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Full Length Research Paper

Hamstring weakness: A sequel of cerebrovascular accident

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Cerebrovascular accident (CVA), commonly known as stroke is a condition that results from infarction of neurons in the brain due to vascular compromise. It is a highly prevalent disease, a leading cause of death and long-term disability. The most frequent sign after stroke is muscle weakness, which leads to loss of functions in the upper and lower limb. The mechanism of muscle weakness in stroke can be neural or structural. The most frequently affected muscle groups are the extensors of the upper limb and flexors of the lower limb. Dysfunctional knee flexion causes disability in performing such activities of daily living like walking, transfers, standing, stair climbing and so on, which negatively affect the quality of life and societal participation in stroke survivors. The hamstring muscles are the muscles responsible for knee flexion. This mini-review gives a brief summary of the available physiotherapy interventions that affect the hamstrings. PubMed, CINAHL and Google Scholar were searched with keywords of various combinations. Several modalities employed in managing hamstring weakness in stroke survivors include exercise therapy, mirror therapy, electrical stimulation, mental practice, functional electrical stimulation and task-specific training at different levels of hamstring muscle strength among stroke survivors. The goal of physiotherapy is to improve the functional level and ultimately facilitate community integration by increasing muscle strength in the stroke survivor.

Key words: Hamstring, cerebrovascular, accident.

INTRODUCTION

Cerebrovascular accident (CVA), also known as stroke, has a high prevalence and is one of the leading causes of disability and death globally (Lindsay et al., 2019; Rutten-Jacobs et al., 2013). Stroke survivors are individuals who suffered a stroke and are living with its sequelae (Clarke et al., 1999). Although various surveillance systems exist for the identification of early signs of stroke and prevention of its consequences, stroke remains a leading cause of mortality and disability-adjusted life-years lost globally with more disturbing trends in low and middle-income countries (Johnson et al., 2016).

What happens during a stroke?

Cerebrovascular accidents can either be ischaemic or

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haemorrhagic in aetiology. An ischaemic stroke happens because of hypoxia, ischaemia, and infarction of brain parenchyma. These result from an impaired supply of blood and oxygen to the brain tissue due to obstruction of the end arteries from an embolus or thrombus (Strandgaard and Paulson. 1990). The ensuing damage could be focal or global. A global cerebral injury could lead to death. Focal CVA occurs following either a reduction or a cessation of blood flow to a localized area of the brain due to arterial occlusion or hypo-perfusion. A prolonged episode of ischaemia brings about infarction in the area supplied by the occluded vessels. Areas damaged and the extent of damage is dependent on the duration of ischaemia and the adequacy of collateral supply (Collins et al., 1989). Blood supply to the brain is mainly by the arteries that make up the circle of Willis and the external carotid-ophthalmic pathway provides a supplement. Partial and inconsistent reinforcement is however available over the surface of the brain from the distal branches of anterior, middle, and posterior cerebral arteries through cortical-leptomeningeal anastomoses. This is not enough supply since there is little or no anastomoses to the deep arteries of the brain that supply the thalamus, basal ganglia, and deep white matter (Chen et al., 2017). A haemorrhagic stroke results from a berry aneurysm rupture. The arterial rupture could also be because of malformations (Hammond et al., 1969).

Clinical presentation depends on the areas of the brain affected by the injury. This often includes motor affectation like muscle weakness, impaired balance and coordination, dysphagia, dysarthria, limitation in performing activities of daily living and non-motor symptoms like Wernicke’s aphasia, changes in behaviour and moods (Rondina et al., 2017; Wist et al., 2016; Adams et al., 1990).

METHODOLOGY

This review followed the guidelines of writing a narrative review as documented by Green, Johnson and Adams (Green et al., 2006). Keyword searches of abstract, full texts and referenced titles in three electronic databases, PubMed, CINAHL and Google Scholar. Keywords used were hamstrings or knee flexors, paresis or weakness, acute stroke or cerebrovascular accident or CVA. More keywords to include the interventions were added while keyword combinations evolved during the course of writing the review.

