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Comparison of Physiological Cost Index in Clinical and Community Set-Up among Patients with Stroke

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Abstract: ***The various gait training program of stroke patients are only done in the stable hospital setting and not in the various environmental factors which are required in the community. Considering the ultimate goal of rehabilitation to be independent functional ability during gait, it is important to understand the difference in performance in clinical and community set up. Hence this study is taken up to investigate if there is any difference in the performance of gait in clinical and community set up, in terms of energy expenditure measured with the help of Physiological Cost Index in patients with stroke.In total 30 samples were selected for the study by the convenience sampling method. Two set up were selected for the study one inside the clinic and the other outside in the community at ground level. PCI was calculated in both clinical and community set up for a distance of 10m. The study showed that the mean PCI value in clinical set up was 0.355 ± 0.347 andcommunity set up was 1.186 ± 1.106. The mean gait speed in clinical set up was 33.93 ± 15.37 and in the community was 27.93 ± 14.57. There was a positive correlation between the PCI and gait speed in clinical setup P-value <0.001 and R=-0.674 and inthe community set up with P-value <0.001 and R=-7.67.This study concluded that the physiological cost index is greater in the community set up than in clinical. The walking speed is greater in the clinical set up as compared to the community. Hence more muscular effort is required for the patient to ambulate outside the clinic.***

Keywords: Energy cost, Physiological cost index, Stroke patients, Community ambulation, clinical set up etc.

1. Introduction

Stroke survivors have cardiorespiratory reconditioning which represents a challenge to improve patient's mobility and quality of life. The increases in the sympathetic stimulation of the heart are due to the increase in the oxygen demand by the muscle which increases the cardiac output, heart rate and cardiac output has a linear relation.Therefore the cost of energy expenditure increases during walking. Reduction in cardiovascular fitness is a real problem limiting patients to return to the community. According to the American heart association, deconditioning can be avoided by moderate aerobic exercises in stroke patients.Gait deviation is the most common symptom after stroke. An asymmetrical gait pattern increases muscular efforts and increases energy expenditure. The energy expenditure of walking in stroke is 1.5-2 times greater than healthy individuals. The consequences of a relatively high energy cost when walking may limit the individual's daily, functional activity. For the evaluation of exercise intervention, gait training methods, to access response to treatment and testing of the orthosis and walking aids the clinically available information of energy expenditure is important

Energy expenditure has been examined in the younger population in a clinical set up by measuring the percentage of expired oxygen, heart rate, gait speed and distance which concluded that the patients with stroke requires a significantly greater oxygen uptake to walk a much shorter distance, and thus walk with a much less efficient gait pattern.[7-10]One of the validated methods of estimating energy expenditure considering heart rate and walking speed (over a certain meter distance) is the Physiological Cost Index (PCI). PCI reflects the increase in the heart rate while walking and is represented in beats/meter.[5] Gives information about the overall walking ability including both physiological and velocity measurements. It is an easy to use by easily accessible equipment, valid and reliable measure of energy expenditure and it is recommended as a useful tool for Physiotherapists in the assessment and evaluation of functional performance. There are many studies carried out in patients with spinal cord injury, disabilities, CP, amputee[11]etc., using PCI as an outcome measure to investigate the efficacy of walking and improve the capability. [12]

Patients with stroke have reported dissatisfaction with their ability to ambulate outdoors and to access their communities.[13]Community walking is the ability of the individual to walk in the various Environment. Most of the test performed in the clinical environment does not reflect the different environment in which the stroke patient usually ambulate daily.[14]Also, the various gait training program of stroke patients includes treadmill walking, task-oriented training, obstacle walking. Such exercises are only done in the stable hospital setting and the various environmental factors which are required in the community are not taken into consideration. [15] Many authors have used PCI as an outcome measure to calculate the energy cost of walking in the hospital setting using two different walking tracks [16] or over the treadmill.[6,5,14]However, no literature is available on the difference in the PCI in stroke patients in a clinical set-up and community environment. Hence, this study aims to find out and narrow down this difference.

Considering the ultimate goal of rehabilitation to be independent, functional ability during gait, it is important to

understand the difference in performance in clinical and community set up. Hence this study is taken up to investigate if there is any difference in the performance of gait in clinical and community set up, in terms of energy expenditure measured with the help of Physiological Cost Index in patients with stroke.

