Background of the Study

*Freezing of gait (FOG)*, or a sudden, brief inability to generate normal stepping movements, is a common symptom of Parkinson’s disease (PD) that affects more than 50% of patients with PD. However, unlike most Parkinson’s symptoms, FOG is resistant to PD medications and the effects of *subthalamic nucleus deep brain stimulation (STN-DBS;* or therapy that sends electricity through *electrodes* (metal conductors) to specific parts of the brain that control movement) is still unknown. Since FOG is one of the leading causes of falls and reduced quality of life in patients with PD, there is a significant need to effectively control FOG episodes in PD.

Accordingly, a recent study conducted by researchers of the University of Kiel and the Deaconess Hospital in Germany, establishes that STN-DBS may provide an opportunity to improve FOG in PD by allowing doctors to adjust the symmetry and coordination of patient gait. According to the study, since FOG patients often display abnormal symmetry and coordination between each leg, these factors may impair the gait process and contribute to freezing in PD. However, by adjusting the *voltage (electrical intensity)* of stimulation in each side of the brain that controls the dysfunction in the respective leg, researchers suggest that STN-DBS may be able to alter gait symmetry and coordination and, thus, improve FOG in PD. This suggestion was based on a comparison of gait coordination and FOG frequency and duration in 13 patients with PD under four different stimulation conditions (i.e. voltage settings) of STN-DBS.

Purpose of Study

The purpose of the study was to explore how adjusting the *voltage (electrical intensity)* of STN-DBS in each side of the brain that controls leg movement affects the symmetry and coordination of gait, consequently, impacting the severity of FOG in patients with PD.

Patients & Study Participants

Participants included 13 PD patients with FOG who previously received STN-DBS surgery at the University of Kiel Medical Center in Germany. To qualify for the study, patients had to meet the classification for “freezer,” according to the study’s preliminary FOG test, which required
patients to experience at least one FOG episode during 11 minutes of continuous walking while “OFF” PD medications and STN-DBS therapy.

Some general characteristics of patients in the study group are:

- 3 participants were female & 10 were male
- The average participant age was 63 years of age
- The average duration of diagnosed PD was 15 years
- None of the participants experienced FOG episodes “ON” PD medications prior to receiving STN-DBS surgery.

**Study Methods**

To investigate how adjusting the symmetry and coordination of gait using STN-DBS affects the severity of FOG in patients with PD, researchers used the following methods:

- Patients were evaluated during a single session in the “OFF” medication state, or at least 12 hours after withholding PD medications. During this session, patients were evaluated under four different stimulation conditions (STN-DBS voltage settings):
  1. “OFF” stimulation with STN-DBS
  2. “ON” standard stimulation settings with STN-DBS
  3. With a 50% “worse side reduction (WSR)” of stimulation for the more impaired leg (i.e. reduced voltage settings in the side of the brain that controls the leg with the shorter step length)
  4. With a 50% “better side reduction (BSR)” of stimulation for the less impaired leg (i.e. reduced voltage settings in the side of the brain the controls the leg with the longer step length)

- As a criteria for identifying FOG episodes, researchers defined FOG as all of the characteristics below:
  - A sudden increase in stepping frequency (i.e. number of steps)
  - A reduction of step height
  - A motor block (sudden inability to walk)

- Then, during each stimulation setting, researchers performed a gait analysis while patients walked on a treadmill set to a “comfortable” walking speed. For the gait analysis, researchers:
  - Recorded patient gait for 40 seconds using a movement analysis system, a device that records and measures gait movements using six infrared cameras connected to a computer
Identified the total number of FOG episodes and calculated the average duration of each episode for each patient.

- Assessed gait coordination using the Phase Coordination Index (PCI), a tool that measures the accuracy and consistency of left-right stepping movements by analyzing the relationship between:
  - **Stride time** ("full gait cycle"): The time from one heel strike to the next heel strike of the same leg.
  - **Step time** ("phase of gait"): The time between the heel strike of one leg and the heel strike of the other leg.

