Physiological Cost Index of Walking in Stroke Patients and their Functional Ambulation Category

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Abstract

Background: Mobility, defined as the ability to walk safely and independently, is integral to the performance of basic activities of daily living.An interruption in the normal gait cycle and the energy conserving characteristics of the trunk and limb motion results in an increased energy expenditure.

Objective: The objective of the study was to compare the Physiological Cost Index(PCI) of walking in stroke survivors with their Functional Ambulation Category(FAC).

Design: Cross Sectional Study

Methods: 30 participants meeting the inclusion and exclusion criteria were included in the study. The participants were graded on FAC. Their heart rate(HR) was recorded pre- and post- 6-Minute-Walk-Test(6MWT). The distance walked was measured and recorded. The PCI was calculated and the data was subjected to statistical analysis.

Results: The mean PCI of all the participants was 0.72(±0.68). A moderate negative correlation existed between the PCI and FAC. The category of FAC increased as the patients PCI of walking decreased.

Conclusion: Increased PCI values could imply lower functional mobility scores on FAC. Therapeutic interventions that alter PCI values and interventions that effectively reduce energy consumption could be identified for better rehabilitation outcomes.

Key words: *Stroke; Physiological Cost Index; Functional Ambulation Classification; 6MWT.*

Introduction

Limb movements are produced as a response to muscle activity. Interruption of the normal gait cycle and the energy conserving characteristics of the trunk and limb motion will result in increased energy expenditure.[1]

Energy expenditure for walking varies with the degree of weakness and spasticity in hemiplegic patients as the condition reduces gait efficiency and increases the energy cost of walking up to twice that of able bodied individuals.[2] The physical capacity of Stroke survivors is often decreased because of de-conditioning thus further increasing the energy demands of activities of daily life.[3]

The Physiological Cost Index(PCI) estimates the energy cost of walking in healthy people, persons with lower limb amputation, walking with prosthesis[4]and also children.[5]It provides insight into endurance for people with stroke though motor impairments impact greatly on the 6-Minute-Walk-Test(6MWT) scores.[6]

The Functional Ambulation Category(FAC) ismeant to assess functional mobility or gait in persons suffering from Stroke.[7] This 6-point scale assesses ambulation status by determining the amount of human support required by patient when walking, regardless of the use of a personal assistive device.[8,9]

Recovery of mobility, specifically the ability to walk safely and independently in the home and community, is one of the most important goals reported by patients following a stroke. Self-efficacy related to balance and falls and environmental determinants that influence community walking have been studied in the past.[10]

Energy cost is an important parameter in the evaluation of locomotor disability. The search for review identified a lack of studies comparing the PCI of walking and the FAC of stroke survivors. Keeping in view, the socioeconomic impact of stroke on patients, families and health service providers, it is of utmost importance to implement various rehabilitation methods which not only improve balance and gait but simultaneously increase the efficiency of performing the task and also reduce the on-going cost of long term care, as both are crucial for the quality of life of stroke victims.

Methodology

Inclusion Criteria: Stroke survivors aged 30 to 64 years with a history of an incident stroke at least 6 months prior to data collection, weremedically stable with an ability to walk independently (with or without lower limb orthoses)[11] for 6 minutes duration were included in the study.

Exclusion Criteria: Persons who disagreed for participation and those with impaired cognitive function (unable to understand information or follow instructions), communicative impairments, neuromuscular diseases, claudication, and severe musculoskeletal problems affecting the lower extremity or spine were excluded. Persons suffering from any other orthopaedic(musculoskeletal problems relating to conditions other than stroke) or neurological (other than stroke-induced) diseases impairing gait were also excluded. Persons with a history of previous myocardial infarction and/or recurrent stroke and those using walking aids(canes, walkers, rollators etc.) also were excluded from the study.

Procedure:

Ethical clearance was obtained from the Institutional Ethical Committee.

The purpose of the study was explained to the 63 stroke survivors referred to physiotherapy for neurorehabilitation.30 patients did not meet the inclusion criteria (4 did not consent for participation, 2 had previous myocardial infarction, 13 couldn't stand while 11 couldn't walk independently for at-least 6 mins). 33 patients were included in the study. 3 patients couldn't come for the test due to personal reasons. Demographic data and baseline characteristics of participants were recorded. The participants were categorized according to the FAC. Participants were explained the procedure of 6MWT in detail and informed that they could take rest in the middle of the test/walk if they felt any fatigue, breathlessness or any other problems.

The participants sat on a chair for about 3 minutes prior to 6MWT. HR at rest was measured using the portable pulse oximeter(Scure) and recorded. The participants were then asked to walk along the predetermined 10 meter long track for 6 minutes at their self-selected speed.

