Original Article

A Comparison of the Effect of Resistance Training on Upper Extremity Motor Function, Motor Recovery, and Quality of Life in Sub-acute Stroke Participants

Prabin Bastola, Priyanka Singh, [1]Deepak Pinto

Department of Physiotherapy, Sikkim Manipal Institute of Medical Sciences, Sikkim Manipal University, Gangtok, Sikkim, [1]MS Ortho, Associate Professor, KMC Mangalore, Manipal University, Karnataka India

Submission: 06-08-2019,
Decision: 05-03-2020,
Acceptance: 27-07-2020,
Web Publication: 03-03-2021

Abstract

Background and Objectives: Previous literature could not find sufficient evidence to support the use of resistance training (RT) protocol and its effect on stroke. Most of the studies were small and of moderate quality. Recommended in previous study that well-design randomized controlled trials with structured protocol are needed to determine the optimal exercise prescription. Hence, the objective of this study was to design a structured protocol of RT for sub-acute ischemic stroke subjects with moderate upper limb impairments. The primary aim of this study was to find the effect of RT on upper extremity (UE) motor recovery, motor function, and secondary aim was to find the effect of RT on health-related quality of life in stroke participants. **Materials and Methods:** There was total number of 40 participants, out of which 20 were in RT group and 20 were in conventional therapy (CT) group. Both the RT group and CT group received the same usual care rehabilitation programs for 30 min, and additionally, had each of their own therapies for 50 min per session, 5 days a week for 8 weeks. The action reach arm test (ARAT), manual muscle testing (MMT), Fugl-Meyer assessment (FMA), and stroke-specific quality of life (SS-QOL) were used as an outcome measure to assess gross manual dexterity, motor recovery of UE, and quality of life at preintervention and postintervention. **Results:** At baseline, participants of both group showed no significant differences regarding ARAT, MMT, FMA, and SS-QOL scores but after 8 weeks of intervention, participants of both group showed statistically significant improvements in all the variables measured ($P < 0{\cdot}05$). Moreover, participants of the RT group had greater improvement in all variables compared to CT group. **Conclusion:** The present study confirms that structured protocol used for RT is an effective treatment technique to improve UE motor recovery, motor function, and quality of life in stroke participants compare to CT. It is cost-effective, easy, and safe method for rehabilitation and most important can be easily administered at home by the participants.

Keywords: *Rehabilitation, resistance exercise, resistance training, stroke, upper extremity*

Introduction

Stroke is defined as "a clinical syndrome typified by rapidly developing clinical signs of focal or global disturbance of cerebral function with symptoms lasting 24 h or longer or leading to death with no apparent cause other than the vascular origin."[1] Stroke is a second leading cause of death and third leading cause of disease burden. In India, it has the prevalence of 200–350 per every 100,000 people with the incidence of 1.9% in urban and 1.1% in rural areas.[2] Occurs

Access this article online

Quick Response Code:

Website: www.mjdrdypv.org

DOI: 10.4103/mjdrdypu.mjdrdypu_227_19

Address for correspondence: Dr. Priyanka Singh, Associate Professor, Sikkim Manipal College of Physiotherapy, Sikkim Manipal University, 5th Mile, Tadong, Gangtok - 737 102, Sikkim, India.
E-mail: drpriyankampt@gmail.com

How to cite this article: Bastola P, Singh P, Pinto D. A Comparison of the effect of resistance training on upper extremity motor function, motor recovery, and quality of life in sub-acute stroke participants. Med J DY Patil Vidyapeeth 2021;14:219-25.

