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# Proactive outcome monitoring and standardisation of physiotherapy stroke rehabilitation — A retrospective functional outcomes analysis of Accelerated Stroke Ambulation Programme (ASAP)

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**Background:** A clinical quality improvement programme named Accelerated Stroke Ambulation Programme (ASAP) was piloted in Physiotherapy Department of Tai Po Hospital from 1st October 2019 to 30th September 2020 and executed as a standard practice afterwards. The goal of ASAP was to facilitate early maximal walking ability of stroke patients in early rehabilitation phase. ASAP featured (1) proactive outcome monitoring and standardised process compliance monitoring by a patient database — Stroke Registry; (2) standardised mobility prediction by Reference Modified Rivermead Mobility Index (MRMI) Gain and (3) standardised intervention database — Stroke Treatment Library. **Objective:** To investigate the effectiveness of ASAP in an inpatient rehabilitation setting for stroke patients in terms of functional outcomes. **Methods:** The design was a retrospective comparative study to analyse the difference in functional outcomes of Pre-ASAP Group (1st October 2018 - 30th September 2019) and Post-ASAP Group (1st October 2020–30th September 2021). The primary outcome measures were MRMI, Berg's Balance Scale (BBS), Modified Barthel Index (MBI), MRMI Gain, BBS Gain, MBI Gain, MRMI Efficiency, BBS Efficiency and MBI Efficiency. **Results:** There 348 subjects in Pre-ASAP Group and 281 subjects in Post-ASAP Group. Both groups had highly significant within-group improvement in MRMI, BBS and MBI ($p < 0.001$). The MRMI Gain of Pre-ASAP Group and Post-ASAP Group was 6.32 and 7.42, respectively; and the difference was significant ($p < 0.05$). The BBS Gain of Pre-ASAP Group and Post-ASAP Group was 8.17 and 9.70, respectively; and the difference was in margin of significance ($p = 0.069$). The MBI Gain of Pre-ASAP Group

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and Post-ASAP Group was 10.69 and 11.96, respectively; but the difference was non-significant ($p = 0.280$). The MRMI Efficiency, BBS Efficiency and MBI Efficiency of Post-ASAP Group were higher than Pre-ASAP Group but the difference was non-significant. The results of this study reflected that stroke rehabilitation programme with proactive outcome monitoring, standardised process compliance monitoring, standardised mobility prediction and standardised intervention database was practical in real clinical practice with better functional outcomes than traditional physiotherapy practice which were dominated by personal preference and experience of therapists. **Conclusion:** Proactive outcome monitoring, standardised process compliance monitoring, standardised mobility prediction and standardised intervention database may enhance the effectiveness in terms of functional outcomes of stroke rehabilitation programme.

**Keywords:** Physiotherapy; stroke; rehabilitation; standardisation; functional outcome.

## Introduction

Stroke, also known as cerebrovascular accident (CVA), is an acute disturbance of focal or global cerebral function with signs and symptoms lasting more than 24 h or leading to death, presumably of vascular origin.[1] The most widely recognised impairment causing stroke is motor impairment which restricts functional mobility including walking.[2,3] Therefore, to improve functional mobility of patients with stroke is one of the main goals of rehabilitation.[3] Traditionally, such as in Bobath concept, Proprioceptive Neuromuscular Facilitation (PNF), motor learning approach, functional approach and the orthopaedic approach, intervention selection and application of neuroplasticity to stroke patients depends on personal preference and experience of therapists.[4] Evidence suggested that a new method of Stroke Registry using big data is an effective modality to improve future stroke care.[5] The development of technologies such as database management system may provide more accessible, efficient, objective, intensive and predictive methods compared to traditional practices in facilitating the process of recovery after brain injury and standardising stroke rehabilitation programmes. A clinical quality improvement programme named Accelerated Stroke Ambulation Programme (ASAP) was piloted in Stroke Rehabilitation Programme of Tai Po Hospital by Physiotherapy Department from 1st October 2019 to 30th September 2020 and executed as a standard practice afterwards. The objective of ASAP is to facilitate early maximal walking ability for stroke patient through the components of (1) Stroke Registry; (2) Reference Modified Rivermead Mobility Index (MRMI) Gain and (3) Stroke Treatment Library. The technology requirement of ASAP was basic data management software, video making software, video taking devices and personal computers. The objective of the study was to investigate the effectiveness of ASAP in an inpatient rehabilitation setting for stroke patients in terms of functional outcomes.