RESULTS AND DISCUSSION

Muscle weakness following a stroke

Muscle weaknesses of the upper and lower limbs contralateral to the brain lesion are the most frequent sign after stroke (Wist et al., 2016). The severity of post-stroke paresis relates to a person’s independence in performing many functional upper limbs and lower limbs tasks. The limited upper limbs functions include fine movements like pinching, holding a pen, fixing a button or gross movements like combing (Blennerhassett et al., 2008). Similarly, in the lower limbs, functions including transfers (Mercer et al., 2009), gait (Mercer et al., 2009; Hesse et al., 2012), standing and stair climbing (Hesse et al., 2012) are limited. Studies comparing muscle strengths across the two sides of the body, upper and lower limbs, and flexor-extensor differences have revealed flexors actions to be more impaired in the lower limbs while extensor actions in the upper limbs. In addition, lower limbs’ actions are averagely more impaired than the upper limbs. The part of the brain injured determines whether the upper limbs or the lower limbs are more affected (Andrews and Bohannon 2000).

Hamstring muscle weakness

Reiterating that the flexor actions of the lower limbs are more impaired in an incident of CVA, it affects essential functions including gaits and transfers. This review focuses on the hamstrings. The hamstring group of muscles consists of four muscles that act across the hip and the knee (Guruhan et al., 2021). These muscles are the long and short heads of the biceps femoris, the semimembranosus and the semitendinosus. All except the short head of the biceps femoris originate from the ischial tuberosity and insert into the tibia fibula. The hamstrings are anatomical and functional flexors of the knee, anatomical and functional extensors of the hip and functional dorsiflexors of the ankle (Nashner 2014). The importance of the hamstrings as a chief flexor in the lower limbs makes it is important to discuss the physiologic functions of the hamstring muscle in executing lower limb functions, the mechanism of hamstring weakness following stroke, and the management of the paresis (Smith et al., 1999).

Role of hamstring in lower limb functions

The major functions of the lower limb are standing, quality of gait, and transfers (Blennerhassett et al., 2008; Mercer et al., 2009; Hesse et al., 2012). Standing is a fundamental position. Several systems where the muscles play pivotal roles are in action when standing. The hamstrings are responsible for hip extension, pelvic retroversion, knee flexion and ankle dorsiflexion during quiet standing (Ada et al., 2003).To maintain a proper standing position, the knee joint must bear the weight of the body. A normal hamstring quadriceps (H/Q) ratio, 50 to 80%, is essential in stabilising the knee for weight-bearing (Nashner 2014; Takacs and Hunt 2012; Straudi et al., 2009). When the hamstrings are weak, there is an abnormal decrease in the H/Q ratio, which reduces stability and results in genu recurvatum compromising the efficiency of standing. In the long term, such standing mechanics can result in chronic knee pain and arthritic conditions.

Gait

The human gait comprises a series of events that occur in the lower limbs while walking or running. The quality of gait is dependent on an interplay between muscle strength, balance and coordination. A breach within the interactions between these factors causes a pathological gait. The pathologic gait associated with CVA is the hemiplegic gait. Multiple factors contribute to the development of hemiplegic gait including balance deficit, weakness of more than one muscle group, pain, loss of proprioception, coordination deficits and the psychosocial factor: lack of confidence. Gait can be observed in the sagittal, coronal or transverse planes (Vaughan et al., 1992) but is best analysed in the sagittal plane allowing the flexion and extension of the knee and ankle to be seen (Vaughan et al., 1992). The hamstring group of muscles plays a crucial role in the gait, primarily extending the hip and flexing the knee (Stewart et al., 2008). The semimembranosus and semitendinosus assist with pelvic internal rotation, while the long head of the biceps femoris assists in pelvic external rotation, acting in synergy to aid pelvic stabilisation during gait (Bailey 2017). The actions of the hamstring muscles in the stance phase are majorly on the hip joint. In synergy with the glutei maximi, they extend the hip causing forward propulsion of the body (Whittle 2011). In the stance phase:

(1) Heel strike or initial contact: The hamstrings eccentrically contracts to modulate or slow hip flexion and knee extension to ease heel strike (Vaughan et al., 1992; Whittle 2011)
(2) Foot flat or loading response: In synergy with the glutei maximi, the hamstrings contract to initiate hip extension. At the knee, the hamstrings also initiate slight knee flexion to absorb shock in preparation for weight-bearing (Vaughan et al., 1992; Whittle 2011).
(3) Mid stance: Concentric isotonic contraction of the hamstrings ceases during this phase of the gait cycle (Vaughan et al., 1992; Whittle 2011).
(4) Heel off to Toe-off: Through the midstance until the toe-off EMG recordings find no electrical activities in the hamstrings. Knee flexion at the terminal stance is by the moment generated from hip flexion and the gastrocnemius muscles. During the toe-off, the knee is already at half the flexion it will assume during midswing (Vaughan et al., 1992; Whittle 2011).

In the swing phase:

(1) Early or initial swing: 30 to 50° of knee flexion occurs as a result of a pendulum effect hip flexion has on the knee. Electrical activities begin to appear in the short head of the biceps as it reinforces knee flexion (Vaughan et al., 1992; Whittle 2011).
(2) Mid-swing: Peak knee flexion, between 60 and 70°, occurs through this phase, by the concentric contraction of all components of the hamstrings. This changes into eccentric contraction to decelerate as the limb enters into late swing in readiness for heel strike (Whittle 2011).

Mechanism of hamstring weakness following stroke

Mechanism of changes in the structure and function of any skeletal muscle after a stroke, hamstring group of muscles being our focus, pivots on the retention of neuromuscular connection coupled with reduced neuromuscular activation and muscular unloading (Hafer-Macko et al., 2008). Hence, presenting hamstring weakness is a result of neural, structural and mechanical changes to this group of muscles.

Structural changes

Three types of fibres exist in large skeletal muscles vis a vis slow-twitch fibres, fast-twitch fibres type 1 and type 2. Slow-twitch fibres possess abundant mitochondria and are fatigue-resistant in contrast to fast-twitch fibres. An incidence of stroke causes the downregulation of total RNA and specific mRNA responsible for the expression of slow-twitch fibres. Reduction in physical activity and muscle unloading due to immobilisation secondary to stroke also causes a corresponding reduction in the cross-sectional area of muscle fibres (Hafer-Macko et al., 2008).

Mechanical changes

Immobilisation and reduction in physical activity following stroke decrease isometric and isotonic muscle strength (Hafer-Macko et al., 2008). The increase in the expression of fast-twitch fibres that follows a stroke precipitates increased fatigability of the muscle group. Studies have also shown a negative correlation between self-selected walking speed and upregulation of the expression of fast-twitch fibres.

Neural changes

This involves the ability of the nervous system to activate muscle groups through motor unit engagement and rate coding. The changes here are an increase in stretch reflex excitability, an increase in antagonist muscle (knee extensors-quadriceps) co-activation, decrease in motor unit firing rates (due to the damage to the motor cortex areas, corticobulbar tracts and descending corticospinal tracts) (Guruhan et al., 2021).

Any disturbance in the smooth flow of these factors impairs the capacity to exert force and compromises the strength or power of the muscle group.

Hamstring strengthening physiotherapy interventions in stroke survivors

The consequences of a weakened hamstring are pronounced when an attempt to ambulate is made. In cases where sensory deficits accompany muscle weakness, afferent signals are read wrongly, which may contribute to abnormal muscle activation, pathologic gait patterns, and impaired responses to perturbation during gait and stance. In addition to hemiplegic gait, “stiff knee” gait is another pathological gait observed in stroke survivors. It is a result of weak knee flexion in the swing phase of gait. Hamstrings weakness ultimately hinders the possible reintegration of a survivor into society. Following an episode of stroke, patients exhibit varying degrees of impairment depending on the power in the affected muscles but in this case, the hamstrings. Some patients may be weak but have enough strength to move against gravity. Such individuals need to not only gain strength but also improve function. Studies on isolated strengthening exercises in stroke survivors who are moderately weak have revealed that an increase in strength often augments function. The aim of physiotherapy management is to ultimately improve the quality of ambulation by strengthening, and re-training balance and coordination in the affected muscles, the hamstrings being our model. This review classified physiotherapy intervention focused on strengthening the hamstring based on the Oxford Muscle Grading System.

