RESEARCH ARTICLE

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A Pilot Study on the Efficacy of a Smart Spoon as an Assistive Tool for Individuals with Parkinson's Disease

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Abstract

Parkinson's disease is a progressive neurodegenerative disorder characterised by motor symptoms like tremors, rigidity, and bradykinesia, which affect daily activities such as eating. Tremors, especially in the hands, can cause difficulties with tasks requiring dexterity, including eating, leading to reduced independence. A smart spoon device has been developed to minimise food spillage. This study aims to evaluate the effectiveness of this smart spoon in improving eating tasks for patients with Parkinson's disease who have moderate tremors. A pilot cross-sectional study was conducted at RV College of Physiotherapy. Eight participants were screened based on the inclusion and exclusion criteria. Participants performed a timed rice transfer task with the smart spoon in both on and off states. Data on rice spillage were collected and analysed. In its current design, all the participants with the smart spoon failed to significantly reduce food spillage during eating tasks for individuals with Parkinson's disease. The current design of the smart spoon does not significantly reduce food spillage during eating tasks for individuals with Parkinson's disease. This suggests that while the technology aims to assist users with motor control challenges, further refinement and development of the device are necessary.

Major Findings: The smart spoon device did not significantly reduce food spillage during eating tasks for individuals with Parkinson's disease. All participants showed similar spillage levels with and without the device. Further design improvements are needed to enhance its effectiveness for users with moderate tremors.

Keywords: Assistive Device, Parkinson's Disease, Smart Spoon, Tremors

1. Introduction

Parkinson's Disease (PD) is a Progressive neurodegenerative disease caused by the loss of dopamine-producing neurons that influence the regulation of movements and emotions[1-3]. It is characterised by motor symptoms such as tremors, rigidity, postural instability, and bradykinesia, which worsen over time[3,4]. The prevalence of PD is expected to rise significantly due to ageing populations, with an estimated 30% increase by 2040[5]. The risk factors of PD are hereditary, genetic, environmental, and industrial chemicals[5].

It has both motor and non-motor symptoms that will contribute to diminishing quality of life. Tremor is a hallmark symptom of Parkinson's disease, often the first sign noticed due to its visibility[3]. Tremors are usually divided into resting and action tremors. The frequency of the resting tremor is between 3 and 6 hertz[6,7]. PD patients often struggle with eating due to hand tremors, which prevent them from accurately controlling utensils and can cause food to spill. The resulting embarrassment can lead to social withdrawal[6,8-10]. While medication is frequently used to manage tremors, its effectiveness varies among Parkinson's patients, and side effects like blurred vision, dizziness, fatigue, and even muscle paralysis are possible. Brain surgery, though an option, is invasive and typically reserved for cases where medication proves insufficient. This has spurred significant research into less invasive,

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side-effect-free alternatives[6,11]. Inspired by recent advances in stabilisation technology, researchers are developing practical devices to counteract hand tremors in Parkinson's patients[12]. These devices combine stabilisation techniques with various control methods to help patients regain independence in daily activities[6]. Tremors associated with Parkinson's disease typically occur within a frequency range of 4–6 Hz, and the smart spoon is precisely calibrated to detect and respond to motion patterns within this range[13].

A smart spoon has been engineered to mitigate eating difficulties caused by Parkinson's disease tremors. Using an Inertial Measurement Unit (IMU) to detect tremors, the spoon's Proportional- Integral-Derivative (PID) controller adjusts two motors to maintain stability, preventing spills. The design incorporates a responsive brushed motor with a gearbox, a detachable spoon, ergonomic features, and a long-lasting battery. This cost-effective device offers a promising solution for Parkinson's patients experiencing moderate tremors[14].