2. Review of Literature

1) Anna Sofia Delussu ET. Al (2014); Conducted a study on "Concurrent Validity of Physiological Cost Index in Walking over Ground and during Robotic Training in Subacute Stroke Patients". The study was conducted on 6 patients with hemiplegia and 6 healthy subjects. All study participants performed an overground walking test and 3 walking tests on the Ground test with three different percentages of body weight support. Mean walking speed during the overground walking test was calculated as the ratio of distance to time; PCI was calculated. They concluded that there are highly significant correlations between physiological cost index and energy cost of walking in all the observed walking conditions and suggest that PCI is a valid outcome measure in sub-acute stroke patients. Also, PCI is comparable to the energy cost of walking in its ability to discriminate between stroke patients and healthy subjects in the overground walking test.
2) Cristiane Carvalho, ET. Al (2010) study on "Walking speed and distance in different environments of subjects in the later stage post-stroke". Thirty-six subjects were included and divided into two groups based on their walking speed in the clinical setting. The subjects performed the walking tests in three different environments: clinical setting, basement setting and outdoor setting. They concluded that Walking speed obtained over a short distance seemed to overestimate long-distance walking capacity for the slow walkers, despite the environment.
3) Ingrid G.van de Port, ET. Al (2008) conducted a study on "Community ambulation in patients with chronic stroke: How is it relatable to gait speed? "To explore the strength of the association between gait speed and community ambulation and whether this association is significantly distorted by other variables. A total of 102 patients after stroke following inpatient rehabilitation were included in the study. Gait speed was assessed by the 5m walking test. They concluded that gait speed is strongly related to community ambulation; however, community ambulation is a complex outcome. Simply improving the gait speed of stroke survivors during rehabilitation is not sufficient for them to regain community walking.
4) Rishi Raj ET. al (2014) conducted a study on "The Repeatability of Gait Speed and Physiological Cost Index Measurements in Working Adults" to determine the performance characteristics of gait speed measurements and the physiological cost index (PCI; heart rate change/gait speed) in working adults. Gait speeds, heart rate changes, and non-steady state PCIs were calculated in 61 volunteers who worked in the health sciences centre. This study demonstrates that gait speed, heart rate change, and PCI measurements are repeatable in healthy working adults and indicates that simple measurements of gait speed will likely provide the most reproducible estimate of functional status.
5) Matiram PunET. Al (2015) study "Estimation of Physiological Cost Index as an Energy Expenditure Index using Macgregor's Equation" was conducted to find out whether physical activity and energy expenditure can be quantified by measuring heart rate, oxygen uptake and respiratory quotient. The study was conducted on 50 randomly selected females who performed a walking test at their self-selected preferred speed.Theauthor concluded that physiological cost index values were similar for varying distances walks. The PCI was the least at the preferred speed of walking and increased when the subjects either walked slower or faster than the preferred speed.
6) Susan E. Lord, MSc ET.Al (2006) conducted a study on "The Effect of Environment and Task on Gait Parameters after Stroke: A Randomized Comparison of Measurement Conditions "to assess the effect of environment and a secondary task on gait parameters in community ambulant stroke survivors and to assess the contribution of clinical symptoms to their gait performance. Twenty-seven people with stroke were included in the study. Gait speed (in m/min), cadence and step length were assessed by using an accelerometer with adjustable thresholds. This study concluded that people with chronic stroke cope well with the challenges of varied environments and can maintain their gait speed while performing a secondary task.
7) Eric Fredrickson, MD, et al (2007) conducted a study on "Physiological Cost Index as a Proxy Measure for the Oxygen Cost of Gait in Stroke Patients". This study tested the usefulness of an indirect index of oxygen cost, the Physiological Cost Index, and the ability of this index to discriminate between healthy adults and stroke survivors. The study was conducted on 17 subjects with stroke and 10 healthy control participants. They concluded that the Physiological Cost Index and oxygen cost had a good to excellent correlation for subjects with stroke. Both oxygen cost and the Physiological Cost Index were comparable in detecting a significantly abnormal elevation for stroke survivors versus healthy adults.
8) Jun-Min LeeET. al. conducted a study on "The effects of a community-based walking program on walking ability and fall-related self-efficacy of chronic stroke patients" the objectives of this study were to evaluate the effects of community-based walking training (CWT) on the walking ability and fall-related self-efficacy of chronic stroke patients and compare the effects of CWT to the conventional walking programs in stroke patients. They concluded that CWT to standard rehabilitation might be an effective meth-old for improving walking ability and fall-related self-efficacy in chronic stroke patients.
9) Anna Danielson ET. al. "Physical Activity, Ambulation, andMotor ImpairmentLate after Stroke" studywas to assess walking capacity and physical activity using clinical measures and to explore their relationships with motorimpairment late after stroke. They concluded that it may be essential to enhance physical activity even late after stroke since in fairly young subjects bothwalking capacity and the physical activity level were lower than the reference.

