Journal of Clinical and Nursing Research, 2026, Volume 10, Issue 8
https://www.bbwpublisher.com/journal/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

Research on Rehabilitation Theory of Manual Gait Correction Training for Hemiplegic Foot

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Abstract: Manual gait correction training relies on the precise manual techniques of rehabilitation therapists to regulate the ankle joint angle, muscle activation sequence, and center-of-gravity transfer trajectory throughout the entire walking cycle of patients with hemiplegic foot drop; it represents a non-instrument-dependent intervention approach with exceptional adaptability in clinical rehabilitation settings. In clinical practice, manual gait correction training is frequently employed to reconstruct normal gait patterns in patients, thereby assisting them in restoring walking function and enhancing their daily activity capacity and quality of life. This article systematically reviews the core theoretical framework of manual gait correction training for hemiplegic foot drop, deconstructs the mechanistic principles underlying manual interventions during different phases—specifically the support phase and the swing phase—clarifies the key intervention points and the biomechanical correction logic, and proposes standardized clinical intervention protocols, aiming to provide a reference for the formulation of clinical rehabilitation plans for patients with hemiplegic foot drop.

Keywords: Hemiplegic foot drop; Manual gait correction; Rehabilitation theory

Online publication: Aug 31, 2026

1. Introduction

Hemiplegic foot drop is a common motor dysfunction after stroke. It is manifested as insufficient propulsive force at the late stance phase and toe dragging during the swing phase in walking cycles. It not only destroys patients' normal gait patterns and increases the risk of falls, hindering the recovery of independent daily mobility, but also causes secondary injuries to the knee and hip joints. If this symptom cannot be improved in a timely and effective manner, patients will easily fall into a vicious cycle: abnormal gait fixation → joint degenerative lesions → further deterioration of motor function. Therapists adopt manual gait correction training to correct compensatory abnormal gait movements for patients with hemiplegic foot drop, break this pathological cycle, and accelerate rehabilitation.

2. Analysis of pathological mechanisms and abnormal gait characteristics of hemiplegic foot drop

2.1. Disrupted motor control logic caused by central nerve injury

During a normal human walking cycle, the central nervous system precisely coordinates the contraction and relaxation sequence of the plantar flexor muscle groups, as well as ankle dorsiflexion, according to the specific demands of the support phase and swing phase, thereby ensuring stable stride length and smooth transfer of the center of gravity. However, patients with hemiplegic foot drop may experience disruption of this coordination due to central nervous system damage resulting from stroke, leading to toe dragging during the swing phase and insufficient propulsion during the support phase [1]. The central nervous system injury induced by stroke can disrupt the signal transmission pathway between the motor cortex, the corticospinal tract, and the motor neurons in the anterior horn of the spinal cord; this disruption causes the muscle groups responsible for ankle dorsiflexion to lose precise regulation from the higher-level central control, rendering the commands for active contraction ineffective. Simultaneously, the triceps surae muscles, which are responsible for ankle plantar flexion, may exhibit abnormally increased muscle tone due to weakened inhibitory regulation from the higher-level central control, thereby disrupting the temporal sequence of muscle activation during the walking cycle. When the central neural control pathway is impaired, the original automated muscle activation logic is completely disrupted, forcing the brain to initiate compensatory movement patterns, specifically, by elevating the affected pelvis and abducting and rotating the hip outward, to allow the lower limb to trace a semicircular trajectory through the air. This phenomenon is commonly referred to in clinical practice as the “circular gait”.

2.2. Secondary pathological changes in peripheral muscles and joints

Prolonged foot drop will trigger a series of secondary pathological changes in peripheral muscles and joints and aggravate dysfunction. Firstly, long-term lack of active dorsiflexion leads to disuse atrophy of the tibialis anterior, which fails to provide sufficient power for ankle dorsiflexion. Secondly, the triceps surae remains in a sustained hypertonic, spastic state, resulting in gradual contracture of muscle fibers and decreased elasticity & extensibility [2]. These problems further limit ankle dorsiflexion and reduce its range of motion. Finally, long-term abnormal stress produces adverse traction on local ankle ligaments and joint capsules, triggering ligament laxity and capsular adhesion, which destroys ankle stability and changes ankle alignment, leading to irreversible structural abnormalities that increase the difficulty of gait correction [3,4].