1.25 times greater in males than female with increasing age, doubling in the decade after sixties.[2] The physical effects of stroke are variable and may include impairment in motor, emotional, and sensory systems, language, perception, and cognitive function. Impairment of motor function involves paralysis or paresis of the muscles on one side of the body contralateral to the site of the brain lesion.[3,4]

Upper limb neuromuscular weakness occurs frequently after stroke with loss of muscle strength and dexterity together considered to produce the largest impact on functional recovery.[5] Upper extremities motor deficits or muscle strength are related to functional ability and may contribute more to loss of functional ability than impaired dexterity, muscle tone sensation, or pain leading to stroke-related disability.[6] Bourbonnais and Giuliani have found the changes after stroke which include denervation potentials, loss of motor units, and selective atrophy of type II muscle fibers, impaired motor unit recruitment, and decreased maximal contractions.[7] The overall contraction time has been found to be prolonged, and some studies have shown a decrease in the motor unit firing rate. All of these factors can contribute to muscle weakness.[8] The resulting weakness may impair movement production and control which leads to limitations in goal oriented activities, independence in everyday living, and work capacity. As substantial remodeling of motor units may occur between 2 and 6 months after stroke.[9]

Recovery of upper limb function involves three phases: First: activation of cell repairs; second: functional cell plasticity, and finally: neuroanatomical plasticity. An effective rehabilitation allows most participants to regain enough movement and control of their limbs to perform their activities of daily (ADL) living.[10] It might be possible to influence this process with therapies directed toward increasing muscle strength and thus motor function.[10] One objective of rehabilitation after stroke is to maximize the subject's independence in gross motor skills and walking and thus improve his/her ADLs.[11] Previous literature for stroke rehabilitation and the studies on the effects of strength training suggest that strengthening exercises may improve functional outcomes.[12]

Poststroke physical activity and fitness levels are low, and most important components of physical fitness are muscle strength, muscle power, flexibility, balance, and body composition. Most of the physical fitness training are classified as either cardio respiratory, resistance training (RT), or mixed training. RT employs activities involving muscle contraction resisted by weight, body mass, or elastic devices. It is related to improve muscle strength and muscle endurance or muscle power. RT has potential to influence body composition and improve flexibility and balance.[13] Evidences have demonstrated that exercise training has a strong capacity to collaborate with the changes on cardiorespiratory capacity, blood cardiovascular risk factors, body composition, mobility, cognition, physical capabilities, and balance of stroke survivors.[14] Some researchers have also proposed that RT that leads muscles to work or hold against an applied weight have a key role in the rehabilitation process after stroke.[15]

The different RT designs will elicit different adaptations. According to the principle of specificity, physical capacity will increased when the stimulus is similar to its performance. Previous studies differ in their RT variables (rest interval between sets and exercises, number of sets, number of repetitions, intensity, duration of training, and weekly frequency) leads to different cardiovascular metabolic and neuromuscular responses.[16] Neural mechanism has been speculated to account for increases in strength, particularly in the first 4 weeks of strength training. There are number of proposed neural mechanisms which include peripheral adaptation such as changes in motor unit behavior, reduced cocontraction of antagonist muscle groups and increased descending drive from supraspinal centers and modification in spinal cord circuitry such as increased motor neuron excitability.[17]

A systematic review of muscle strength training after stroke has found positive effects on both strength and functional activity.[5] Flansbjer *et al*. 2012 showed that there is a long-term benefit of progressive resistance exercise (PRE) in chronic stroke.[18] This implies that progressive RT could be an effective training method to improve and maintain muscle strengthening long term perspective.[19] Aidar *et al*. 2012 have also found that strength training may provide an improvement in trait and state anxiety.[20] A meta-analysis done by Ming-De Chen and Rimmer shown the moderate support for the use of exercise to improve health-related quality of life (HRQOL) in stroke survivor; however, effective strategies could not be identified so, further studies were suggested.[21] Donaldson *et al*. have found that RT can be considered in the treatment of stroke participants.[22]

It has been stated in previous study that even enough evidence is available to implement fitness training for stroke, the optimal exercise prescription has yet to be defined. Saunders *et al*. did a systematic review to find out the effects of physical fitness training on disability, dependency, and death. They could not find sufficient evidence to support the use of RT and its effect. Most of the studies were small and of moderate quality on chronic stroke participants. They recommended that well design randomized controlled trials are needed to determine the optimal exercise prescription and identify its long-term benefits.[13] Given the importance of RT in the treatment of stroke, the objective of this study was to design a structured protocol of RT for sub-acute stroke participants with moderate upper limb impairments so that health professionals will be more scientifically informed when prescribing resistance exercises for stroke individuals. The primary aim of this study was to find the effect of RT on upper extremity (UE) motor recovery and motor function, and secondary aim was to find the effect of RT on HRQOL in stroke participants.