## Method

This was a retrospective comparative design for the functional outcomes of stroke patients one year before and one year after a one-year trial period (1st October 2019–30th September 2020) of ASAP. The subjects were eligible for inclusion if their principle diagnosis were stroke, CVA, or hemiplegia who admitted into Tai Po Hospitals and received physiotherapy gym session training in Pre-ASAP Period (on or after 1st October 2018; and discharged on or before 30th September 2019) and Post-ASAP Period (on or after 1st October 2020; and discharged on or before 30th September 2021). They were excluded if they were transfer out of the hospital, discharged against medical advice (DAMA) or died. The eligible subjects from Pre-ASAP Period were assigned to Pre-ASAP Group and from Post-ASAP Period were assigned to Post-ASAP Group.

### *Control group: Traditional physiotherapy treatment*

The Pre-ASAP Group was the control group of the study which received traditional physiotherapy treatments which were based on the corporate stroke rehabilitation protocol of Hong Kong Hospital Authority.[6] The protocol was designed with reference to the International Classification of Functioning, Disability and Health framework of the World Health Organization[7] that delineated the current practice patterns of physiotherapy intervention including limbs mobilisation, muscle tone normalisation, muscle strengthening, electrical muscle stimulation, transfer training, gait training and balance training for patients with stroke. The protocol allowed variations in clinical practice and ultimate decision about a particular clinical treatment depended on each individual patient's condition, circumstances and clinical judgment of physiotherapists. The physiotherapy treatments were delivered by same team of physiotherapists from 5 to 7 days per week. The duration of each physiotherapy session was 60–90 min depended on patients' tolerance and motivation.

## Experimental group: Accelerated Stroke Ambulation Programme

The Post-ASAP Group was the experimental group in this study which received ASAP on top of traditional physiotherapy treatments. The goal of ASAP was to facilitate early maximal walking ability of stroke patients in early rehabilitation phase. ASAP features (1) proactive outcome monitoring and standardised process compliance monitoring by a patient database — Stroke Registry; (2) standardised mobility prediction by Reference MRMI Gain and (3) standardised intervention database — Stroke Treatment Library. The physiotherapy treatments were delivered by same team of physiotherapists from 5 to 7 days per week. The duration of each physiotherapy session was 60–90 min depended on patients' tolerance and motivation.

## Stroke Registry: Proactive outcome monitoring/Standardised process compliance monitoring

Stroke Registry was a longitudinal stroke rehabilitation database to bridge the gap between evidence-practice and clinical practice by big data concept.[5] The function of Stroke Registry was proactively monitoring functional outcomes of patients and process compliance of interventions delivered to patients. It was in Excel format and contained patients' clinical information such as patient characteristics, day since stroke, type of stroke, episode of stroke, premorbid mobility level, present mobility level, number of gym session received and discharge arrangement. The data of stroke patients were entered by their case therapists after baseline assessment, weekly reassessment and pre-discharge assessment. Stroke Registry could generate a Reference MRMI Gain of each patient after the entry of baseline assessment so as to provide proactive outcome monitoring of patients before they were discharged from the programme. As a standardised process compliance monitoring, Stroke Registry would provide treatment suggestion for two interventions, i.e. Knee–Ankle–Foot Orthoses (KAFO) and Robotic-Assisted Gait Training (RAGT) if patients fulfilled the preset criteria in Stroke Registry. The Stroke Registry also has a built-in Stroke Treatment Library to suggest suitable intervention to therapist.

## Reference Modified Rivermead Mobility Index Gain: Standardised mobility prediction

MRMI Gain indicated the mobility improvement of subjects and was deviated from a mobility score — MRMI.[8] Reference MRMI Gain was a clinical prediction model apply business intelligence concept to standardise the mobility prediction of stroke patients upon completion of the in-patient phase of stroke rehabilitation programme. The predict clinical outcome gave therapists a standardised objective goal in mobility training within the stroke rehabilitation programme. To achieve this function, Stroke Registry generates a Reference MRMI Gain from a preset formula which contained patients' age, premorbid mobility level in term of Modified Functional Ambulation Category (MFAC) and admission mobility level in term of MRMI. The development of Reference MRMI Gain was based on past clinical data of patients discharged from our stroke rehabilitation programme from 2011 to 2018 ($n = 4,136$). The correlation of Reference MRMI Gain and actual MRMI Gain was investigated and showed a moderate correlation (Pearson correlation = 0.386) between Reference MRMI Gain and Actual MRMI gain. Therefore, therapists and the stroke term could monitor the progress of stroke patients by compare the weekly MRMI to the Reference MRMI Gain and adjust the treatment parameters accordingly.