2.3. Fixation mechanism of compensatory abnormal gait patterns

Essentially, the abnormal gait induced by hemiplegic foot drop is a compensatory motor strategy formed by the central nervous system to make up for ankle dysfunction. Repeated use of this compensatory strategy forms automatic abnormal motor memory and gradually fixes the compensatory gait [5]. Even if patients partially recover ankle function later, they will unconsciously adopt circumduction and toe-dragging gait due to the ingrained abnormal motor memory [6]. At the same time, long-term compensation subjects the pelvis and hip/knee joints to persistent abnormal stress, breaking the tension balance of periarticular muscles and aggravating pelvic tilt, compensatory hip external rotation, knee hyperextension or flexion, thus forming a vicious cycle where pathological changes and abnormal gait reinforce each other.

3. Core theoretical basis of manual gait correction training

3.1. Neural plasticity regulation theory

Neural plasticity refers to the ability of the central nervous system to undergo structural and functional remodeling through appropriate intervention measures following injury or stimulation, thereby partially repairing damaged neural control pathways. This characteristic of neurons provides a physiological basis for performing manual gait correction training and correcting abnormal motor memory. During manual correction training for hemiplegic foot drop, the therapist guides the patient repeatedly to perform ankle joint movements that conform to normal gait biomechanics, continuously delivering correct motor sensory information to the central nervous system to disrupt the originally established abnormal motor memory pathways [7,8]. Simultaneously, this training activity promotes the reconstruction of correct motor control pathways in the unaffected brain regions and facilitates the reformation of automated motor memory consistent with normal gait requirements.

3.2. Motor control reconstruction theory

Normal gait control is an automated process in which the central nervous system integrates multi-sensory information, sequentially activates muscle groups according to the distinct phases of the walking cycle, and precisely regulates the force vector and center of gravity transfer. Hemiplegic foot drop results from damage to the motor control system, which disrupts the normal logic of muscle group activation, thereby producing an abnormal gait pattern. Consequently, motor control reconstruction serves as the theoretical foundation for manual gait correction training. In such training, the core intervention aimed at facilitating patient recovery does not merely focus on enhancing muscle strength; rather, it involves reconstructing a motor control system that aligns with the requirements of normal walking. Therapists must employ manual contact to deliver appropriate proprioceptive information to the patient, simultaneously correcting abnormal ankle joint angles, force vectors, and muscle activation sequences during the walking process, thereby enabling the patient to establish a new motor control logic through continuous sensory feedback and learning of the correct movement patterns, ultimately reducing reliance on abnormal compensatory mechanisms [9].

3.3. Lower limb biomechanical chain regulation theory

Walking with the lower limbs involves a complete biomechanical transmission chain; any structural or functional abnormality occurring at any link within this chain can adversely affect the entire walking process [10]. Abnormalities at the ankle joint resulting from hemiplegic foot drop can propagate upward along the biomechanical transmission chain, disrupting the balance of the entire lower limb biomechanical chain and subsequently inducing compensatory changes in the knee joint, hip joint, and even the trunk. Manual gait correction training is precisely guided by the Lower Limb Biomechanical Chain Regulation Theory, which begins with an assessment of the overall force line to adjust the local function of the ankle joint and the load distribution across the entire lower limb biomechanical chain; this approach gradually eliminates the abnormal stresses generated by compensatory mechanisms, enabling each joint to return to a proper alignment and positioning consistent with normal walking requirements. As the lower limb biomechanical chain gradually restores its balance and the function of the ankle joint improves, the efficiency of the entire gait movement chain will be further enhanced, thereby providing a structural foundation that aligns with biomechanical principles for the reconstruction of a normal walking pattern [11].