3. Methodology

In total 30 samples were selected for the study by the convenience sampling method. The study design was a cross-sectional study. It was conducted in the department of Neuro physiotherapy, VIMS Hospital Ahmednagar and Puntamba Stroke centre. Patients with first-ever stroke episode, sub-acute and chronic stage stroke, both the genders and who were able to walk a minimum of 10m distance with or without assistance were included in the study. Exclusion criteria were participants who hadsevere co-morbidities such as cardiovascular diseases, neurological disorders, musculoskeletal disorders, metabolic disorders, etc. and who underwent recent surgeries.

After approval from the Ethical Committee, a screening for inclusion and exclusion criteria was carried out. The patients of stroke were taken from the IPD and Physiotherapy OPD of VIMS Hospital, Ahmednagar and Puntamba stroke centre.For the participants who meet the inclusion criteria, an orientation was given regarding the purpose, procedure and possible benefits of the study. Two set up were selected for the study one inside the clinic and the other outside in the community at ground level. PCI was calculated in both clinical and community set up.Instructions to the participants before the commencement of the test were to wear comfortable footwear, non-restrictive clothing and to walk at self-paced speed. A 10m distance was marked in a clinical set-up and a community environment at ground level. At the beginning of the test, each participant was given 5 minutes to rest. After 5 minutes, the Resting Heart Rate was taken with the help of pulse oximetry. Then, the participant was asked to walk at their normal "preferred pace" first in the clinical set-up. The participant was informed that in case of any discomfort or breathlessness, he/she can take rest anytime during the test and incase of any unusual feeling/ severe discomfort or breathlessness, the participant can stop the test anytime. The time required to complete the distance and walking heart rate wasnotedafter walking for 10 meters with the help of a stopwatch and pulse oximetry. The person's PCI in beats. Per meter will be calculated using the following equation:

$$\text{PCI (beats/min)} = \frac{\text{Walking HR} - \text{Resting HR}}{\text{Speed (m/min)}}$$

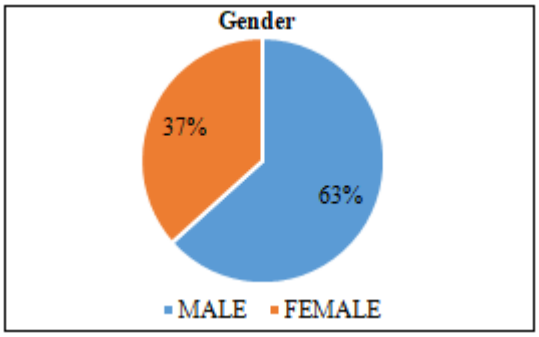
The participant was then made to sit on a chair. This procedure was repeated 3 times with requisite rest periods in between. Mean PCI in the clinical set-up was calculated. The same procedure was repeated outside the hospital on the ground level and finally, a mean PCI in the community set up was obtained.

4. Result

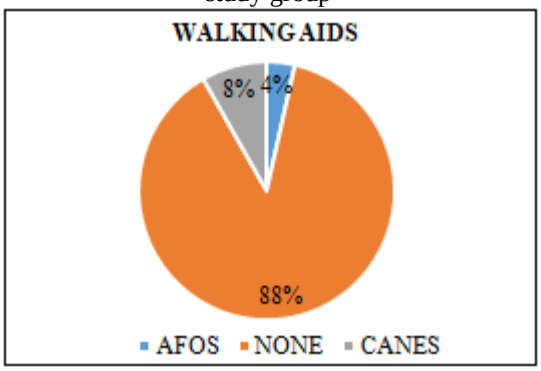
The result of the study was analyzed by calculating the physiological cost index in the clinical and community set up among patients with stroke and comparing the PCI of both the setups. Statistical analysis was done by using Graph Padin Stat software. The collected data were entered into an excel spreadsheet. Statistical measures such as Mean, SD were calculated. A paired t-test was used to compare the physiological cost index, walking heart rate and walking speed between the clinical and community set up. Pearson's correlation was used to compare the PCI with the walking speed between the setups.A total of 30 participants were selected for the study based on the inclusion and the exclusion criteria. All of the participants agreed to participate in the study and there were no dropouts.