## *Stroke treatment library*: *Standardised intervention database*

The aim of Stroke Treatment Library was to facilitate standardised intervention prescription to stroke patients with different mobility level by providing timely clinical decision support to therapists. It was a database with a basket of 85 selected physiotherapy interventions in video format located inside Stroke Registry. According to recent high-level evidence, the selection of intervention had priority to intensive high repetitive task/task-oriented/task-specific training.[9,10] In order to provide task difficulty matching, i.e. repetitive practice of movement tasks at the "just right" level of challenge,[11] the interventions were categorised from easy to hard level according to the scores (0–5) and sub-items (1–8) of MRMI. The role of therapists was to adjust appropriate dose at appropriate time following the Challenge Point Framework (CPF)[12] and base on clinical experience, individual circumstances and patient preferences as appropriate.[13,14]

## *Knee–Ankle–Foot Orthoses*: *Intervention*

Manual-assisted standing and walking training for dense stroke patients with lower limb paralysis are labour-intensive. Use of external support such as orthosis seems to be the easiest way to assist patients to try standing and walking, especially in the early stage of stroke. However, conventional gaiter, ankle foot orthosis (AFO) or air splint will only be able to support knee or ankle joint separately. Clinically meaningful improvement in functional mobility promoted active rehabilitation and facilitated quick recovery in patients with stroke by KAFO were reported.[15–21] KAFO allowed patients to gain stability in paralyzed foot and walked with better dynamic balance.[21] ASAP employed a set of KAFO (Gait Innovation (Dial Lock) + GS Double Klenzak) which was designed to be shared in the hospital with quickly and easily adjustable circumference of thigh cuff, heights of lower leg cuff, knee joint and thigh cuff by the lever and slides. A hold foot mechanism allowed subjects' heels were held in the orthosis by tightening ankle belts. The insole and calf padding were custom-molded by the colleagues from Prosthetic and Orthotic Department. Physiotherapists would select suitable subjects for 5–10 sessions of mobility training with assistance by KAFO according inclusion criteria (premorbid MFAC above 3 and current MFAC from 1 to 3) and exclusion criteria (skin problem, increase tone, poor mental and medically unstable).

## *Robotic-Assisted Gait Training*: *Intervention*

The RAGT was provided by a robot system device (Lokomat Pro; Hocoma Inc., Zurich, Switzerland) and operated by trained physiotherapists with Lokomat certification. The system for lower limb training was a motor-driven gait orthosis secured to the patient's lower limbs. The patient's whole body was supported by a body weight support system over a synchronised treadmill. The patients' legs were guided on the treadmill according to a pre-programmed physiological gait pattern, which in combination with body weight support system, transmitted the treadmill movement to levers that induce the stance and swing phases. The system allowed specific level of guidance compatible to the patients' clinical condition to achieve enhancement in gait speed, endurance and gait quality whilst minimising destructive compensatory gait pattern and avoidable stress to the patient. The physical stress of physiotherapy staff could also be reduced. The consistency and duration of training session could be ensured. Physiotherapist would select suitable subject, for 3–5 sessions per week, according the selection inclusion criteria of premorbid MFAC above 3 and current MFAC from 3 to 5; and exclusion criteria of skin problem, increase tone, poor mental and medically unstable. Each session lasted for 15–30 min depending on patients' tolerance. The amount of bodyweight support was adjusted to maximise lower-extremity weight-bearing whilst ensuring correct stance and swing. The treadmill speed was set at a comfortable level that was specific to the patient, starting from 1.5 km/h (equal to 0.278 m/s) and was increased as tolerated. RGAT has been used in our department for stroke rehabilitation since 2014 and shown extra benefits to stroke patients in terms of ambulation, mobility and balance.[22]

## *Demographic characteristics*

Patient's demographic and hospital information including age, gender, premorbid accommodation, stroke type, day since stroke, discharge destination and gym session were retrieved from the database of Physiotherapy Department of the Hospital and Clinical Management System of Hong Kong Hospital Authority. Gym session was the total number of physiotherapy gym session in the rehabilitation programme. The demographic characteristics and average functional outcomes of all subjects were demonstrated in number and percentage or mean and standard deviation.

