How Health Services Research Can Translate to a Better Future:
Singapore’s Tele-Rehabilitation Experience

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Post-Stroke Functional Recovery in Singapore

- Greater participation in supervised rehabilitation at day rehabilitation centre >25% of time at 1 and 6 months independently predicted higher Barthel Index (BI) scores 1 year by 25%, adjusted for baseline function, socio-demographic variables, cognition, depression, stroke severity & other variables.

- Unsupervised rehabilitation at home had no effects on function at 1 year.

<table>
<thead>
<tr>
<th></th>
<th>Adjusted Mean BI Score at 1 Year (95% CI)</th>
<th>Adjusted ( \beta )-estimate (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performing therapy at home</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One month</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 75% of the time</td>
<td>64.7 (54.0 – 75.3)</td>
<td>-4.7 (-10.5 – 1.0)</td>
<td>0.103</td>
</tr>
<tr>
<td>≤ 75% of the time</td>
<td>69.4 (58.5 – 80.3)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Six months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 75% of the time</td>
<td>67.5 (56.8 – 78.2)</td>
<td>1.0 (-5.0 – 7.0)</td>
<td>0.729</td>
</tr>
<tr>
<td>≤ 75% of the time</td>
<td>66.5 (55.6 – 77.4)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Performing therapy at outpatient rehab centre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One month</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 25% of the time</td>
<td>72.4 (61.6 – 83.1)</td>
<td>10.7 (3.3 – 18.2)</td>
<td>0.006</td>
</tr>
<tr>
<td>≤ 25% of the time</td>
<td>61.7 (50.3 – 73.0)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Six months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 25% of the time</td>
<td>74.7 (64.1 – 85.3)</td>
<td>15.3 (7.1 – 23.5)</td>
<td>0.001</td>
</tr>
<tr>
<td>≤ 25% of the time</td>
<td>59.4 (47.7 – 71.1)</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Koh GCH, Saxena SK, Ng TP, Yong D, Fong NP. The effect of duration, participation rate and supervision during community rehabilitation on functional outcomes in the first post stroke year in Singapore. *Arch Phys Med Rehabil* 2012;93:279-86.
Performance of Rehabilitation after Discharge

- The proportion of stroke patients performing supervised rehabilitation at day rehabilitation centre after discharged dropped to 25.3% at 1 month and declined to 19.0% by 1 year.
Performance of Rehabilitation after Discharge

- Performance of rehabilitation in day rehabilitation centre at 1 month was very strongly predictive of performance of supervised rehabilitation at 6 months and 1 year.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Adjusted OR (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At one month</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age &gt;75 years (vs. ≤75 years)</td>
<td>0.43 (0.20 – 0.91)</td>
<td>0.028</td>
</tr>
<tr>
<td><strong>At six months</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caregiver availability (vs. none)</td>
<td>0.07 (0.01 – 0.49)</td>
<td>0.007</td>
</tr>
<tr>
<td>Performance of supervised therapy &gt;25% of the recommended time at 1 month</td>
<td><strong>11.64</strong> (4.52 – 29.97)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>At one year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance of supervised therapy &gt;25% of the recommended time at 6 months</td>
<td><strong>76.46</strong> (12.52 – 466.98)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Why Patients Do Not Go for Rehabilitation in Singapore

• Although the majority (76.8%) acknowledged that inpatient rehabilitation was beneficial, only 40.0% wanted to continue with rehabilitation after discharge.

• The barriers to adherence with rehabilitation after discharge were:
  • Functional
  • Social
  • Financial

Functional Barriers

Problems with ambulating from home to rehabilitation centre 62%
Problems with ambulating within the home 21%

“It’s very hard to get around…
Upgrading works are in progress around my home at the moment. Now, I have to take a lift to the fifth floor before taking the stairs to the third storey where I live.”

[62-year-old Chinese female]
Functional Barriers

Problems with ambulating from home to rehabilitation centre  62%
Problems with ambulating within the home  21%
Social Barriers

Inconvenient for subject 57%
No caregiver available to accompany subject 31%
Subject does not wish to burden caregiver 29%
Inconvenient for caregiver 21%
Caregiver is too busy 19%
Subject is too busy 12%

“I am afraid I might fall again if I go alone. However, I would like to continue rehabilitation if I can.”

[69-year-old Chinese male]

“There is no one to bring me for my rehabilitation sessions if there will be any. However, I would like to continue rehabilitation if I am able to do so as I find it good and useful.”

