’ group. These children have the opportunity to walk independently before six years of age, so an appropriate treatment plan would be meant to maintain the walking ability and the cardiopulmonary fitness of the children or to encourage social participation. When children with CP grow into adolescence, they may effectively experience a decline in the walking ability. However, our data show that adolescents with CP aged 12 to 18 succeeded in walking in comparison with children with CP aged 2 to 6 (OR=3.26; 95% CI=1.59–6.72). There are studies that support the possibility that some children with CP continue to maintain and develop the walking ability into adolescence.[6, 25-27] On the other hand, Kerr et al.[28] point out that the lowest effective walking ability is at about 12 years of age, and that deterioration of the gross motor skill takes over after the age of 13. This issue in adolescence remains unclear. However, in adults, it has been showed that when children with CP grow into adulthood (>20 years), they have the potential to experience walking decline due to exhaustion, inability of ambulation, or expanded joint agonies.[26, 29]

For instance, the sum scores for a child with spastic diplegia (score=3) aged four (score=0) who can sit independently before age two (score=3) and eats independently now (score=1.5) is 7.5 (0 + 3 + 3 + 1.5, see Figure 5.1). This means that in the period of age ranging from 2 years to 6 years, he is able to walk with assistive devices. When he grows up (score=1, for the age range 6–12), the sum scores will have one point added, as 8.5 (1 + 3 + 3 + 1.5, see Figure 5.1), which means that he has a chance to walk independently. However, this data still had 10% of overestimation (children were detected as over true ambulatory levels) and 12.1% of underestimation (children were detected as under true ambulatory levels) which can be the result of other predictors, such as primitive reflexes, not being taken into consideration for the analyses, but this is acceptable. So, this tool is reliable for the classification of the ambulatory status in children with CP. Additionally, the discriminative and predictive abilities of this tool showed that the performance of the model was good.

Some limitations of this study need to be mentioned. First, the routine data had some of the predictors missing; however, the authors assumed that they were missing completely at random. Consequently, they confirm that the data collection was unbiased. Additionally, an adequate sample size was considered that at least 10 to 15 subjects per predictor should be included in the study.[30] For this reason, this study had an adequate sample with 471 subjects, and the final model contained 10 variables. Second, primitive reflex and postural reaction, which are associated with ambulatory status, were excluded from this study since it is not routine data. Finally, this score chart may be restricted, in generalization to other contexts, because it was constructed from routine clinical practice of the settings in northeastern and northern Thailand. These settings are in the form of hospitals or special schools for children with physical disability that the parents take their children to for treatment when they find their children encountering problems with regard to carrying out normal functions, routine functions which these children have not been able to perform since birth. Some children with CP who walk independently, they may not be discovered in this study. Thus, this prognostic tool holds potential and should be externally validated in a different setting before utilization in clinics.

3. Conclusion

Most parents want to know that their children with CP will ambulate or not. A simple tool to predict ambulatory status and one which uses GMFCS is still lacking. A simple ambulatory prognostic score chart from this thesis was derived from age, type of CP, sitting independently at age two, and eating independently. These items were combined into a clinical prediction score: non-ambulation (scores <7), assisted ambulation (scores 7-8), and independent ambulation (scores >8). It shows high discriminative values of ambulatory status in children with CP. However, the validation of this score chart should be tested in other subjects before clinical practice application.

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