Participants were asked to sit on the chair after completing the duration of walk and the post-walk HR was measured and recorded. Distance walked by the participants was measured and recorded for calculating the speed of walking. Data thus collected was used for calculating the PCI of walking using the formula below.[11,12]

PCI = Post Walking HR(beats/min) – Resting HR(beats/min)

Speed(m/min)

Results

Data of the 30 participants was subjected to appropriate statistical data analysis, using SPSS-version23.0.

Table–1: Participants'Demographic Data

	Females	Males	t-value	P-value
N(%)	7(23)	23(77)		0.001*
Mean Age(Years±SD)	52.4(±6.9)	55.4(±8.8)	-0.80237	0.43
Mean PCI(±SD)	0.99(±1.10)	0.65(±0.52)	1.2792	0.21
Mean BMI(±SD)	24.1(±2.9)	23.4(±3.3)	0.491	0.63
6MWD(±SD)	117(±36.8)	124(±37.8)	-0.44435	0.66
Walking Speed	19.5(±6.1)	20.7(±6.3)	-0.45463	0.65

*p<0.05 was statistically significant.

Table–1 demonstrates the participants' demographic details. The participants included 23(77%) male and 7(23%) female stroke patients with a mean PCI of 0.65(±0.52) and 0.99(±1.10) respectively. The Z-Score for 2 population proportions was 4.1312 with a p-value of 0.001 which was significant. The population of males (0.767)among stroke survivors was significantly higher as compared to females (0.233). The mean ages of the men and women were 55.4(±8.8) and 52.4(±6.9) years, while BMI were 23.4(±3.3) and 24.1(±2.9) respectively. There was no significant difference in the mean ages and BMI of both the genders. Gender also did not influence the 6MWD and walking speed.

16 and 14 patients had a right and left sided stroke respectively. 15(50%) patients had a dominant side stroke while an equal number had a non-dominant side stroke, with no difference in proportion. The PCI of patients with dominant(0.58)side stroke and non-dominant(0.88)side stroke were non-significantly different at a *t*-value of -1.2019 and *p*-value of 0.24.

Table–2 shows the participants'details according to the type of Stroke. 21(70%) and 9(30%) suffered an ischaemicstroke(IS) and haemorrhagic stroke(HS) respectively. The proportion of IS(0.7) was significantly higher as compared to HS(0.3) with a mean PCI of 0.84 and 0.45 respectively, at a Z-Score for proportion of 3.0984 and p-value of 0.002.

Table–2: Participants' details according to type of Stroke

	HS	IS	t value	P value
No. of Participants n(%)	9(30)	21(70)		0.002*
Mean Age in Years(±SD)	50.56(±10.37)	56.52(±7.33)	1.80272	0.08
Mean PCI	0.45(±0.34)	0.84(±0.68)	1.45824	0.16

*p<0.05 was statistically significant.

Persons with 1 or more co-morbid conditions, hypertension or diabetes or both, were 13(43%) with a frequency of 7, 3 and 3 respectively. PCI of persons with 1 or more co-morbidities(0.79) was not significantly different from those without co-morbidities(0.68).

The mean 6-minute-walk-distance(6MWD) of all patients was 122.6(±37.04)meters and walking speed was 20.41(±6.1)m/min. The mean blood pressure(BP) of the participants were 131.3(±8.6)/91.16(±11.11) and 138.8(±9.53)/93.83(±10.72) at rest and post 6MWT respectively.

Table–3: Age wise frequency distribution of patients

	30 – 41	42 – 53	54 – 64
No. of Participants n(%)	2(10)	9(27)	19(63)
Mean Age in Years(±SD)	36(±3)	47.1(±4.04)	60.3(±3.04)
Mean PCI	0.24	0.58	0.85

The frequency distribution (Table–3) of participants in the age groups of 30–41, 42–53 and 54–64 years was 2, 9 and 19 with a mean PCI of 0.24, 0.58 and 0.85 respectively. The highest prevalence of stroke was found in the age group of 54–64 years. The Kruskal-Wallis chi squared statistic of 6.097, with a p-value=0.047,signified that one or more of the independent groups were different.

The Dunn test(Table–4), said to be appropriate for groups with unequal number of observations, was used for Post-hoc pairwise multiple comparisonto discern the pairs with significant differences.A PCI was significantly higher among the 54-64 year age group as compared to that of 30-41 years at p-value 0.03.

Table–4: Dunn's p values

Age Classes	30 – 41	42 – 53
42 – 53	0.21	
54 – 64	0.03*	0.12

*p<0.05 was considered statistically significant.

Table–5: Mean PCI, 6MWD and Speed of persons according to FAC

FAC	N	PCI	6MWD	Speed
3	10	1.1	95	15.8(± 4.5)
4	14	0.6	135.7	22.6(± 6)
5	6	0.5	138.3	23(± 5)
Pearson's Correlation Coefficient r		-0.93	0.89	0.89

The mean PCI of walking of all the patients was 0.72(±0.68). The value of r for Pearson's correlation between PCI and the FAC was -0.38. Although technically a weak negative correlation existed between the two variables, the p-value from Pearson(R) Calculator for the same was significant at 0.039.

