

ORIGINAL ARTICLE

Open Versus Closed Kinetic Chain Exercise: a Comparison of Walking Capacity in Chronic Post-Stroke Phase

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ABSTRACT

Introduction: The chronic post-stroke phase is often accompanied by various sensory, cognitive, motoric, coordination, and balance impairments. Decreased strength and motoric control contribute to walking capacity in patients with stroke. Open Kinetic Chain (OKC) and Closed Kinetic Chain (CKC) were reported to improve strength, functional mobility and balance in the chronic post-stroke phase. However, there is a physiologically differences between CKC and OKC exercise. This study aims to compare the result of two methods of progressive resistant training (PRT) on walking capacity in the chronic post-stroke phase.

Methods: This study is a quasi-experimental pre- and post-controlled trial group design. Twenty subjects were randomized into two groups of equal size: the CKC group (n=10) and the OKC group (n=10). There was one subject from each group who dropped out at the end of the study. CKC and OKC groups were trained for 6 weeks. The walking capacity was measured with 2 Minutes Walking Test (2WMT).

Results: 2WMT results showed improvement in both groups after 6 weeks of intervention, while CKC group show greater improvement in walking distance $56,17 \pm 10,95$ □ to $57,43$ compared to OKC group $57,04 \pm 8,58$ to $58,19 \pm 8,77$ ($p < 0.002$).

Conclusions: This study shows CKC group showed slightly better improvement in walking capacity after 6 weeks of progressive resistance training compare to OKC group. However, there were no statistically differences between the groups

Keywords: chronic post-stroke phase, closed kinetic chain exercise, open kinetic chain exercise, walking capacity

ABSTRAK

Pendahuluan: Pada pasien pasca stroke fase kronik sering disertai dengan berbagai gangguan sensorik, kognitif, motorik, koordinasi, dan keseimbangan. Penurunan kekuatan dan kontrol motorik berkontribusi terhadap kapasitas berjalan pada pasien stroke. *Open Kinetic Chain* (OKC) dan *Closed Kinetic Chain* (CKC) dilaporkan dapat meningkatkan kekuatan, mobilitas fungsional dan keseimbangan pada fase kronis pasca stroke. Namun, ada perbedaan fisiologis antara latihan CKC dan OKC. Penelitian ini bertujuan untuk membandingkan hasil dari dua metode *progressive resistance training* (PRT) terhadap kemampuan berjalan pada pasca stroke fase kronis

Metode: Desain penelitian ini adalah *quasi-experimental pre- and post-controlled trial group*. Dua puluh subjek secara acak dikelompokkan ke dalam dua kelompok penelitian dengan jumlah yang sama; kelompok CKC (n=10) dan OKC (n=10). Terdapat satu subjek dari masing-masing kelompok yang *drop-out* pada akhir penelitian. Kelompok CKC dan OKC menjalani program latihan selama 6 minggu. Kemampuan berjalan diukur dengan *Two-minutes Walking Test* (2MWT)

Hasil: Uji 2MWT menunjukkan perbaikan kemampuan berjalan pada kedua kelompok latihan setelah 6 minggu intervensi, dimana kelompok CKC menunjukkan peningkatan lebih baik pada jarak tempuh jalan $56,17 \pm 10,95$ to $57,43 \pm 11,29$ ($p < 0.001$) dibandingkan kelompok OKC $57,04 \pm 8,58$ to $58,19 \pm 8,77$ ($p < 0.002$).

Kesimpulan: Studi ini menunjukkan kelompok CKC menunjukkan peningkatan kemampuan berjalan yang sedikit lebih baik setelah 6 minggu pelatihan resistensi progresif dibandingkan dengan kelompok OKC. Namun, tidak ada perbedaan statistik antara kelompok.