Materials and Methods

Study population

Stroke participants were recruited from Central Referral Hospital in Sikkim, India, by the simple random sampling method. SMIMS Institutional ethics committee approved the study on April 23 with IEC registration number IEC/316/15-039. This study was not register for clinical trial registry in INDIA. Stroke was defined as an acute event of cerebrovascular origin causing focal or global neurologic dysfunction lasting more than 24 h, as diagnosed by a neurologist and confirmed by computed tomography or magnetic resonance imaging. Participants were included in the study if they (1) had a first episode of unilateral ischemic stroke with hemiparesis from 14 to 90 days (2) had a Brunnstrom score between stages II and III for the UE, (3) both gender of 30–80 years of age, (4) mini-Mental State Examination score (MMSE) ≥to 24 (21 for illiterate). (5) Able to sit independently for 60 min. We also applied the following exclusion criteria: Participants with hypertension, severe aphasia, severe shoulder pain affecting therapy, or any comorbid condition that could limit UE function, visual or hearing impairment.

Recruitment and randomization

We used a randomized controlled design in which the assessor was blinded to the group allocation of each participant. All assessments were performed by the same investigator who was blinded to the treatment assignment. The baseline data regarding name, age, sex, hospital number, poststroke duration, the side of involvement, MMSE, and brunnstorm recovery stage was taken after informed consent for all participants. Participants were individually randomized into RT and conventional therapy (CT) groups by using the computer generated random numbers [Figure 1]. Blocks were numbered, after which we used a random-number generator program to select numbers that established the sequence in which blocks were allocated to one or the other group. A physical therapist who was blinded to the research protocol and was not otherwise involved in the trial conducted the random-number program. There was total number of 46 participants, out of which 24 were in RT group and 22 were in CT group. Both the RT group and CT group received the same usual care rehabilitation programs for 30 min, and additionally, had each of their own therapies for 50 min per session, 5 days a week for 8 weeks.

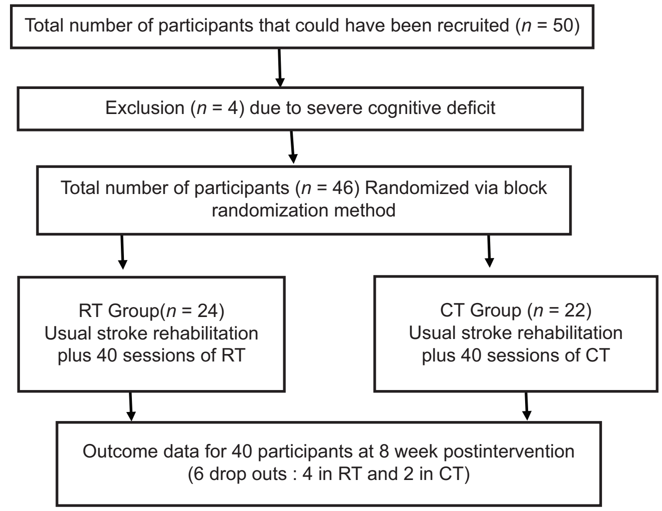

Figure 1: Flow diagram for randomized subject assignment in this study

Intervention and conventional therapy group

RT group subjects made to sit on a chair, feet were firmly positioned on the floor, the trunk was erect and positioned against the chair back. All participants received individually tailored structured RT for affected upper extremity (UE). All participants were given RT in the morning time which was started after the evaluation of individual one-repetition maximum (1-RM). It is the maximum resistance muscle can contract against to produce an adequate range of motion for a repetition to be considered complete.[23] Prior to RT warm up was given for 10 min for all participants who was followed by RT of 3 sets of 8 repetitions of each 4 exercises with 2 min rest in between sets. There were four strengthening exercises focus on shoulder flexion (SF), elbow flexion¸ elbow extension, and wrist extension for affected UE with weight cuff (1/2 kg or 1 kg) which was according to 1-RM of participants. These musculatures were targeted because extending as well as flexing of these muscles (shoulder, elbow, and wrist) against gravity is functionally relevant in many goal-directed movements and is an important component for motor retraining therapies following stroke.