In power 0 &1: Passive range of motion exercises

Several studies have expressed a positive effect of passive range of motion, not only on improving soft tissue extensibility and maintaining joint integrity but also on improving strength and functional capacity in patients within the first month. These studies showed that no significant differences were observed in the observed effect after three months depicting that the effect of passive exercises is time-specific. In one of these studies, passive exercises began 48 h after the incidence, for 16 to 40 min, six to eight times per day for 13 weeks (Hosseini et al., 2019).

Mirror therapy

Mirror therapy uses visual cues to stimulate mirror neurons in the motor cortex. Recent studies have applied mirror therapy as a means of intervention to improve muscle strength, quality of gait, balance and coordination, (Thieme et al., 2018) either solely or in combination with other intervention strategies. In one study, where patients performed movement with the non-paretic limb repeating movements 30 times in a set, 5 times daily, 5 times weekly for 4 weeks (Kim et al., 2018), significant improvements were found in muscle strength of both knee extensors and flexors of the paretic limb. This study however highlights the importance of time in the use of mirror therapy. Mirror therapy in combination with transcranial electrical stimulation and treadmill training to improve muscle strength and quality of gait in patients with chronic stroke (Lee and Kim, 2020).

Functional electrical stimulation

In lieu of trials based on muscle strength, studies have utilised electrical stimulation in trials based on the phase of stroke incidence, whether acute, post-acute or chronic phase. A presentation of hamstring weakness of 0 or 1 on the OMGS is expected to happen in the acute phase. In one study, within three days of incidence, FES was delivered to the hamstrings along with other muscles of the lower limb with 0.3-ms pulses at 30 Hz, maximum tolerance intensity (20 to 30 mA), 30 minutes, 5 days per week for 3 weeks (Yan et al., 2005). In addition, another study showed stimulation frequencies with FES cycling range from 20 Hz to 60 Hz, pulse duration from 300 µs to 450 µs and a 25 Hz with only tolerable intensity (Bauer et al., 2015).

In power 2, 3 & 4: Functional electrical stimulation

FES throughout the day for 6 weeks was effective for hamstring strengthening but affects the pre-swing hip hyperextension, which occurs between the heel off and toes off. (Morris et al., 2004).

Progressive resistance training (PRT)

The hamstring is able to contract in gravity reduced or gravity eliminated positions. Resisted active exercises in a gravity eliminated position increases muscle strength. A systematic review by Morris et al. (2004) on progressive resistance training among stroke survivors showed 5 clinical trials which all showed a large positive effect on muscle strength (impairments). Three of these showed an improvement in activities such as walking and stair climbing (activity limitation). Isokinetic training was between 6 and 10 reps for 3 sets, 3 to 5 times per week, for 4 to 13 weeks.

Task-specific training (TST)

Evidence that treadmill exercise and other ambulatory training for 3 months improve hamstring strength and activity participation was supported by Sullivan et al. (2007) and Combs et al. (2010), respectively.

Intensive aerobic exercising (IAE)

Lee et al. (2016) suggested that an aerobic exercise program of moderate intensity, 3 days per week, for 20 weeks should be considered for greater effect on cardiorespiratory fitness, muscle strength, and walking capacity in stroke patients (Odetunde et al., 2020). Home programs are essential to sustain the neural and structural changes acute and subacute physiotherapy interventions had obtained (Lee and Stone, 2020). Reports from studies show that after discharge from rehabilitation, stroke survivors tend to return to a sedentary lifestyle. Aerobic exercises using available modalities improves muscle strength as well as cardiorespiratory fitness in stroke survivors (Winstein et al., 2016)

A minimum strength to move against gravity is needed for a survivor to at least initiate ambulation and carry out daily tasks. As a result, paralysed patients or survivors with very weak muscles need to gain strength early during rehabilitation. At different levels of hamstring muscle strength among stroke survivors, appropriate rehabilitation interventions are available, and it is up to the whims of the therapist to employ them in a situation and individual-specific fashion. The goal is to improve muscle strength with an associated increase in function and societal participation in community integration.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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