Kata Kunci: kemampuan berjalan, latihan rantai kinetik terbuka, latihan rantai kinetik tertutup, pasca stroke fase kronik

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INTRODUCTION

Stroke is the second leading cause of death worldwide and responsible for 4.4 million deaths each year. According to US National

Center for Health Statistics, the mortality rate of stroke has decreased over the year.^{1,2} However, the disability rate following stroke remains high. Muscle weakness, incoordination, and loss of dexterity limit the recovery of physical functioning, such as balance, walking capacity, and activities of daily life.³ Approximately fifteen to thirty percent of survivors remain permanently disabled whilst independent walking after stroke has been reported as varying from 26,7% to 75%.⁴

Many rehabilitation strategies for stroke have been suggested, though the choice of appropriate

programs remains uncertain.⁴⁻⁶ A major focus of stroke rehabilitation is to increase muscle strength and enhance proprioceptive function, thus improving walking function to a safe level for community ambulation.⁷⁻⁹ Muscle strengthening for stroke generally consists of high-intensity resistance training, low-intensity resistance training, and progressive resistant training (PRT). The principles of PRT are to provide sufficient resistance, progressively increase the amount of resistance as strength increases, and continue the training program for benefits to accrue without exacerbating the spasticity after stroke.^{3,6} The effects of Closed Kinetic Chain (CKC) and Open Kinetic Chain (OKC) exercises in patients with stroke have not been well suggested, however some studies founds PRT is effective in improving muscle strength following a stroke.¹²

PRT is largely classified into CKC and OKC exercises.^{5,6,10} OKC is an exercise where the distal aspect of the extremity is not fixed to an object and terminates free in space. The movements are typically non-weight bearing exercises and are characterized by a rotatory stress pattern at the joint. The opposite of OKC is CKC, where the distal aspect of the extremity is fixed to a stable object that generates compressive force in the proximal aspect. CKC exercise has been shown to increase muscle strength and neuromuscular control of the lower extremity in young athletes (Fleming et al., 2005; Jan et al., 2009). The benefits of CKC exercise are becoming increasingly accepted and employed in the clinical setting^{3,4}

OKC and CKC were reported to improve muscle strength, gait and functional mobility in the chronic post-stroke phase. However,

CKC exercise considered to be more functional and resemble real life movement such as walking. Exercises that strengthen the muscles of agonists and antagonists in a way simultaneously is a more physiological for the lower limbs. CKC also increase proprioceptive stimulation in the knee joint that improves the stability of the joints and balance. As for physiologically differences between CKC and OKC, moreover, there is a lack of studies emphasizing the difference effect of OKC and CKC on walking capacity. The purpose of this study, therefore, was to compare the result of OKC vs CKC exercise on walking capacity in the chronic post-stroke phase.

METHODS

Subjects

Twenty patients with hemiparesis due to a chronic stroke participated in this study. Each subject was randomly assigned to a CKC exercise group ($n=10$) and an OKC exercise group ($n=10$). Inclusion criteria were as follows: (1) a stroke occurring 6 to 18 months before the start of the study, (2) age between 50 to 65 years, (3) Modified Ashworth Scale Score <3 , (4) lower extremities motoric strength >3 , (5) sufficient cognition for participating in the study (MOCA-Ina Score >26), and (6) able to walk without a walking aid. Exclusion criteria were (1) bilateral hemiparesis, (2) open wound, bleeding, inflammation, and malignancy on the lower extremities (3) visual, vestibular, proprioceptive, and perception impairments, (4) postural and gait abnormalities. All the participants understood the purpose of this study and gave their written informed consent before experimental involvement. The study was

approved by the Ethics Research Committee of Diponegoro University, Semarang, Indonesia.

Training methods

A warm-up set of four repetitions was performed to begin each training session. The main training session consists of 3 sets (10 repetitions per set) with 3-minutes rest between each set; the first set at 50% of their 1-repetition maximum (1RM), followed by the second set at 75% of the 1RM, and the last set at 100% of the 1RM using a sandbag in various weights. The training sessions were performed 2 times per week for 6 weeks in both CKC and OKC exercise groups, supervised by a physical therapist.