All participants initially started with low intensity, i.e., 50% of (1-RM) in first 3 weeks and moderate intensity, i.e., 70% of (1-RM) for next 5 weeks. Duration of RT was 60 min/session for weekly frequency as 5 days/week for 8 weeks. Pattern of muscle contraction used was concentric muscle contraction for shoulder, elbow, and wrist. The initial volume (i.e., repetitions/sets) and intensity (i.e., resistance) of RT were selected based on a previous study that elicited the cross education effect and corticospinal adaptations to an axial muscle of the UE.[24] Progression was made over a period of 40 sessions by reducing the speed, changing the weight, and adding more sets to the individual. Thus, the training load varied across participants and was contingent upon the ability to progress over the course of RT. Training load was calculated by multiplying the total no. of repetitions performed in each session by the respective percent of 1-RM training, intensity, then summing the resulting value across all 40 sessions.

The CT was subject specific and consists of Rood's facilitation techniques, Bobath techniques and Motor relearning program., neurodevelopmental facilitation techniques, occupational therapy, and speech therapy (if needed). CT was given for 50 min per session, 5 days a week for 8 weeks.

Outcome measures

To measure improvement in motor recovery of UE the action research arm test (ARAT), manual muscle testing (MMT) and for motor functioning Fugl-Meyer assessment (FMA), was administered. HRQoL was also assessed by stroke-specific quality of life (SS-QOL) questionnaire. The ARAT, MMT, and FMA were administered as the primary outcome, whereas SS-QOL as the secondary outcome. The outcome measures were performed at 0 months (pretreatment) and at 8 weeks (posttreatment).

The ARAT[25] is a standardized ordinal scale that measures UE (arm and hand) function. It is a 19-item measure divided into four basic movements: Grasp, grip, pinch, and gross movements of extension and flexion at the elbow and shoulder which assesses the ability to handle smaller and larger objects with a variety of qualitatively rated items. It is reliable and valid measure to assess upper limb functions in stroke participants. Muscle strength was analyzed by MMT with MRC grading. Grades of the MMT were recorded as numerical scores ranging from zero that represent no activity to five that represent a normal response to the test. The reliability of MMT is of concern, and it remains an important screening and diagnostic tool. Reliability is increased by adhering to the same procedure for each test (for one or several examiners), by providing clear instructions to the subject, and by having a quiet and comfortable environment for the test.[26] The FMA is 3-point ordinal scale to measure the impairments of volitional movements. Its motor score includes 33 items related to the movements of the proximal and distal parts of the UE. The total score ranges from 0 to 66. It has good validity and high reliability. It is having four components: shoulder/elbow/wrist, wrist, hand and coordination/speed.[27] The SS-QOL was developed using standard psychometric techniques from interviews with stroke survivors, and it includes 49 items encompassing 12 domains: Energy, family roles, language, mobility, mood, personality, self-care, social roles, thinking, vision, UE function, and work/productivity. Each item is ranked on a 5-point Likert scale, with higher scores indicating better function.[5]

Statistical analysis

The data were statistically analyzed using the SPSS software 22.0 version. All statistical analysis was performed on the final 40 participants because 4 drop outs were in RT group and 2 were in CT group. Four subjects stopped coming for exercise at 4th week of intervention and 2 participants discontinued due to their ill health at 2nd and 3rd week. The mean and standard deviation of the data were obtained through the descriptive statistics. Data were normally distributed. *Post hoc* analysis with Bon-Feronni test was used to see the changes in the group and between the groups. The main effect and interaction effect, i.e., F value was computed with level of significance fixed at <0.05 ($P < 0.05$).