Table 1: Showing the demographic data of the profile.

Baseline Characteristics		Mean ± SD
Age (years)		51.5 ± 14.5
Gender	Male	19 (63.33)
	Female	11 (36.66)
Side of Hemiplegia	Right	13 (56.66)
	Left	17 (56.66)
Duration of Stroke (years)		1.54 ± 1.93
Walking aids used	None	25 (83.33)
	AFOS	1 (3.33)
	Cane	4 (7.76)



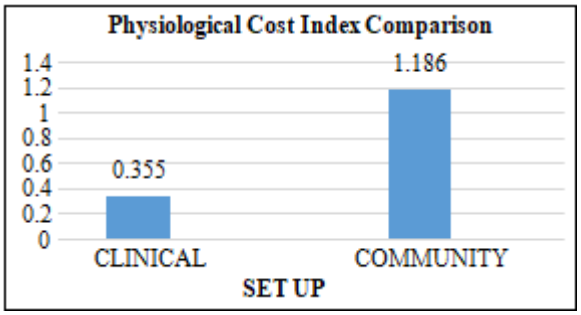
Graph 1: Shows the mean percentage of Gender in the study group



Graph 2: Shows the mean percentage of different walking aids used in the study group

Table 2: Shows the physiological cost index of patients with stroke in clinical and community set up.

Set Up	PCI (beats/meter)	P value
Clinical Set up	0.355 ± 0.347	0.0001
Community Set up	1.186 ± 1.106	

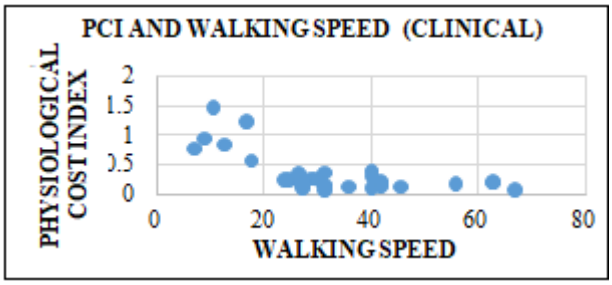


Graph 3: Shows the comparison between the mean physiological cost index of patients with stroke in clinical and community set up.

Physiological cost index (PCI) was capable of discriminating a highly significant difference between the clinical and community set up (P<0.001). A bar graph shows greater PCI value in the community set-up.

Table 3: Shows the mean PCI and the walking speed of patients with stroke in the clinical setup.

	PCI (beats/meter)	Walking speed	P-Value	R-Value
Clinical Set up	0.355 ± 0.347	33.39 ± 15.37	<0.001	-0.674

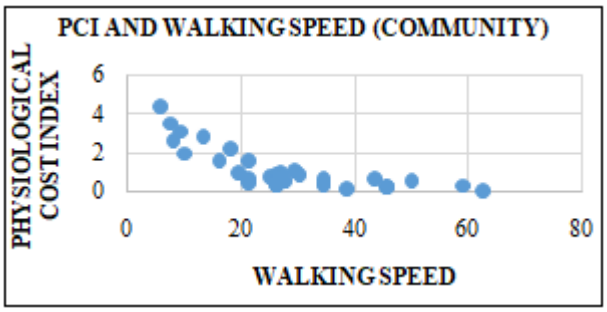


Graph 4: Shows the correlation between the physiological cost index and a walking speed of study group in clinical set up

The physiological cost index has a highly significant correlation with the walking speed among patients with stroke in the clinical setup. (P<0.001 r=-0.674)

Table 4: Shows the mean PCI and the walking speed of patients with stroke in the community set up

	PCI (beats/meter)	Walking speed	P-Value	R-Value
Community Set up	1.186 ± 1.106	27.93 ± 14.57	<0.001	-0.767