Features of the smart spoon:

- PID controller - Intelligently controls the motor to rotate in the opposite direction of the tremor
- Brushed motor with gearbox and Encoder - more responsive than the servo motors
- IMU (Inertial Measurement Unit) - 9 degrees of freedom make the smart spoon more sensitive to tremors
- Robust and Stable Design - All the sensors and motors are stationary to each other
- Customised 3D printed components - Easier to enhance between prototypes
- Specially designed for PD Patients with moderate level tremors
- Compact and easy-to-hold Design. Ergonomic Design – knurling pattern to increase grip.
- Easily detachable spoon - Using a wingnut which can be easily loosened
- Long battery life and easily rechargeable
- Cost-effective so that it's reachable to a wider community across the globe.

This study evaluates the smart spoon's effectiveness in reducing tremor-induced food spillage among Parkinson's patients. By testing the device in controlled conditions, the study aims to determine its impact on the patient's ability to perform essential eating tasks independently.

2. Materials and Methods

The pilot cross-sectional study was conducted at the RV College of Physiotherapy's neurological physiotherapy outpatient department. It was held between May 30, 2023, and May 30, 2024. After ethical approval, subjects were recruited by screening them for inclusion and exclusion criteria using H and Y scale (1-3), UPRDS for eating task[15], and Cognitive impairment was assessed by Montreal cognitive assessment, with informed consent obtained before proceeding. 8 Participants aged 50 to 80 were selected using convenience sampling, provided they met the inclusion criteria, such as having sufficient cognitive ability and a confirmed PD diagnosis with tremors. Exclusion criteria included other neurological deficits, unstable health conditions, and recent musculoskeletal injuries[16].

The study evaluated the effectiveness of a smart spoon in reducing tremor-induced food spillage during a sixty-second timed transfer task. Patients were seated and asked to transfer rice between two bowls 50 cm apart using the smart spoon, with three trials performed for each state (on and off) of the spoon[16,17]. The state of the spoon was blind to the participants, and the amount of rice spillage was measured in both conditions. Data from the trials were collected for further analysis to assess the device's performance.

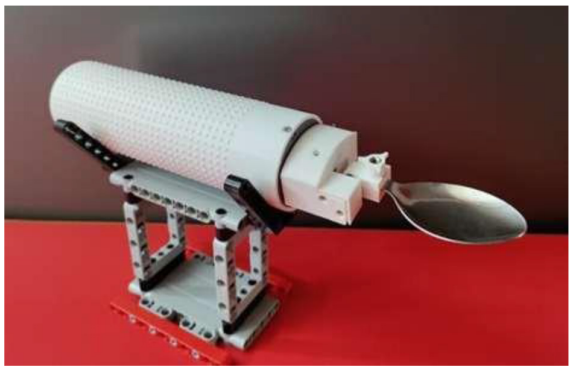


Figure 1. 3D printed smart spoon (front view).

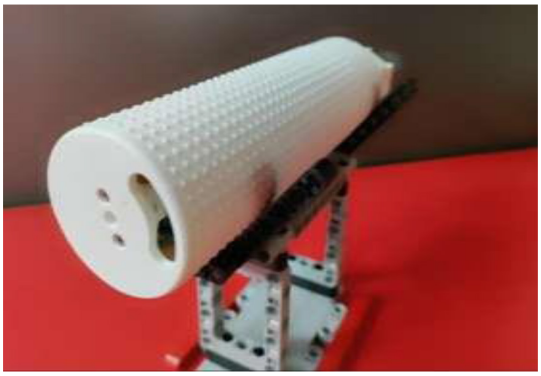


Figure 2. 3D printed smart spoon (back view).

3. Outcome Measures

The primary outcome measure for this study was the amount of rice spillage during the 60-second timed transfer task. This task evaluated participants' ability to transfer rice from one bowl to another using a smart spoon under two conditions: with the spoon in the "on" state (active stabilisation) and in the "off" state (no stabilisation). The spillage amount, measured in grams, served as an indicator of motor function and task performance.

This study focuses on individuals in Stages 1-3, where participants retain enough motor control to perform tasks but may show signs of mild to moderate disability. The UPDRS eating task specifically evaluated participants' ability to perform a task involving fine motor skills, which is critical for assessing how well they manage daily activities affected by PD.