## Clinical outcomes

The primary clinical outcomes of the study were MRMI, Berg's Balance Scale (BBS) and Modified Barthel Index (MBI). These functional scores of subjects derived admission MRMI, discharge MRMI, MRMI Gain, MRMI Efficiency; admission BBS, discharge BBS, BBS Gain, BBS Efficiency, admission MBI, discharge MBI, MBI Gain and MBI Efficiency. MRMI Gain was the difference between discharge MRMI and admission MRMI. MRMI Efficiency was the average gain in total MRMI ratings per gym session which was calculated by MRMI Gain divided by the number of gym session. The BBS Gain, BBS Efficiency, MBI Gain and MBI Efficiency were measured by same methods. The gain of a score indicated the overall effectiveness of rehabilitation programme and the efficiency of a score indicated the overall efficiency of rehabilitation programme.[23] Both gain and efficiency of scores were included to facilitate comparisons to other studies.

## Modified Functional Ambulation Category

MFAC[24,25] was used to classify subjects walking capacity in this study. MFAC is a seven-point Likert Scale divided gait into seven categories (MFAC 1–MFAC 7), ranging from no ability to walk; and requires manual assistance to sit; or is unable to sit for 1 min without back or hand support (MFAC 1: Lyer) to the ability to walk independently on level and non-level surfaces, stairs and inclines (MFAC 7: Outdoor Walker).[24] The inter-rater reliability of the MFAC in term of intraclass correlation coefficient (ICC) was 0.982 (0.971–0.989), with a kappa coefficient of 0.923 and a consistency ratio of 94% for stroke patients.[26] Recent evidence also shows that MFAC could serve as a stratification tool of patients with stroke in inpatient rehabilitation.[23]

## Modified Rivermead Mobility Index

MRMI was used to assess subjects' mobility in this study. The MRMI is highly reliable between raters (ICC = 0.98) and has high internal consistency (Cronbach's alpha = 0.93) to early-stage patients with stroke. The MRMI consists of eight test items, including turning over, changing from lying to sitting, maintaining sitting balance, going from sitting to standing, standing, transferring, walking indoors and climbing stairs. The score of MRMI ranges from 0 to 40. One main characteristic of the MRMI is that subjects are scored by observation of their performance on the items directly.[7]

## Berg's Balance Scale

The BBS was used to assess patients' balance in this study. The BBS has been shown to have excellent inter-rater (ICC = 0.98), intra-rater reliability (ICC = 0.98) and is internally consistent (0.96) to subjects with acute stroke.[27] BBS is shown to have 53% sensitivity to predict falls in elderly persons[28] and was able to detect changes in balance of patients with acute stroke.[29] The BBS is composed of 14 tasks. The scoring of each task is from 0 to 4. A score of 0 is given if the participant is unable to do the task, whilst a score of 4 is given if the participant is able to complete the task in accordance with the respective criterion. The total score of the BBS is 56.[27,30–32] The value of 45 points is used to calculate relative risk estimates which demonstrated predictive validity.[28] Hence, a score of 45 is shown to be an appropriate cutoff for safe and independent ambulation, and the need for assistive devices or supervision.[32]

## Modified Barthel Index

MBI was used to assess subjects' basic activities of daily living (ADL) in this study. MBI measures the subject's performance on ten functional items including self-care, continence and locomotion. The values assigned to each item are based on the amount of physical assistance required to perform the task and added to give a total score ranging from 0 to 100 (0 = fully dependent, 100 = fully independent) with higher scores indicating higher levels of physical function.[33] There is no subtotal score because there is no sub-scale.[33] The internal consistency reliability coefficient for MBI is 0.90.[33]

### Statistical analysis

The between-group differences of patient characteristics were analysed by independent-sampled $t$-test or Chi-square. The within-group differences of admission MRMI and discharge MRMI; admission BBS and discharge BBS; as well as admission MBI and discharge MBI were analysed by paired $t$-test. The between-group differences of the characteristics including premorbid MFAC, admission MRMI, admission BBS, admission MBI, MRMI Gain, MRMI Efficiency, BBS Gain, BBS Efficiency, MBI Gain and MBI Efficiency were analysed by independent-sampled $t$-test. Results were considered statistically significant when $p < 0.05$ and statistically highly significant when $p < 0.001$. Data were analysed with the use of the SPSS v28.0.0.0 (190) statistical package (IBM SPSS Statistics).