OKC exercise was performed with the knee maintained at 90 degrees of flexion with a free distal extremity. Participants were asked to extend their paretic leg and then slowly flex the knee joint into starting position (Figure 1). This main exercise was performed in a sitting and prone position and then ended with 1 minute cooling down session.



Figure 1. Open kinetic chain exercise

CKC was performed in a sitting position with the paretic foot fixed on the floor. Participants were asked to perform the sit-to-stand exercise,

starting with 4 repetitions without weights, followed by 3 sets of the sit-to-stand exercise set at 50%, 75%, and 100% of 1RM, respectively (Figure 2). This exercise ended with a 1-minute cooling-down session.



Figure 2. Closed kinetic exercise

Outcome measurement

Walking capacity was assessed by using a Two-minutes walking test (2MWT) before and after the intervention (Figure 3). Good intra-rater and interrater reliability have been described for distances achieved during 2MWT in patients with stroke, multiple sclerosis, and older adults residing in long-term care. According to Bohannon et al., the distance walked in 2 minutes is a valid indicator of the distance covered in 6 minutes.¹¹



Figure 3. Two-minutes walking test

Statistical analysis

Data analysis was performed with the SPSS software. Normality of data distribution was tested with the Shapiro-Wilk test, which revealed normal distribution for the parameters. The Independent t-test was used to perform a hypothetical analysis. The paired t-test was used to identify the differences before and after intervention in both exercise groups. A *p*-value of <0.05 and a Confidence Interval (CI) of 95% was used as the criterion for statistical significance.

RESULTS

A total of 20 participants met the inclusion criteria and were randomized into either the CKC exercise group (n=10) or the OKC exercise group (n=10). There was one drop-out from the CKC exercise group due to transportation problems and one drop-out from the OKC exercise group due to an illness unrelated to the PRT and these subjects were excluded from the statistical analyses. There were no significant differences between the groups. A summary of the baseline characteristics of each group is presented in Table 1.

Table 1. Baseline characteristics of each group

Variable	Exercise Group		p
	CKC	OK	
Sex			
Male	6 (66,70%)	6 (66,70%)	0,690¥
Female	3 (33,30%)	3 (33,30%)	
Age (years)	56,89 ± 5,26	56,56 ± 3,36	0,875§
Post-stroke duration (month)	11,89 ± 4,01	12,33 ± 3,16	0,797§
Paretic side			
Right	3 (33,30%)	2 (22,20%)	0,500¥
Left	6 (66,70%)	7 (77,80%)	

CKC: Closed Kinetic Chain. OKC: Open Kinetic Chain. § Independent t-test; ¥ Fisher's exact test

Walking capacity was assessed using 2MWT before and after the intervention. In Table 2, the mean values before and after are presented, together with the between-group differences. For the CKC exercise group, the 2MWT result increased significantly after the intervention (56.17 ± 10.95 to 57.43 ± 11.29 ; $p < 0.05$). For

the OKC exercise group, the 2MWT result also increased significantly after 6 weeks of intervention (57.04 ± 8.58 to 58.19 , $p < 0.05$). There was no significant difference between the CKC and OKC exercise groups before ($p = 0.852$) and after the intervention ($p = 0.876$).

Table 2. Comparisons of walking capacity in CKC and OKC groups

2MWT	Exercise Group		p
	CKC	OK	
Pre test	56,17 ± 10,95	57,04 ± 8,58	0,852§
Post test	57,43 ± 11,29	58,19 ± 8,77	0,876§
<i>p</i>	0,001¶*	0,002¶*	
Delta	1,27 ± 0,72	1,14 ± 0,74	0,725§

CKC: Closed Kinetic Chain. OKC: Open Kinetic Chain. 2MWT: Two-minute walking test. Values are presented as mean ± SD. *Significant difference ($p < 0.05$); §Independent t-test; ¶ Paired t-test

DISCUSSION

Stroke frequently results in muscle weakness and damage to the proprioceptive systems, which consequently causes poor balance, difficulties with voluntary movements, and impaired walking capacity.^{4,6-8} The relationship between muscle strength and functional skills has been described as curvilinear.^{3,5,12} Therefore, the major focus of stroke rehabilitation is to increase muscle strength and enhance proprioceptive function, thus improving walking capacity to a safe level for community ambulation.⁷⁻⁹

A majority of stroke patients are able to walk but their gait is characterized by low velocity, low cadence, short stride length, increase double support phase and asymmetrical single limb support phases. They commonly have a decreased stance time on their affected leg and consequently short time on their affected leg and consequently a short step length with their nonaffected leg.¹³

In the current study, subjects in both CKC and OKC exercise groups improved to a similar extent in 2MWT results after the intervention.