Results

Mean age in RT group was 51 · 0 ± 12 · 7 and in CT group, it was 56 · 4 ± 1 · 23. Out of 20 participants in RT group, 15 were male and 5 were female. In CT group, 12 were male and 8 were female. Demographic and clinical characteristics of the 40 participants, as well as baseline comparisons of the groups, are presented in Table 1. Baseline comparisons revealed that age, sex, duration, type, side of involvement, and MMSE scores did not differ between the groups. At baseline, participants of both groups showed no significant differences regarding ARAT, FMA, MMT, and SS-QOL scores [Tables 2 and 3]. Data given in the Table 2 show the

Table 1: Demographic characteristics of the mirror and control groups and baseline measurements

Variables	RT group	CT group
Age	51.0±12.7	56.4±1.23
Sex (male : female)	15:5	12:8
Side of involvement (right: left)	17:3	12:8
Duration (in weeks)	3.65±1.6	6.5±3.1
MMSE	23.2±1.3	22.6±1.5

Values are number or mean±SD, ranges provided for continuous variable. MMSE: Mini-mental state examination, RT: Resistance training, CT: Conventional training, SD: Standard deviation changes in variables from pre to postintervention in RT group. After 8 weeks of intervention, participants of both groups showed statistically significant improvements in all the variables measured [Tables 2 and 3]. No relevant adverse event was noted during the study in both groups. Table 4 presents the between group comparisons of the change score for ARAT, FMA, MMT, and SS-QOL from baseline to postintervention. ANOVA test was performed to analyze the change within resistance group.

Discussion

The present study demonstrated that 8 weeks structured program of RT can safely improve the motor function, motor recovery, and quality of life in sub-acute stroke participants. In this study, muscle strength has significantly increased in targeted muscle groups by RT as compare to CT group. The mechanism of these strength gains are likely to be mediated by both improvements in neural activation and muscle structure and function.[28] Gabriel DA in 2006 has found that an increase in neural drive is due to increase in the magnitude of efferent neural output from the CNS to activate muscle fibers.[29] Muscle structure and functions have been explained by the training that can result in improvement in the ability to generate the force in individual with stroke by increase in the recruitment of motor unit.[28] Motor units are also capable of increasing their discharge rate with strength training.[30] Strength training has potential to alter passive viscoelastic properties of the muscle and tendon.[31]

The gain in muscle strength in this study is in line with the previous studies where they examined the effects of resistance exercises in chronic stroke participants like Flansbjer *et al*. did a study to determine the lasting effects of progressive RT in chronic stroke participants after 10 weeks of resistance intervention, and they found improvement in muscle strength of lower limb.[18] Aidar *et al.* and Aidar *et al.* reported significant gains in maximal strength, i. e., 1-RM in a range of upper and lower body muscle groups after RT compared with the control group.[32,33] Similarly, the Cochrane review by Saunders *et al*. was conducted to determine whether fitness training after stroke reduces death, dependence, and disability. They have found that the resistance exercise was beneficial for stroke subject to improve muscle strength, quality to life resulting in improvement in performance of everyday activity.[6]

Another Cochrane review by Saunders *et al*. was related to cardiorespiratory intervention, resistance interventions, and mixed interventions effects on disability, dependency and death. They could not find sufficient evidence to support the use of RT and its effects due to lack of optimal RT protocol, and most of the study were small and of moderate quality.[13] Hence, this study used a structured protocol for RT in ischemic sub-acute stroke participants without hypertension. The dose of RT components of a RT protocol was according to American college of sports medicine (ACSM) criteria for developing and maintaining muscle strength (ACSM 1998).