### Ethics statement

This study was performed in compliance with the principles of the Declaration of Helsinki to protect human subjects. The Joint Chinese University of Hong Kong–New Territories East Cluster Clinical Research Ethics Committee (The Joint CUHK-NTEC CREC) approval was obtained prior to commencement of the study. This trial design was registered prospectively with the ClinicalTrials.gov Protocol Registration and Results System (ClinicalTrials.gov ID: NCT05420103).

## Results

### Baseline characteristics of subjects

There were totally 1,023 stroke patients screened for the study. In Pre-ASAP Period, 524 subjects received ASAP but 139 had no gym session, and amongst the remained 385 subjects, 29 transferred out, 7 DAMA and 1 died that 348 subjects were finally assigned to Pre-ASAP Group. On the other hand, in Post-ASAP Period, 499 subjects received ASAP but 166 had no gym session, and amongst the remained 333 subjects, 44 transferred out, 2 DAMA and 6 died that 281 subjects were assigned to Pre-ASAP Group (Fig. 1). The baseline characteristics of subjects from Pre-ASAP Group and Post-ASAP Group are shown in Table 1. The Pre-ASAP Group ($n = 348$) consisted of 208 (59.8%) male, with the mean age of $71.76 \pm 13.21$ and the mean day since stroke was $9.27 \pm 8.01$. For the type of stroke, 73.6% was cerebral infract and 26.4% was cerebral hemorrhage. For the episode of stroke 77.0% was first stroke and 23.0% was recurrent stroke. The mean premorbid MFAC was $6.25 \pm 1.38$; the mean admission MFAC was $2.77 \pm 1.43$; the mean admission MRMI was $15.95 \pm 9.90$; the mean admission BBS was $12.37 \pm 14.82$ and the mean MBI was $40.55 \pm 28.24$. The Post-ASAP Group ($n = 281$) consisted of 137 (48.8%) male, with the mean age of $72.79 \pm 13.22$ and the mean day since stroke was $9.90 \pm 7.58$. For the type of stroke, 80.8% was cerebral infract and 19.2% was cerebral hemorrhage. For the episode of

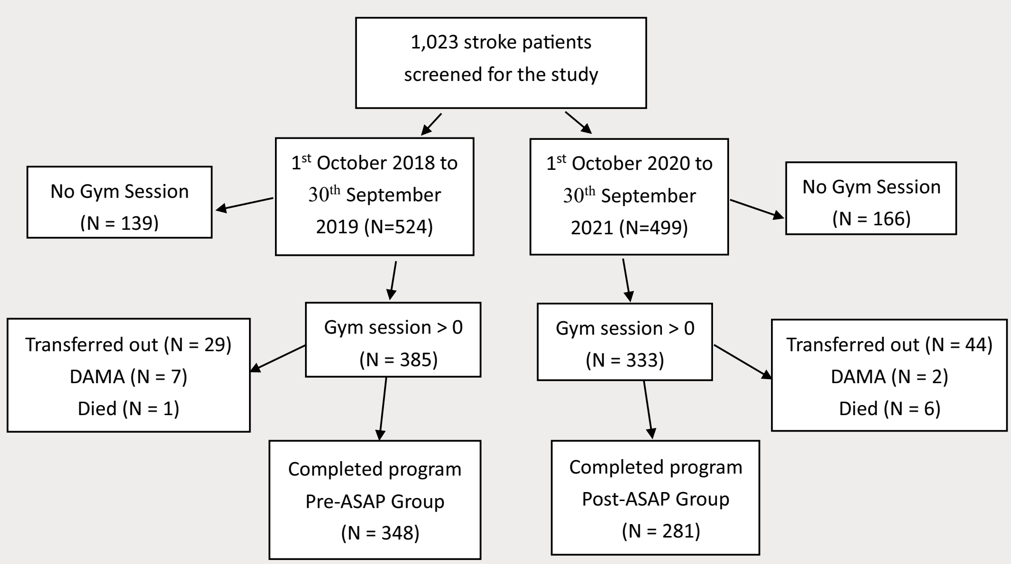


Fig. 1. Flowchart of patient assignment. DAMA = Discharged against medical advice.