OKC exercise principle of reciprocal inhibition, stretching or contraction of the flexor muscles inhibits the activity of the flexor motor neurons can isolate a specific muscle group for intense strengthening and endurance exercises. In addition, OKC exercise can develop strength in a very weak muscle that may not function properly in the CKC system because of muscle substitution. Although OKC produces a greater amount of shear, this exercise may produce great gains in peak force production and is usually limited to one joint in a single plain.^{4,13}

Bohannon et al., 2014. found that the gait speed can be expected to be reduced in individuals of greater age and lesser height and lower extremity muscle strength. Gait performance is correlated with measures of knee extensor muscle torque (KET) in stroke patients. To be more specific muscle strength of the paretic side, whether indicated by force torque measurements has been found to correlate with gait speed, cadence and distance.¹¹

In contrast, CKC exercise may help strengthen the quadriceps and hamstring simultaneously, while also using the hip and ankle joints, thus providing feedback from the entire lower extremity to increase the stimulation of mechanoreceptors around the joint and firing muscle spindles. The CKC exercise requires a more eccentric knee extensor strength to control the movement than the OKC exercise, therefore activating more muscle spindles and Golgi tendon organs. Additionally, CKC exercise increases the intra-articular pressure and enhances joint position sense by stimulating Ruffini nerve endings, which are sensitive to the changes in intracapsular fluid volume. This would, provide feedback from the entire lower extremity (rather than simply from the exercised joint in OKC exercise), and hence the increase in the stimulation of mechanoreceptors around the joint and firing muscle spindles. CKC stimulates proprioceptors, increase joint stability, increases co. activation, allow better utilization of the said principle and permit more functional patterns of movement particularly in lower extremity because they closely stimulate the actual movement patterns encountered in daily activities.⁴

In addition, the tibialis anterior activation may work more effectively together with higher force generation after calf muscle stretching. Insufficient activation of the gastrocnemius and tibialis anterior are often observed at this point of the gait cycle in stroke patients, and leads to an insufficient push off and toe clearance that can affect stride length and cadence. These results indicate that CKC exercise could be the proper rehabilitation method for stroke patients.^{4,5,9,13}

It was noted that the subjects in our CKC group had a slightly higher improvement of 2MWT compared to the OKC group. However, there was no significant difference between the groups. This may be explained by the fact that the improvement in strength from resistance training does not necessarily translate into significant gains in walking capacity. In other cross-sectional studies, walking capacity following stroke has been related to various physical factors, such as motor recovery, balance ability, spasticity, leg muscle strength and cardiorespiratory fitness, also psychological factor such as balance confidence.^{4,13,14}

LIMITATION OF STUDY

This study has several limitations. First, the number of participating subjects was relatively small, which affected the statistical power and some of the lack of significance between the OKC and CKC groups could be due to this reduced power. Secondly, another variance in change in walking capacity remains unexplained. The determinants of walking capacity may be multifactorial, and not all the potential determinants were measured in this

study. Finally, the duration of the PRT, only 6 weeks, might have been too short and a longer period could have resulted in larger strength improvements and thereby greater differences in walking capacity between the groups. Therefore, further studies may be needed to clarify these issues.

CONCLUSION

This study shows significant improvement in walking capacity after 6 weeks of progressive resistance training. CKC exercise can improve lower limb muscle strength and balance in the chronic post-stroke phase, and it may carry over into an improvement in walking capacity.

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