

# The Application of Cycling and Cycling Combined with Feedback in the Rehabilitation of Stroke Patients: A Review

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Stroke is a leading cause of long-term disabilities, such as hemiparesis, inability to walk without assistance, and dependence of others in the activities of daily living. Motor function rehabilitation after stroke demands for methods oriented to the recovery of the walking capacity. Because of the similarities with walking, cycling leg exercise may present a solution to this problem. The aim of this article is to review the state of the art applications of cycling leg exercise as a (1) motor function rehabilitation method and an (2) aerobic training method for stroke patients as well as the commonly used (3) assessment tools. The cycling characteristics and applications, the applied test protocols as well as the tools used to assess the state and the recovery of patients and types of cycling devices are presented. In addition, the potential benefits of the use of other therapies, like feedback, together with cycling are explored. The application of cycling leg exercise alone and combined with feedback in stroke rehabilitation approaches has shown promising results. Positive effects on motor abilities were found in subacute and chronic patients. However, larger and normalized studies and assessments are needed because there is a high heterogeneity in the patients' characteristics, protocols and metrics. This will allow the comparison between different studies related with cycling. **Keywords:** Cycling—feedback—hemiparesis—lower limbs rehabilitation—rehabilitation—stroke—walking.  
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Population aging is increasing the susceptibility to stroke and neurodegenerative diseases, with stroke being the second main cause of death. The patients that survive generally exhibit sequels with consequences in their normal life, such as hemiparesis, incapacity to walk

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without assistance, aphasia, and dependence in the activities of daily living (ADLs).<sup>1</sup>

Rehabilitation's major objective in patients with motor impairments in the lower limbs is to recover walking capacity.<sup>2</sup> This problem, besides the negative influence on the patient's independence, leads to immobility. Musculoskeletal disturbances (e.g., muscle atrophy, osteoporosis, contractures) and cardiovascular problems (e.g., minimized maximal oxygen consumption) as well as low aerobic endurance significantly affect the patient's ADL performance and, in severe cases, may lead to death.<sup>3</sup>

Some stroke patients are unable to perform exercises that are normally used in the rehabilitation of walking ability (e.g., walk with the support of parallel bars, treadmill gait training) because the muscle force in the lower limbs is too weak to allow a secure body weight support.<sup>4</sup> Therefore, there is a demand for rehabilitation methods oriented to the recovery of the walking capacity of stroke

patients. Because of the similarities with walking,<sup>5</sup> cycling leg exercise may present a solution to this problem and might be an alternative motor function rehabilitation method.<sup>6</sup> Cycling allows a continuous repetition of movements, during an unlimited period, requiring fewer therapists, and with a lower physical load. Because balance control is not required during cycling exercise, it can be used as a rehabilitation method in an early poststroke phase, when gait training is not yet possible. Besides, to recover from motor impairments and to minimize the risk of secondary diseases that derive from immobility, stroke patients require an enduring therapy, like aerobic cycling exercise.<sup>3</sup> Assessment tools are needed to quantify the efficiency and efficacy of the applied cycling therapies. These tools assess the patient state and performance during different tasks, based on specific criteria.

Different therapies have been used together with cycling leg exercise to improve cycling's potential as a rehabilitation method, such as limb-load cycling,<sup>4,7</sup> functional electrical stimulation (FES),<sup>8-14</sup> and feedback.<sup>7,15-19</sup>

However, first, it is important to clarify several issues before the use of cycling as a rehabilitation method, such as the similarities and differences between cycling and walking, the advantages and limitations of cycling leg exercise when compared with walking on the rehabilitation of motor impairments, and the type of stroke patients, which may benefit from cycling therapies. Moreover, information about the type of purposes where cycling leg exercise can be used, the applied protocols as well as the tools used to assess the state and the recovery of patients, are important to analyze the potential of cycling as a rehabilitation method. Finally, it is also important to verify if the use of other therapies together with cycling may lead to beneficial effects and, for instance, if it allows to overcome some cycling limitations. This article attempts to review each of these issues in the current state of the art.

In terms of therapies that can be used together with cycling, emphasis will be given to feedback-based therapies in this article. Extrinsic feedback can be provided in cases where the patient's ability to evaluate their own movement is incapacitated.<sup>20</sup> This artificial information provided by an external source can be beneficial to motor recovery. It allows the assessment of the patient medical state and increases the performance and motivation of the patient on the execution of different cycling exercises.<sup>20</sup> Extrinsic feedback can also provide motivational mechanisms by displaying the performance metrics during the exercise, which promotes the participation of the patient during the rehabilitation process.

This article covers studies regarding the application of cycling therapies in stroke patients to identify the clinical evidence on the effectiveness of cycling therapies. Additionally, it tries to identify the main challenges that remain

to be tackled. Considering health care scenarios, it is very important to assess if there is a robust evidence-based support to therapies before they become established in clinical settings. This article addresses lower limb cycling (leg exercise) and hereafter will be referred simply by cycling.

The article is organized as follows. In the Stroke section, a brief review of the stroke origin, consequences, and associated rehabilitation processes is presented. Then, the cycling characteristics and applications are reviewed, especially its application as a rehabilitation and aerobic method as well as the assessment tools used to measure patient's impairments and recovery. In addition, some therapies combined with cycling are also introduced, presenting a more detailed review of the characteristics and applications of feedback. Finally, some of the existing cycling devices are explored.

## Stroke

Stroke (or cerebrovascular accident) is the most common brain disorder and is characterized by sudden neurological symptoms, such as paralysis or loss of sensation resulting from the destruction of brain tissue. Intracerebral hemorrhage (bleeding from a blood vessel in brain)—hemorrhage stroke—and emboli (blood clots), or atherosclerosis (formation of plaques that block blood flow) of the cerebral arteries—ischemic stroke—are the common causes of stroke.<sup>21,22</sup> Of all strokes, 87% are ischemic, 10% are intracerebral hemorrhage, and 3% are subarachnoid hemorrhage strokes.<sup>1</sup> The risk factors of stroke include high blood pressure, high blood cholesterol, heart disease, diabetes, smoking, obesity, and excessive alcohol intake, among others.<sup>21,22</sup>

In the United States, each year approximately 795,000 people are victims of a new or a recurrent stroke (data from 1999). About 610,000 of these are first attacks.<sup>1</sup> According to 2000 census,<sup>23</sup> the US population comprised 281,421,906 people; therefore, the annual incidence (number of new cases of a disease that develop in a population per unit of time<sup>1</sup>) of first stroke per 1000 population was around 2.16. A study conducted<sup>24</sup> between 2004 and 2006 in 6 European countries found an annual stroke incidence of first stroke per 1000 population of 1.41 in men and .94 in women.

Stroke is a leading cause of long-term disabilities, such as hemiparesis, inability to walk without assistance, and dependence of others for ADL's.<sup>1</sup> Motor impairments are characterized by paralysis (hemiplegia) and weakness (hemiparesis), contralateral to the affected hemisphere of the brain.<sup>22</sup> Postural imbalance, muscle weakness (paresis), spasticity, asymmetrical movements between lower limbs, abnormal movement synergies, lack of mobility, loss of interjoint coordination, and loss of sensation are generally observed in hemiparetic patients.<sup>22,25</sup> Perform continuous and smooth reciprocal movements,

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