Table 1. Baseline characteristics of subjects.

| | Total ($n = 629$) | Pre-ASAP ($n = 348$) | Post-ASAP ($n = 281$) | $t$-tests $p$ | Chi-square $p$ |
|---|---|---|---|---|---|
| Age (year), mean (SD) | 72.22 (13.21) | 71.76 (13.21) | 72.79 (13.22) | 0.334 | / |
| Gender, males, number (%) | 345 (54.8) | 208 (59.8) | 137 (48.8) | / | 0.006* |
| Day since stroke (days), mean (SD) | 9.84 (7.6) | 9.27 (8.01) | 9.90 (7.58) | 0.688 | / |
| Type of stroke (%) | | | | / | 0.371 |
| Cerebral infract | 78.7 | 73.6 | 80.8 | / | / |
| Cerebral hemorrhage | 21.3 | 26.4 | 19.2 | / | / |
| Episode of stroke (%) | | | | / | 0.196 |
| First stroke | 76.5 | 77.0 | 80.1 | / | / |
| Recurrent stroke | 23.5 | 23.0 | 19.9 | / | / |
| Premorbid MFAC, mean (SD) | 6.36 (1.27) | 6.25 (1.38) | 6.49 (1.12) | 0.204 | / |
| Admission MFAC, mean (SD) | 2.81 (1.36) | 2.77 (1.43) | 2.87 (1.26) | 0.355 | / |
| Admission MRMI, mean (SD) | 16.57 (9.60) | 15.95 (9.90) | 17.33 (9.14) | 0.071 | / |
| Admission BBS, mean (SD) | 13.10 (14.85) | 12.37 (14.82) | 14.00 (14.88) | 0.171 | / |
| Admission MBI, mean (SD) | 43.48 (26.85) | 40.55 (28.24) | 46.86 (24.15) | 0.003* | / |

*Notes*: $*p < 0.05$. Between-group difference by independent-sampled $t$-test or Chi-square.

stroke, 80.1% was first stroke and 19.9% was recurrent stroke. The mean premorbid MFAC was $6.49 \pm 1.12$; the mean admission MFAC was $2.87 \pm 1.26$; the mean admission MRMI as $17.33 \pm 9.14$; the mean admission BBS was $14.00 \pm 14.88$ and the mean MBI was $46.86 \pm 24.15$. All the baseline characteristics of subjects from both groups had no significant difference except the gender ($p = 0.006$) and admission MBI ($p = 0.003$) indicating that both groups were homogeneous except gender and admission basic ADL.

## Programme content

The programme content of Pre-ASAP Group and Post-ASAP Group is shown in Table 2. Both groups received traditional physiotherapy. Post-ASAP group had Stroke Registry, Reference MRMI Gain and Stroke Treatment Library. Post-ASAP group had mobility training with KAFO ($n = 25$) but not in Pre-ASAP group ($n = 0$). Both groups had mobility training with RAGT (Pre-ASAP Group, $n = 14$; Post-ASAP Group, $n = 26$). The mean number of gym session of both groups (Pre-ASAP Group was $12.30 \pm 9.64$ sessions; Post-ASAP Group was $11.45 \pm 9.83$ sessions) had no statistically significance ($p = 0.168$).

## Functional outcomes

The functional outcomes of Pre-ASAP Group and Post-ASAP Group are shown in Table 3. Both groups had highly significant within-group improvement in MRMI, BBS and MBI ($p < 0.001$). The MRMI Gain of Pre-ASAP Group and Post-ASAP Group was 6.32 and 7.42, respectively; and the difference was significant ($p < 0.05$). The BBS Gain of Pre-ASAP Group and Post-ASAP Group was 8.17 and 9.70, respectively; and the difference was in margin of significance ($p = 0.069$). The MBI

Table 2. Programme content of Pre-ASAP Group and Post-ASAP Group.

| | Pre-ASAP ($n = 348$) | Post-ASAP ($n = 281$) | $t$-tests $p$ |
|---|---|---|---|
| Traditional Physiotherapy | Yes | Yes | / |
| Stroke Registry | No | Yes | / |
| Reference MRMI Gain | No | Yes | / |
| Stroke Treatment Library | No | Yes | / |
| Mobility training with KAFO | No | Yes (25 patients, 178 sessions) | / |
| RAGT | Yes (14 patients, 94 sessions) | Yes (26 patients, 190 sessions) | / |
| Number of gym session, Mean (SD) | 12.30 (9.64) | 11.45 (9.83) | 0.168 |

*Notes*: KAFO: Knee–ankle–foot orthoses, RAGT: Robotic-assisted gait training.