In addition to gain in strength, this study has also shown the improvement in the level of hand function, UE function by showing the significant improvement in ARAT, and FMA outcome measures, respectively. There was higher improvement in grasp and grip components as compare to the pinch components of ARAT and that suggested that gross motor function of hand improve more as compare to fine motor function. The mechanism for changes in functional ability in response to strength training is less clear, with some studies demonstrating significant gains in function.[34] These finding are in accordance with the findings by Bohannon who has also found the improvement in the strength after strength training which lead to improvement in functional activities.[35]

Some studies investigating strength training after chronic stroke has also predicted a gain at the participatory level and in HRQoL. Meta-analysis done by Ming-De Chen *et al*. has also found the improvement in HRQoL

Table 2: Motor recovery and motor functioning scores of stroke participants at pre- and post-intervention in resistance training group

Variables	Preintervention	95% CI	Post intervention	95% CI
EF MMT	3.4±0.5	3.2-3.6	4.5±0.5	4.3-4.7
EE MMT	3.4±0.5	3.1-3.6	4.6±0.5	4.3-4.8
SF MMT	3.2±0.5	2.9-3.5	4.5±0.5	4.2-4.7
WE MMT	3.2±0.5	2.9-3.4	4.3±0.4	4.1-4.5
ARAT	28.5±12.2	22.8-34.2	33.0±12.6	27.0-38.9
FMA	107±11.54	102.09-112.9	115±8.5	111.8-119.8
SS-QOL	130±39.4	111.5-148.4	147±40.5	128.7-166.0

EF: Elbow flexors, EE: Elbow extensors, SF: Shoulder flexors, WE: Wrist extensors, MMT: Manual muscle testing, ARAT: Action reach arm test, FMA: FuglMeyer assessment, SS-QOL: Stroke-specific quality of life, CI: Confidence interval

Table 3: Motor recovery and motor functioning scores of stroke participants at pre- and post-rehabilitation in conventional training group

Variables	Pre CT	95% CI	Post CT	95% CI
EF MMT	3.1±0.3	2.9-3.2	3.6±0.4	3.4-3.8
EE MMT	3.1±0.3	2.9-3.2	3.6±0.4	3.4-3.8
SF MMT	3.0±0.2	2.9-3.1	3.3±0.4	3.1-3.5
WE MMT	3.0±0.2	2.9-3.1	3.4±0.5	3.1-3.6
ARAT	27.6±8.0	23.8-31.3	29.2±7.9	25.5-32.9
FMA	97.5±14.1	90.9-104.1	103.8±12.5	97.9-109.6
SS-QOL	137.4±3.2	121.3-153.4	142.9±37.11	125.5-160.2

EF: Elbow flexors, EE: Elbow extensors, SF: Shoulder flexors, WE: Wrist extensors, MMT: Manual muscle testing, ARAT: Action reach arm test, FMA: FuglMeyer assessment, SS-QOL: Stroke-specific quality of life, CI: Confidence interval

Table 4: Between-group differences in change scores for outcome measures

Variables	RT group mean difference	CT group mean difference	*P*	*F*
EF MMT	1.1	0.5	<0.05	24.40
EE MMT	1.2	0.5	<0.05	9.940
SF MMT	1.2	0.3	<0.05	11.563
WE MMT	1.1	0.3	<0.05	8.624
ARAT	4.4	1.6	<0.05	195.761
FMA	8.3	6.2	<0.05	38.053
SS-QOL	17.6	5.5	<0.05	34.716

EF: Elbow flexors, EE: Elbow extensors, SF: Shoulder flexors, WE: Wrist extensors, MMT: Manual muscle testing, ARAT: Action reach arm test, FMA: FuglMeyer assessment, SS-QOL: Stroke-specific quality of life, CI: Confidence interval, RT: Resistance training

with exercise in chronic stroke participants.[21] One small trial by Kim *et al.* on 20 stroke participants did not show any significant differences between the RT group and the control group in either the physical or mental health component of the SF-36 at the end of intervention.[36] Most of the previous literature has used SF-36 questionnaire to predict HRQoL in stroke participants, whereas the present study used more specific outcome measure, i.e., SS-QOL to predict HRQoL in stroke participants and found improvement in HRQoL after RT. As compared to other components of SS-QOL such as self-care, UE function, energy, mood, personality, and work/productivity have more improvement after 8 weeks of intervention. The improvement in SS-QOL can be due to improvement in the hand and limb function resulting from improved muscle strength.