4. Standardized clinical intervention measures of manual gait correction training

4.1. Neural activation and muscle tension regulation in early bedridden stage

When patients cannot stand yet, therapists adopt manual gait correction interventions to conduct neural facilitation and tension regulation on the affected lower limbs, reawaken motor control of tibialis anterior and reduce spastic tension of triceps surae, laying foundations for subsequent standing and walking training [12]. For example, therapists slowly control patients' ankles, passively dorsiflex the ankle to normal range with even force and hold before slow release. Repeated stretching relaxes spastic, shortened triceps surae, gradually reduces muscle tension, and expands passive ankle dorsiflexion range, while inputting proprioceptive signals to help the central nervous system re-perceive ankle position and movement. Besides, therapists adopt light tapping and rapid friction on the belly of the tibialis anterior for neural facilitation, and guide patients to take initiative ankle dorsiflexion following manipulative stimulation to strengthen active contraction awareness of the tibialis anterior [13,14].

4.2. Gravity control and weight-bearing capacity building in sit-to-stand transition stage

After patients gain basic sitting balance, the goal of manual correction shifts to building lower limb weight-bearing and gravity transfer control to cultivate standing proprioception. First, therapists conduct manual gravity shift training in sitting position: standing on the affected side, they assist patients' knees and guide gradual gravity transfer to the affected foot until the sole fully contacts the ground. Pressure stimulation from weight-bearing strengthens proprioceptive input and rebuilds the sensory connection of gravity distribution. Later, the training advances to sit-to-stand conversion: one hand stabilizes the ankle in neutral dorsiflexion, the other guides patients to shift gravity forward and downward until the buttocks leave the chair to stand. After standing, gentle pushes are applied to guide forward/backward/left/right gravity fine-tuning and improve standing balance stability [15]. Training at this stage prevents patients from shifting gravity to the healthy side during walking and establishes normal weight-bearing perception.

4.3. Ankle control and decomposed gait training in standing stage

When patients maintain stable independent standing, ankle control and decomposed gait training can be carried out, which is the core of manual decomposed training and critical for reconstructing ankle control logic in walking cycles. Therapists conduct targeted correction for stance phase and swing phase separately.

For stance phase correction: stand on the affected side, place one hand on the anterior distal tibia and support the heel with the other, guide gravity transfer to the affected limb, and keep the ankle in neutral dorsiflexion to prevent plantar inversion during weight-bearing.

After stance training, proceed to decomposed swing training: stabilize the trunk and maintain ankle dorsiflexion, guide hip & knee flexion for pre-swing preparation, and timely correct compensatory elevation of the pelvis and hip abduction/external rotation, so patients gradually perceive normal ankle trajectory and muscle activation sequence in swing phase.

4.4. Integrated continuous walking and abnormal pattern correction in late stage

After patients finish decomposed stepping independently, therapists arrange integrated continuous walking training to combine segmented movements into intact normal gait. At the initial stage, therapists follow the affected side all the way to assist ankle and knee control and timely correct toe dragging, pelvic elevation, and circumduction gait. When stable continuous walking is achieved, auxiliary force is gradually reduced

to real-time tactile reminders and manipulation only upon abnormal movements. As patients' autonomous control improves, all assistance is withdrawn for independent walking. Meanwhile, therapists set graded walking distance targets according to individual conditions to boost patients' confidence, consolidate correct motor memory, and strengthen active ankle control through progressive training.

5. Conclusion

Manual correction provides an equipment-free, multi-stage adaptive solution for hemiplegic foot drop rehabilitation. Therapists adjust lower limb force lines and muscle activation in real time through tactile feedback, which better fits individual abnormal gait characteristics compared with conventional equipment training. Manual gait correction training bears great application value in hemiplegic foot drop rehabilitation, especially early gait reconstruction. Therapists can adopt corresponding standardized manual intervention measures according to different rehabilitation stages to accelerate patients' recovery of walking ability.

Disclosure statement

The author declares no conflict of interest.

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