[74-year-old Chinese female]
Financial Barriers

- Financial problems from out-of-pocket payments: 29%
- Financial problems from high cost per session: 21%
- Financial problems from long duration of rehabilitation: 5%

“I think (the cost of rehabilitation) will be okay for the first few weeks but will be a problem if it goes beyond that. After all, I already have to pay for my (other medical) bills.”

[62-year-old Chinese female]

“Money is an important factor. I am concerned that I cannot use Medishield or Medisave* (government insurance) for physiotherapy and transport. I currently have no income, thus I cannot pay.”

[52-year-old Indian male]

* From July 2012, Medisave was allowed to be used for day rehabilitation up to S$20 per day, subject to a maximum of S$1,500 a year.
### Financial Barriers

<table>
<thead>
<tr>
<th></th>
<th>Specialist Outpatient</th>
<th>Day Rehabilitation Centre</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost per Visit</strong></td>
<td>$150 per visit</td>
<td>$50 per visit</td>
</tr>
<tr>
<td><strong>Ratio of Cost Per Visit</strong></td>
<td>3 : 1</td>
<td></td>
</tr>
<tr>
<td><strong>No. of Visit Over 3 Months</strong></td>
<td>1 visit</td>
<td>Twice a week X 12 weeks = 24 visits</td>
</tr>
<tr>
<td><strong>Total Cost Over 3 Months</strong></td>
<td>$150</td>
<td>$1,200</td>
</tr>
<tr>
<td><strong>Ratio of Cost for Visits Over 3 Months</strong></td>
<td></td>
<td>1 : 8</td>
</tr>
</tbody>
</table>
How Did Barriers to Rehabilitation After Discharge Change with Time?

- Problems with ambulating from home to rehabilitation centre (p<0.001)
- Inconvenient for subject (p<0.001)
- Inconvenient for caregiver (p=0.105)
- Financial problems from long duration of rehabilitation (p=0.005)
- Not interested to participate in rehabilitation (p<0.001)
How Can We Increase Adherence to Rehabilitation?

Home Rehabilitation?

Advantages

• No need for patient to overcome physical barriers
• No need for caregiver to take time off to accompany patient to rehabilitation centre (but will need to be present during tele-rehabilitation)

However...

• Currently, there are means-tested subsidies available
• Cost = $150 per visit X 2 visits a week
  = $3,600 over 12 weeks (3 months)
• 3X more expensive than centre-based rehabilitation
How Can We Increase Adherence to Rehabilitation?

Tele-Rehabilitation?

Advantages
• Therapist does not need to visit patient at home
• No need for patient to overcome physical barriers
• Caregiver need not go to rehabilitation centre
• May be provided after office hours

However...
• Currently no public subsidies in Singapore
• Estimated cost = $125 per week = $1,500 over 3 months
• Just slightly more expensive than centre-based rehabilitation
• Caregiver needs to be present during rehab and video-conference session
Studies on Telerehabilitation

Current published trials on tele-rehabilitation have used a combination of:

- Home visits
- In-home messaging device
- Telephony
- *Store-and-forward* video recording by therapy aide during home visits

However:

- Still require face-to-face home visits which are expensive
- Does not leverage on *live (real-time)* video-conferencing which is more cost-effective and efficient
- No physical data collected
- Unlike in tele-psychiatry & tele-dermatology, tactile data is important in tele-rehabilitation

Tele-Rehabilitation

Can we use instead:

- *Training* for patients & caregivers on use of telerehabilitation system before discharge to home;
- *Live real-time video-conferencing* (e.g. FaceTime on iPads);
- *Sensors* to capture *physical data* to help therapists assess recovery process and prescribe next level of exercises;
- *Pushing training videos of* therapist-prescribed exercise to patients?
Tele-Rehabilitation

- Since 2010, National University of Singapore has been developing a tele-rehabilitation system in collaboration with acute and community hospitals in Singapore
- Incorporates previously mentioned elements
- Its effectiveness is currently being evaluated in a randomized controlled trial.
- Its efficiency was evaluated in a time motion study.
Mdm Doris Zen’s Story
(1:48)

How the Tele-Rehab System Works
(1:11)
Accuracy of Sensors

Accuracy of Sensors (Upper Extremities, UE)

Figure 4(a)  Upper Extremity Sensor-Goniometer Plot for Range of Motion for All Joints in 19 Normal Subjects