The frequency distribution of patients(Table–5) across FAC 3, 4, and 5 showed 10, 14 and 6 participants in each category with a mean PCI of 1.1, 0.6 and 0.5 respectively. The PCI of patients with FAC 3 was twice that of those with a FAC 4 or 5. Patients with FAC 4 and 5 demonstrated a 43-45% greater 6MWD and speed of walking as compared to patients with a FAC 3. A correlation of the mean PCI's with the FAC category showed a strong negative correlation(r=-0.93,p=<0.00001). The speed and 6MWD strongly positively correlated with the FAC category(r=0.89,p=<0.00001).

Table–6: Analysis of PCI, 6MWD and Speed of persons with FAC

	adjusted H	d.f.	P value	Dunn p-values		
				FAC 3 & 4	FAC 4 & 5	FAC 3 & 5
Speed	9.587	2	0.008*	0.01*	0.49	0.01*
6MWD	9.587	2	0.008*	0.01*	0.49	0.01*
PCI	2.628	2	0.269			

* p<0.05 was considered statistically significant.

The Kruskal-Wallis chi squared statistic comparing the FAC with speed, 6MWD and PCI (Table–6) was 9.587, with p-value 0.008 for both speed and 6MWD. This p-value signifies that one or more of the independent groups are different. The post-hoc pairwise multiple comparisons(Dunn p-valuesfurther adjusted by Benjamini-Hochberg FDR method)showed that speed and 6MWD among persons with a FAC 4 and 5 was significantly higher than that of those with FAC 3. Thespeed and 6MWD of persons with FAC 4 and 5 were not significantly different.

Discussion

This cross-sectional study aimed to compare the PCI of walking among30-64 years old stroke survivors with their FAC.

30 patients were included in the study. The prevalence of men with stroke was significantly higher than women. The male participants were

three times the female participants. These results are supported by studies which report a 41% higher prevalence of stroke in men than women.[13] Mean ages and BMI were not differentamong both the genders. Influence of gender on 6MWD and walking speed was compared as women and men have different anthropometric characteristics, however no influence was observed. Previousstudy also reports that, there were no differences in preferred walking speed(velocity) and cadence in men and women.[14]

A comparison ofhand dominance and side of occurrence of stroke showed an equal number of patients with dominant and non-dominant side strokes, with a non-significant difference in their PCI. A study reported that 45% stroke survivors were affected by stroke on the dominant arm side, similar to our findings.[15]

70% of the participants in the case group suffered an IS. This is supported by a study which reports that 80% of all strokes are IS while 15% are hemorrhagic strokes.[16] The high prevalence of IS could be due to presence of risk factors (Hypertension and diabetes) which are accounted for increase in the total IS.A higher prevalence of hypertension and diabetes has been reported in men as compared to women in recent studies. In India the crude prevalence of diabetes has been reported at 7.3% and 7.8% among women and men respectively, while that of hypertension was 23.6% and 27.4% women and men respectively.[17] IS has also been reported to be highest among smokers.[18] Age did not influence the type of Stroke in our sample. The PCI of walking in ISsurvivorswere double those in HS survivors.

43% patients reported a presence of comorbid conditions. Highest frequency(33%) of hypertension was noted among participating patients. Elevated BP was reported highly prevalent across different stroke subtypes.[19] The PCI of persons with 1 or more co-morbidities and without co-morbidities were 0.79 and 0.68 respectively. Comparison for habits affecting the PCI was not undertaken as only 5 patients reported a presence of one or more habits (Alcohol consumption, Smoking, Beetle Nut and Tobacco chewing).

The results demonstrated highest frequency of stroke patients after 54 years of age, which was 9 times and 2 times greater than the 30–41 and 42–53 age groups respectively. Significantly higher PCI of walking was also noted in this age group. Increasing prevalence of stroke was noted with increasing age.Previous data which states that risk of stroke more than doubles each decade after the age of 55supports this result.[20] The American Heart Association statistics of 2015 shows increasedstroke prevalence in persons above 60 years.[21]

Results showed that PCI of walking decreased with increased FAC. This may indicate that persons requiring a lower PCI for walking, may tend to require lesser assistance for walking. The speed and distance of walking were also found to be greater in persons with a higher FAC.

Conclusion

The small sample size of the study may be a drawback making the generalization of the result difficult. However walking being a major daily activity, impaired walking function may contribute to greater functional disability after stroke. Factors affecting it need to be assessed and managed appropriately, as improved walking function is the goal most often stated by patients with stroke. We suggest that the stroke-specific exercise guidelines should include PCI as an outcome measure to help patients walk with lesser energy consumption for a more independent and better living.