Table 3. Functional outcomes of Pre-ASAP Group and Post-ASAP Group.

| | Total ($n = 629$) | Pre-ASAP ($n = 348$) | Within group $p$ | Post-ASAP ($n = 281$) | Within group $p$ | Between group $p$ |
|---|---|---|---|---|---|---|
| Admission MRMI | 16.57 (9.60) | 15.95 (9.90) | < 0.001** | 17.33 (9.14) | < 0.001** | |
| Discharge MRMI | 23.38 (10.33) | 22.27 (10.68) | | 24.75 (9.72) | | |
| MRMI Gain | 6.81 (6.26) | 6.32 (6.48) | | 7.42 (5.94) | | 0.029* |
| MRMI Efficiency | 0.35 (0.44) | 0.75 (1.55) | | 0.93 (1.09) | | 0.102 |
| Admission BBS | 13.10 (14.85) | 12.37 (14.82) | < 0.001** | 14.00 (14.88) | < 0.001** | |
| Discharge BBS | 21.98 (17.47) | 20.59 (17.47) | | 23.71(17.34) | | |
| BBS Gain | 8.86 (10.48) | 8.17 (10.46) | | 9.70 (10.46) | | 0.069 |
| BBS Efficiency | 1.01 (1.98) | 0.93 (1.89) | | 1.11 (2.09) | | 0.248 |
| Admission MBI | 40.55 (28.24) | 40.55 (28.24) | < 0.001** | 46.86 (24.15) | < 0.001** | |
| Discharge MBI | 54.81 (27.58) | 40.55 (28.24) | | 58.82 (23.91) | | |
| MBI Gain | 11.29 (14.33) | 10.69 (15.03) | | 11.96 (13.48) | | 0.280 |
| MBI Efficiency | 0.49 (0.76) | 1.15 (3.15) | | 1.42 (2.92) | | 0.275 |

*Notes*: $^*p < 0.05$, $^{**}p < 0.001$. Difference within group by paired $t$-test; difference between group by independent-sampled $t$-test. All functional outcomes were expressed as Mean (SD).

Gain of Pre-ASAP Group and Post-ASAP Group was 10.69 and 11.96, respectively; but the difference was non-significant ($p = 0.280$). The MRMI Efficiency, BBS Efficiency and MBI Efficiency of Post-ASAP Group ($0.93 \pm 1.09$; $1.11 \pm 2.09$; $1.42 \pm 2.92$, respectively) were higher than those of Pre-ASAP Group ($0.75 \pm 1.55$; $0.93 \pm 1.89$; $1.15 \pm 3.15$, respectively) but the difference was non-significant ($p = 0.102$; $p = 0.248$; $p = 0.275$, respectively).

## Discussion

The results of this study reflected that stroke rehabilitation programme with proactive outcome monitoring, standardised process compliance monitoring, standardised mobility prediction and standardised intervention database was practical in real clinical practice with better functional outcomes than traditional physiotherapy practice which were dominated by personal preference and experience of therapists. According to the baseline characteristics including the mean day since stroke, the mean premorbid MFAC and mean admission MFAC, the majority of subjects in both groups were in their early stroke rehabilitation phase with the average mobility of independent walker before stroke and average mobility of sitter after stroke. In addition, all the baseline characteristics of subjects from both groups had no significant difference except the gender and admission basic ADL. The significant imbalance of gender between both groups may reflect the trend of the epidemiology of stroke in Hong Kong under the effect of COVID-19, although the relationship between COVID-19 and acute cerebrovascular diseases was still unclear.[34] For the between-group gender different, evidence showed that women with stroke had poorer functional outcomes than do men,[35] our finding did not echo with that, the Post-ASAP Group had more women and better Admission MBI than Pre-ASAP group. In order to minimise the confounding bias of different Admission MBI amongst both groups, this study used the difference in functional score such as MBI Gain to compare the between-group differences. In fact, the main objective of ASAP was to facilitate early maximal walking ability of stroke patients in early rehabilitation phase, therefore there was more essential that the functional outcomes with more ambulation oriented such as Premorbid MFAC, Admission MFAC, Admission MRMI and Admission BBS did not have significant between-groups difference rather than Admission MBI.