Study limitations

A potential limitation of this study is the generalizability of the results that these findings may not be applicable to chronic stroke participants with hypertension and severe cognitive deficits. Another limitation could be muscle tone which was not assessed, and it is important component because any activity/intervention that involves attempted repetitive effortful muscle contraction can result in increase motor unit activity and spasticity after stroke. Other possible limitations could be lack of follow-up at postintervention. As a further limitation of our work, we did not use imaging technique to demonstrate brain reorganization after RT.

Future studies may investigate the effectiveness of RT on other treatment technique like CIMT and find its effect on cognitive or perceptual impairment. Investigate RT as a home treatment because it is simple and easy technique and follow-up subjects to know its long-term effects. Finally, perform functional brain imaging studies on the underlying mechanism of motor recovery after RT in stroke participants.

Conclusion

The improvement in UE motor function, motor recovery, and quality of life can be achieved efficiently and safely with structured RT program as compared to other conventional regimen. This study is important to help to inform the health and physical conditioning professionals about the RT in exercise prescription for sub-acute stroke participants. It also provides well-designed RT protocols and their benefits on the prognosis of stroke participants.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Sacco RL, Kasner SE, Broderick JP, Caplan LR, Connors JJ, Culebras A, *et al*. An updated definition of stroke for the 21st century: A statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2013;44:2064-89.
2. Ferri CP, Schoenborn C, Kalra L, Acosta D, Guerra M, Huang Y, *et al*. Prevalence of stroke and related burden among older people living in Latin America, India and China. J Neurol Neurosurg Psychiatry 2011;82:1074-82.
3. Gambassi BB, CoelhoJunior HJ, Schwingel PA, Almeida FJF, Gaspar Novais TM, Lauande Oliveira PL, *et al*. Resistance Training and Stroke: A Critical Analysis of Different Training Programs. Stroke Res Treat 2017;2017:4830265.
4. Dombovy ML. Stroke: Clinical course and neurophysiologic mechanisms of recovery. Critical Rev Phys Rehabil Med 1991;2:171-88.
5. Williams LS, Weinberger M, Harris LE, Daniel O. Clark and José biller. Development of a stroke-specific quality of life scale. Stroke 1999;30:1362-9.
6. Saunders DH, Greig CA, Mead GE, Young A. Physical fitness training for stroke subjects. Cochrane Datab Syst Rev 2009;4:CD003316.