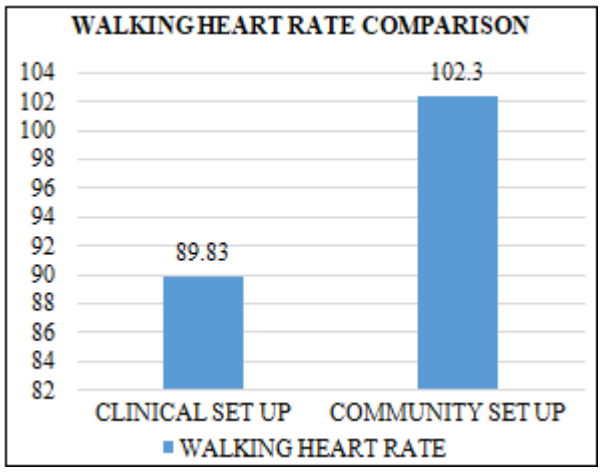


Graph 5: Shows the correlation between the physiological cost index and a walking speed of a study group in the clinical setup.

The physiological cost index has a highly significant correlation with the walking speed among patients with stroke in the clinical setup. (P<0.001 r= -0.767)

Table 5: Shows the mean walking heart rate of patients with stroke in clinical and community set up.

	Walking heart rate	P-Value
Clinical Set up	89.83 ± 11.03	0.0001
Community Set up	102.3 ± 12.64	

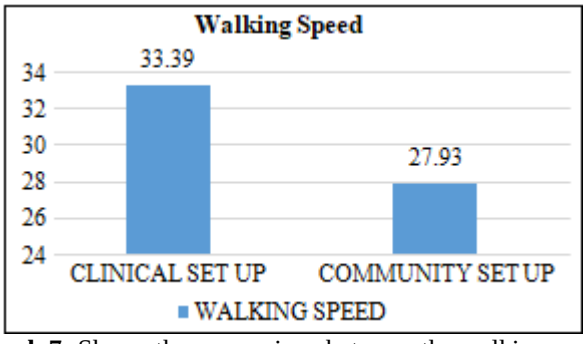


Graph 6: Shows the comparison between the walking heart of study group in clinical and community set up

Walking Heart Rate (WHR) was capable of discriminating a highly significant difference between the clinical and community set up (P<0.001). A bar graph shows greater WHR in the community set-up.

Table 6: Shows the mean walking speed of patients with stroke in clinical and community set up.

	Walking Speed	P-Value
Clinical Set up	33.39 ± 15.37	0.0001
Community Set up	27.93 ± 14.57	



Graph 7: Shows the comparison between the walking speed of the study group in clinical and community set up.

Walking speed was capable of discriminating a highly significant difference between the clinical and community set up (P<0.001). A bar graph shows greater walking speed in the clinical set-up.

5. Discussion

A total of 30 participants with stroke were included in the study. The mean age of participants selected was 51.5 ± 14.5 yrs. The gender ratio of the study group was 19:11 (19 Male, 11 Female). The mean duration of symptoms in the participants was 1.5 ± 1.9 yrs. The percentage of Right-side involvement was 56.33% and Left 43.33%. Most of the participants didn't require any walking aids however one participant used AFOS while walking and four used canes.

This study aimed at finding out the difference between the physiological cost index (PCI)in the Clinical and community set up among patients with stroke. To accomplish the aim the energy expenditure between the two setups was

compared by calculating the resting heart rate, walking heart rate and walking speed.

We found out that the PCI value was greater in the community set up as compared to the clinical setup.The structural lesion in the nervous system results in changes in the vagal and sympathetic activity, which contributes to an altered response to exercise. PCI has a linear relation with the heart rate and indicates an increase in the energy cost during walking. In our study, there is an increase in the walking heart rate in the community environment. The participants required more muscular efforts to walk in a community set up than clinical therefore the greater PCI value.