$r^2_p = 0.97$

$r^2_p$ denotes Pearson's correlation coefficient.
Accuracy of Sensors (Lower Extremities, LE)

Figure 4(b) Lower Extremity Sensor-Goniometer Plot for Range of Motion for All Joints in 19 Normal Subjects

$r_p^2 = 0.99$

$r_p^2$ denotes Pearson's correlation coefficient.
Singapore Tele-technology Aided Rehabilitation in Stroke (STARS) Study: A Randomized Controlled Trial

Primary hypothesis
Among stroke survivors, a tele-rehabilitation intervention involving video-conferencing with a therapist and use of wearable monitoring devices during the first three months after stroke results greater functional recovery at three months, compared to usual care.

Study Workflow

Assessed for eligibility

Excluded
• Did not meet eligibility criteria
• Declined to participate
• Other reasons

Randomization

Allocation to tele-rehabilitation intervention for 3 months involving:
• Baseline assessment
• Daily exercise using iPad-based system with recording of daily exercise (video and sensor data)
• Weekly video-conference with tele-therapist after review to video and sensor data collected
• (N=50)

Allocation to usual care (N=50)

Lost to follow-up (with reasons)
Discontinued intervention (with reasons)

Follow-up at 3 & 6 months

Lost to follow-up (with reasons)
Discontinued intervention (with reasons)
Preliminary Results

• The primary time-point for outcomes in the RCT is 3 months and the target size is 50 controls and 50 intervention subjects.

• These are the results of an interim analysis of 30 subjects recruited so far (14 control and 16 intervention subjects) as of end 2014.
  – Of the 14 control subjects, 2 subjects defaulted follow-up, leaving 12 control subjects available for analysis for data at 3 month time-point.
  – Of the 16 intervention subjects, 2 subjects defaulted follow-up, leaving 14 intervention subjects available for analysis for data at 3 month time-point.

• Statistical significance cannot be assessed in this interim analysis because target sample has not been reached and hence current sample size is not powered.

• This interim analysis only reports preliminary primary findings.
## Difference in Barthel Index (BI) score between baseline and three months

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Change</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usual Care</td>
<td>-0.75</td>
<td>The tele-rehabilitation group improved in the functional status by 9.07 BI points while the usual care declined by 0.75 BI points.</td>
</tr>
<tr>
<td>Tele-rehabilitation</td>
<td>+9.07</td>
<td></td>
</tr>
</tbody>
</table>

[Barthel Index (BI) ranges from 0 to 100. The higher the improvement in Barthel Index score, the greater the functional improvement.]
Usual Care  
+2.4  
The tele-rehabilitation group continued to improve between 3 and 6 months, even after tele-rehabilitation ended at 3 months.

Tele-Rehabilitation  
+11.50  

(Barthel Index (BI) ranges from 0 to 100. The higher the improvement in Barthel Index score, the greater the functional improvement.]
Attendance at day rehabilitation centre during study

• At recruitment, 41.7% of controls were going for day rehab but only 14.3% of telerehab subjects were going for day rehab which is expected as the telerehab group were already receiving telerehab.

• In contrast, at three months, 33.3% of controls were going for day rehab (a drop from 41.7%) but 64.3% of telerehab subjects (an increase from 14.3%) continued rehabilitation (after telerehab stopped) by going for day rehab.
# Time Motion Study Results

<table>
<thead>
<tr>
<th></th>
<th>Mean Time Spent per Therapist Session (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Therapist</td>
</tr>
<tr>
<td><strong>Day Rehabilitation</strong></td>
<td>70</td>
</tr>
<tr>
<td><strong>Home Rehabilitation</strong></td>
<td>86</td>
</tr>
<tr>
<td><strong>Tele Rehabilitation</strong></td>
<td>30</td>
</tr>
</tbody>
</table>
Acknowledgements

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• National University of Singapore
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• National Medical Research Council
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11th Singapore Public Health & Occupational Medicine Conference
Contemporary Challenges, Sustainable Solutions

29 - 30 September 2016
28 September 2016 (Pre-Conference Workshops)
Grand Copthorne Waterfront Hotel, Singapore

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Professor of Political Economy and Sociology
Oxford University

Prof Sarah Harper
DIRECTOR
Professor of Gerontology and Senior Research Fellow Nuffield College

Dr Richard Horton
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