As the original intention and design of the study, the programme content of both groups did had a lot of differences. Apart from the traditional physiotherapy, the Post-ASAP Group had a basket of enhancements in term of logic of intervention selection governed by Stroke Registry, Reference MRMI Gain and Stroke Treatment Library rather than additional interventions. The only intervention which was absent in Pre-ASAP Group was mobility training with KAFO, only 8.9% of patients (25 out of 281) in Post-ASAP Group has used. Another intervention with has been used in both groups was RAGT, in this study 4.0% (14 out of 328) of Pre-ASAP Group had RAGT and 9.2% (26 out of 281) of Post-ASAP Group had RAGT. It was safe to assume that the increase of using RAGT would be the effect of standardised process compliance monitoring by Stroke Registry in Post-ASAP Group; and more RAGT would provide more gain in mobility outcomes of patients in terms of ambulation, mobility and balance.[21] In addition, the number of gym session of both groups (Pre-ASAP Group: 12.30; Post-ASAP Group: 11.45) had no significant difference ($p = 0.168$) indicated that any difference in outcomes of both group was not due to the training duration in term of gym session.

The MRMI Gain of Post-ASAP Group was higher than Pre-ASAP Group and the difference was significant ($p < 0.05$) and the MRMI Efficiency of Post-ASAP Group was higher than that of Pre-ASAP Group although the difference was non-significant ($p = 0.102$). The BBS Gain and BBS Efficiency of Post-ASAP group were higher than those of Pre-ASAP group but the difference was non-significant ($p = 0.069$, $p = 0.248$, respectively), although 0.069 would be in the margin of significance. The higher MRMI Gain than BBS Gain would be explained by using of Reference MRMI Gain which draw more attention of therapists to the patients' performance in MRMI. On the other hand, statistically, there was no significant difference in MBI Gain between both groups, implicating that the effect of ASAP was similar to that of traditional physiotherapy for stroke patients in terms of basic ADL. This result may be explained by the specificity of training principle.[36] Since the major aim of ASAP was to enhance ambulation and mobility function of patients, improvement in stroke patients was reflected by gait-related outcome measurements such as MRMI and BBS instead of MBI. It was shown that factors that contributed most in ADL after stroke were balance, upper-extremity function and perceptual and cognitive functions.[37] The overall finding of this study supports the view of Stroke Registry big data is an effective modality to improve future stroke care.[5] The results of this study reflected that stroke rehabilitation programme with proactive outcome monitoring, standardised process compliance monitoring, standardised mobility prediction and standardised intervention database, in the format of the enhancement in Post-ASAP Group, was practical in real clinical practice with slightly better functional outcomes than traditional physiotherapy practice, as the content of Pre-ASAP Group, which were dominated by personal preference and experience of therapists.

The limitation of the study included information bias introduced by functional scores; selection bias to the subjects in Chinese population of Hong Kong; and confounding bias by confounding variables such as, due to unexplained reasons, the experimental group had significant higher baseline MBI than that of control group. However, the effects of the confounding bias had been minimised by statistical analysis. The intervention fidelity monitoring was another limitation of the study. The complete picture of the relationship of stroke rehabilitation programme design and functional outcomes seemed very complicated, and could not be explained by a single clinical study. In addition, the type of stroke or episode of stroke impacts the programme outcomes have not been investigated in this study. Further studies with a higher level of evidence, such as randomised controlled trials to investigate the effectiveness of stroke rehabilitation programme with Proactive outcome monitoring, standardised process compliance monitoring, standardised mobility prediction, standardised intervention database as well as how to refine ASAP to increase the likelihood of interventions utilisation in the future are suggested.

## Conclusion

Proactive outcome monitoring, standardised process compliance monitoring, standardised mobility prediction and standardised intervention database may enhance the effectiveness in terms of functional outcomes of stroke rehabilitation programme.

## Conflict of Interest

The author declares that he has no financial affiliations (including research funding) or involvement with any commercial organisation that has a direct financial interest in any matter described in this paper. The author has no other financial or non-financial conflicts of interest related to any matter in this study.

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## Author Contributions

Bryan Ping Ho Chung contributed to the design, data collection, data analysis and paper writing of the study. Titanic Fuk On LAU contributed to the creation of original idea and overall supervision.


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