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References

1. Waters R, Mulroy S. The energy expenditure of normal and pathologic gait. Gait & Posture. 1999;9(3):207-231.
2. Delussu A, Morone G, Iosa M, Bragoni M, Traballesi M, Paolucci S. Physiological responses and energy cost of walking on the Gait Trainer with and without body weight support in subacute stroke patients. Journal of NeuroEngineering and Rehabilitation. 2014;11(1):54.
3. IJmker T, Houdijk H, Lamoth C, Jarbandhan A, Rijntjes D, Beek P et al. Effect of Balance Support on the Energy Cost of Walking After Stroke. Archives of Physical Medicine and Rehabilitation. 2013;94(11):2255-2261.
4. Vllasolli T, Orovcanec N, Zafirova B, Krasniqi B, Murtezani A, Krasniqi V et al. Physiological Cost Index and Comfort Walking Speed in Two Level Lower Limb Amputees Having No Vascular Disease. ActaInformaticaMedica. 2015;23(1):12.
5. Raja K, Joseph B, Benjamin S, Minocha V, Rana B. Physiological Cost Index in Cerebral Palsy. Journal of Pediatric Orthopaedics. 2007;27(2):130-136.
6. Lord S, Rochester L. Measurement of Community Ambulation After Stroke. Stroke. 2005;36(7):1457-1461.
7. Rehabilitation Measures [Internet]. Shirley Ryan AbilityLab - Formerly RIC. 2019 [cited 18 May 2019]. Available from: http://www.rehabmeasures.org/Lists/RehabMeasures/DispForm.aspx?ID=920
8. Functional Ambulation Categories (FAC) - Stroke Engine [Internet]. Stroke Engine. 2019 [cited 18 May 2019]. Available from: https://www.strokengine.ca/assess/fac/
9. Mehrholz J, Wagner K, Rutte K, Meiβner D, Pohl M. Predictive Validity and Responsiveness of the Functional Ambulation Category in Hemiparetic Patients After Stroke. Archives of Physical Medicine and Rehabilitation. 2007;88(10):1314-1319.
10. Robinson C, Matsuda P, Ciol M, Shumway-Cook A. Participation in Community Walking Following Stroke: The Influence of Self-Perceived Environmental Barriers. Physical Therapy. 2013;93(5):620-627.
11. Danielsson A, Willén C, Sunnerhagen K. Measurement of Energy Cost by the Physiological Cost Index in Walking After Stroke. Archives of Physical Medicine and Rehabilitation. 2007;88(10):1298-1303.
12. Peebles K, Woodman-Aldridge A, Skinner M. The physiological cost index in elderly subjects during treadmill and floor walking. New Zealand Journal of Physiotherapy [Internet]. 2003 [cited 18 May 2019];31(1). Available from: https://www.thefreelibrary.com/_/print/PrintArticle.aspx?id=160592626
13. Kurth T, Gaziano J, Berger K, Kase C, Rexrode K, Cook N et al. Body Mass Index and the Risk of Stroke in Men. Archives of Internal Medicine. 2002;162(22):2557-2562.
14. Chiu M, Wu H, Chang L. Gait speed and gender effects on center of pressure progression during normal walking. Gait & Posture. 2013;37(1):43-48.
15. Harris J, Eng J. Individuals with the Dominant Hand Affected following Stroke Demonstrate Less

Impairment Than Those with the Nondominant Hand Affected. Neurorehabilitation and Neural Repair. 2006;20(3):380-389.

16. Men and Stroke [Internet]. Cdc.gov. [cited 18 May 2019]. Available from: https://www.cdc.gov/stroke/docs/men_stroke_factsheet.pdf
17. Geldsetzer P, Manne-Goehler J, Theilmann M, Davies J, Awasthi A, Vollmer S et al. Diabetes and Hypertension in India. JAMA Internal Medicine. 2018;178(3):363.
18. Stroke [Internet]. Gum.rgare.com. 2012 [cited 18 May 2019]. Available from: https://gum.rgare.com/SupplementalContent/files/4/stroke.pdf
19. Qureshi A, Ezzeddine M, Nasar A, Suri M, Kirmani J, Hussein H et al. Prevalence of elevated blood pressure in 563704 adult patients with stroke presenting to the ED in the United States. The American Journal of Emergency Medicine. 2007;25(1):32-38.
20. Mozaffarian D, Benjamin E, Go A, Arnett D, Blaha M, Cushman M et al. Heart Disease and Stroke Statistics—2015 Update. Circulation. 2015;131(4).
21. Appelros P, Stegmayr B, Terént A. Sex Differences in Stroke Epidemiology. Stroke. 2009;40(4):1082-1090.