- Measured the patients’ average gait velocity (meters/second), stride length (cm), step height (mm), and cadence (steps/min).

Lastly, researchers compared all the clinical data and gait measurements collected while patients were in the “OFF”, “ON”, WSR, and BSR stimulation conditions.

**Study Results**

In response to the effectiveness of STN-DBS on FOG in PD, the study found that while a “better side reduction (BSR)” of stimulation voltage significantly improved gait coordination and FOG severity in patients with PD, a “worse side reduction (WSR)” of stimulation voltage had the reverse effect and worsened gait coordination and freezing. Overall, these results suggest that:

- Poor leg symmetry and coordination is strongly associated with FOG in PD.
- STN-DBS can either improve or worsen FOG by altering gait symmetry and coordination.

This finding was based on a comparison of gait characteristics (i.e. velocity, stride length, and cadence), gait coordination measured by the Phase Coordination Index (PCI), and FOG frequency and duration in 13 patients with PD under the following STN-DBS stimulation conditions: “OFF” stimulation, “ON” standard stimulation settings, with a 50% WSR of stimulation, and with a 50% BSR of stimulation.

In terms of patient gait characteristics, researchers found that:

- There was a significant improvement “ON” compared to “OFF” stimulation in:
  - Gait velocity, which increased from 0.39 to 0.50 meters/sec
  - Stride length, which increased from 39 to 52 cm
  - Cadence, which decreased from 164 to 138 steps/min

- WSR had no effect on gait, whereas BSR further improved stride length from 52 to 60 cm and cadence from 138 to 106 steps/min.
Altogether, these study findings suggest that while patient gait improved in both the “ON” and BSR stimulation conditions, the effect of BSR on gait was significantly better than standard stimulation. Conversely, patient gait was unaffected by both the “OFF” and WSR stimulation conditions.

Moreover, according to the Phase Coordination Index (PCI), BSR stimulation also improved coordination of gait more significantly than any of the three other stimulation conditions, with WSR stimulation actually worsening coordination between legs. Overall, researchers found that:

- BSR significantly reduced PCI (in other words, BSR improved coordination) to 16.5% from “OFF” (33.8%) and “ON” (26.3%) stimulation
- In contrast, WSR increased PCI (in other words, WSR made coordination worse) to 35.1% from “OFF” (33.8%) and “ON” (26.3%) stimulation.

Lastly, in terms of the average frequency and duration of FOG episodes, researchers found that:

- From “OFF” to “ON” stimulation, FOG frequency decreased (improved) from 2 to 1.4 episodes and FOG duration decreased (improved) from 12.2 to 2.6 seconds
- Compared to “ON” stimulation, BSR further reduced FOG frequency to 0.2 episodes and FOG duration to 0.2 seconds, whereas WSR had no effect on FOG frequency and increased (worsened) FOG duration to 5.2 seconds.

Altogether, these study findings indicate that a 50% reduction of stimulation voltage for the “better side” (BSR) was more effective in improving FOG severity than standard STN-DBS stimulation settings, whereas a 50% reduction of stimulation voltage for the “worse side” (WSR) was actually worse for FOG than being completely “OFF” stimulation therapy.

**Study Discussion & Implications**

The study suggests that poor leg coordination and lower leg symmetry are strongly associated with FOG in PD and both factors can be adjusted using STN-DBS. This finding is evident by the change in FOG frequency and duration and PCI gait coordination measurements after researchers altered the stimulation voltage of STN-DBS in each side of the brain. Researchers recommend that if patients with FOG and STN-DBS show abnormalities of gait symmetry and coordination, stimulation voltage should be reduced by 50% for the leg on the “better side” (i.e. leg with the longer step length). Moreover, 50% BSR of stimulation voltage can significantly improve patient coordination of gait and, as a result, reduce the severity of FOG episodes in patients with PD.
Controlling Gait Coordination with STN-DBS Improves Freezing of Gait in Parkinson’s disease