An increase in the walking heart rate in the community was obtained as various factors were affecting the heart rate during walking such as environmental, stress, psychological, etc. Most of the participants found it easier to walk in a clinical environment than community. The participants were familiar with the clinical set up used for the study and have been performing gait training session inside the clinic. It required more effort to walk in a community set up hence the greater heart rate. They were trained regularly to walk inside the clinic in closely spaced. So, walking in an opened environment at ground levelsuddenly was more difficult. Also, the community walkway was of concrete tiles and even surface but no slopes. Some of the patients were even more conscious and alert while walking outside in the community to prevent themselves from fall. These factors also led to a decrease in the walking speed in the community. Therefore, the clinical setting is less complex to walk than a community setting for patients with stroke.Most of the studies used a treadmill test to calculate the PCI such as in the study"Physiological Cost Index as a Proxy Measure for the Oxygen Cost of Gait in Stroke Patients" by Eric FredricksonET. Al. used treadmill with the initially comfortable chosen speed and later set gait speed to calculate the energy cost.They concluded that the Physiological Cost Index and oxygen cost had a good to excellent correlation for subjects with stroke.

Both oxygen cost and the Physiological Cost Index were comparable in detecting a significantly abnormal elevation for stroke survivors versus healthy adults and many other studies.[11] However, we preferred the floor test (ground level) because of the ability to select the self-paced walking speed and the possibility of using walking aids during the test.

A positive correlation between the walking speed and the physiological cost index in both the community and clinical set up was obtained. The decrease in the gait speed increases the muscle effort while walking which increases the PCI value. Gait speed was also decreased due to the altered gait pattern. Also, the energy cost during walking is highly correlated to the other aspects of walking. Similar to the studies by Anna DanielsonET. Al. "Measurement of energy cost by physiological cost index in walking after stroke" [12] and "The Repeatability of Gait Speed and Physiological Cost Index Measurements in Working Adults" by Rishi Raj ET. Al. which demonstrates that gait speed, heart rate change, and PCI measurements are repeatable in healthy working adults and indicates that simple measurements of gait speed will likely provide the most reproducible estimate of functional status.[19] Some studies concluded that altered gait pattern in patients with stroke decreases the gait speed.

Few of the participants used walking aids while walking. Use of such aids increases muscle effort while walking.The material of the walking aids also affects the speed of walking the lighter the material the more the speed. The participants using walking aids show the greater value of PCI as more effort was required. It was easier for them to walk inside the clinic with the walking aids but difficult to walk outside due to the uneven surface. One of the participants found it easier to walk in the community set up because he perceived the clinical environment as a compact space. Walking with aids support increases energy consumption and lowers the walking speed. Study supporting this finding is by Teuta Osmani Vilasoli ET. al. "PCI and comfort walking speed in two-level lower limb amputees having no vascular diseases" [14] in which the energy consumption was compared between the walking aid support group and the control group.

Limited information is available about the relevance of walking ability measured in clinical compared with the community. It was difficult to compare our findings with different authors as there is no literature available for comparing PCI in such two setups. However, there are studies such as by Anna Sofia Delussu ET. At. "Concurrent Validity of Physiological Cost Index in Walking over Ground and during Robotic Training in Subacute Stroke Patients" in which they have compared PCI in 2 different walking conditions over the ground and gait trainers with bodyweight support and have concluded excellent correlation between PCI and energy cost of walking and greater PCI value over the ground walking. [15] Another study by Rose et al. of PCI comparison in different walking speed. Also, other authorsCristiane Carvalho ET. Al.on "Walking speed and distance in different environments of subjects in the later stage post-stroke "which was on short and long-distance walking. [13]But they didn't compare the PCI between the two different clinical and community setups at ground level at the same time.

Therefore, if community ambulation training is started earlier in patients with stroke it would be much easier in the long term. Gait training programs which include flat community walking, uneven surface walking, obstacle walking in the community with gradually increase in the intensity will increase the speed and endurance while walking, increase the range of physical activity, motivation and interest in therapy and reduce stress. Hence overall promoting the quality of life on the patient.

6. Limitations

The major limiting factor in the present study was the smaller sample size. So further study can be done by taking a larger study group. In this study, the walkway used in the clinical and community set up was of 10m distance. Further studies can be done by increasing the walking distance or by changing the community environment instead of just an uneven surface.

7. Conclusion

From this study, we conclude that the physiological cost index is greater in the community set up than in clinical. The walking speed is greater in the clinical set up as compared to the community. Hence more muscular effort is required for the patient to ambulate outside the clinic. Moreover, community ambulation should be included in the rehabilitation protocol of stroke patients. The indoor setting test is mostly used during rehabilitation programs too often advice the patient regarding the community activities.

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