7. Gemperline JJ, Allen S, Walk D, *et al*. Characteristics of motor unit discharge in subjects with hemi paresis. Muscle Nerve 1995;18:110114.
8. Bourbonnais D, Vanden Noven S. Weakness in patients with hemiparesis. Am J Occup Ther 1989;43:313-9.
9. Hara Y, Masakado Y, Chino N. The physiological functional loss of single thenar motor units in the stroke patients: When does it occur? Does it progress? Clin Neurophysiol 2004;115:97-103.
10. Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: A systematic review. Lancet Neurol 2009;8:741-54.
11. Morrissey MC, Harman EA, Johnson MJ. Resistance training modes: Specificity and effectiveness. Med Sci Sports Exerc 1995;27:648-60.
12. Hankey GJ, Warlow CP. Treatment and secondary prevention of stroke: Evidence, costs, and effects on individuals and populations. Lancet 1999;354:1457-63.
13. Saunders DH, *et al*. Physical fitness training for stroke patients. Cochrane Datab Syst Rev 2016;24;3:CD003316.
14. Saunders DH, Greig CA, Mead GE. Physical activity and exercise after stroke: Review of multiple meaningful benefits. Stroke 2014;45:3742-7.
15. Wist S, Clivaz J, Sattelmayer M. Muscle strengthening for hemiparesis after stroke: Ameta-analysis. Ann Phys Rehabil Med 2016;59:114-24.
16. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, *et al*. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. Med Sci Sports Exerc 2011;43:1334-59.
17. Folland JP, Williams AG. The adaptations to strength training: Morphological and neurological contributions to increased strength. Sports Med 2007;37:145-68.
18. Flansbjer UB, Lexell J, Brogårdh C. Long-term benefits of progressive resistance training in chronic stroke: A 4-year follow-up. J Rehabil Med 2012;44:218-21.
19. Pollock A, Farmer SE, Brady MC, Langhorne P, Mead GE, Mehrholz J, *et al*. Interventions for improving upper limb function after stroke. Cochrane Database Syst Rev 2014 Nov 12; Issue 11 :CD010820.
20. Saunders DH, *et al*. Physical fitness training for stroke patients. Cochrane Database Syst Rev. 2013 21:CD003316.
21. Ming-De Chen MS, Rimmer JM. Effects of exercise on quality of life in stroke survivors. A meta-analysis. Stroke 2011;42:832-7.
22. Donaldson C, Tallis R, Miller S, Sunderland A, Lemon R, Pomeroy V. Effects of conventional physical therapy and functional strength training on upper limb motor recovery after stroke: A randomized phase II study. Neurorehabil Neural Repair 2009;23:389-97.
23. Goodwill AM, Pearce AJ, Kidgell DJ. Corticomotor plasticity following unilateral strength training. Muscle Nerve 2012;46:384-93.
24. Kidgell DJ, Stokes MA, Pearce AJ. Strength training of one limb increases corticomotor excitability projecting to the contralateral homologous limb. Motor Control 2011;15:247-66.
25. Nijland R, van Wegen E, Verbunt J, van Wijk R, van Kordelaar J, Kwakkel GA. Comparison of two validated tests for upper limb function after stroke: The wolf motor function test and the action research arm test. Source J Rehab Med 2010;42:694-6.
26. Daniel's and Worthingham's Manual Testing. Technique of Manual Examination and Performance Testing. 9th ed.. Ch. 1-2. 2018. p. 2-16.
27. Sanford J, Moreland J, Swanson LR, Paul W, Gowland C. Motor performance in subjects following stroke. reliability of the Fugl-meyer assessment for testing motor performance in subjects following stroke. Phy 1993;73:447-54.
28. Kamen G, Knight CA. Training-related adaptations in motor unit discharge rate in young and older adults. J Gerontol A Biol Sci Med Sci 2004;59:1334-8.
29. Gabriel DA, Kamen G, Frost G. Neural adaptations to resistive exercise: Mechanisms and recommendations for training practices. Sports Med 2006;36:133-49.
30. Field MJ, Jette AM, Martin L, Rimmer JH, Shenoy SS. Impact of exercise on targeted secondary conditions. In: Field MJ, Jette AM, Martin L, editors. Based on a Workshop of the Committee on Disability in America: A New Look. Washington, DC: The National Academies Press; 2006. p. 205-22.
31. Signal NE. Strength training after stroke: Rationale, evidence and potential implementation barriers for physiotherapists. New Zealand J Phys 2011;42:101-7.
32. Aidar FJ, de Oliveira RJ, Silva AJ, de Matos DG, Mazini Filho ML, Hickner RC, *et al*. The influence of resistance exercise training on the levels of anxiety in ischemic stroke. Stroke Res Treat 2012;2012:298375.
33. Aidar FJ, de Matos DG, de Oliveira RJ, Carneiro AL, Cabral BG, Dantas PM, *et al*. Relationship between Depression and Strength Training in Survivors of the Ischemic Stroke. J Hum Kinet 2014;43:7-15.
34. Teixeira-Salmela LF, Olney SJ, Nadeau S, Brouwer B. Muscle strengthening and physical conditioning to reduce impairment and disability in chronic stroke survivors. Arch Phys Med Rehabil 1999;80:1211-8.
35. Bohannon RW. Muscle strength and muscle training after stroke. J Rehabil Med 2007;39:14-20.
36. Kim CM, Eng JJ, MacIntyre DL, Dawson AS. Effects of isokinetic strength training on walking in persons with stroke: A double-blind controlled pilot study. J Stroke Cerebrovasc Dis 2001;10:265-73.