4. Results

The study population consisted of 8 participants, with 3 females (37.50%) and 5 males (62.50%).

The severity of Parkinson's disease symptoms among participants was evenly distributed.

The results of this pilot cross-sectional study began with screening an initial pool of 13 participants diagnosed with Parkinson's disease at Hoehn and Yahr (HandY) Stages 1-3. Out of these, 8 participants met the inclusion criteria, which included being within the specified HandY stages, having sufficient cognitive function as assessed by the Montreal Cognitive Assessment (MOCA), and meeting other study requirements. These 8 participants, comprising 3 females (37.50%) and 5 males (62.50%), were enrolled and completed the data collection phase. The study population included 4 participants at HandY Stage 2 and 4 at Stage 3, with no participants in Stages 4 or 5. The eating task scores showed that 62.50% (5 participants) had a "Slight" rating, and 37.50% (3 participants) had a "Mild" rating. There were no cases rated as "Normal," "Moderate," or "Severe."

All 8 participants completed the 60-second timed transfer task, with no missing data reported. The data were analysed using the Wilcoxon Signed Rank Test to compare the spillage amounts in the "off" and "on" states of the smart spoon. The median spillage for the spoon in the "off" state was 0 grams (IQR 0, 0.25), indicating minimal spillage. In contrast, when the spoon was in the "on" state, the median spillage was 2 grams (IQR 1, 2.33). The test produced a p-value of 0.028, signifying that the increase in spillage with the spoon in the "on" state was statistically significant.

This study found no major confounders, as the selection criteria controlled for participant stage and cognitive ability. Additionally, no further categorisation of continuous variables was performed. The data demonstrated that the smart spoon, in its current design, did not reduce spillage during the eating task for individuals with Parkinson's disease. This finding suggests that, under the study conditions, the device was not effective in aiding fine motor function for the intended purpose. No subgroup or sensitivity analyses were conducted in this study.

Table 1. Descriptive analysis

Characteristic	N = 8[1]
Gender	
F	3 (37.50%)
M	5 (62.50%)
HandY	
2	4 (50.00%)
3	4 (50.00%)
Eating Task Score	
Normal	0 (0.00%)
Slight	5 (62.50%)
Mild	3 (37.50%)
Moderate	0 (0.00%)
Severe	0 (0.00%)
[1]n (%)	



Figure 3. Total spillage with and without a spoon for all patients.

Table 2. Comparing the total spillage between spoon off and spoon on

Variable	N	Range	Median. IQ	Statistical value	P Value1
SPOON.OFF.spillage.in.grams	8	0,1	0(0,0.25)	2	0.028 * (W)
SPOON.ON..spillage.in.grams	8	0,3.1	2(1,2.33)		

[1](W): Wilcoxon Signed Rank Test,

5. Discussion

This study aimed to assess the effectiveness of a smart spoon as an assistive device for individuals with Parkinson's Disease (PD) who experience tremors. The results demonstrated that the smart spoon's current design failed to significantly reduce food spillage during eating tasks compared to traditional utensils. The findings of this study are consistent with prior research. A pilot study conducted by Ryden *et al.* reported minimal functional improvements associated with the use of a gyroscopic spoon, indicating that existing assistive technologies may not provide significant benefits for all individuals[17]. Likewise, Anand *et al.* examined stabilising spoons and underscored the inherent complexities in developing effective tremor-cancelling mechanisms. These challenges align with the present study's findings, despite the integration of advanced features such as a PID controller and IMU sensors[18]. Heusinkveld's research highlights the significant impact of tremors on daily tasks, particularly fine motor activities such as eating, which aligns with the focus of this study. Her findings reinforce that the challenges individuals with Parkinson's disease faced in this study did not significantly improve food stability, reflecting the limitations of current assistive technologies. These results underscore the need for further innovation in tremor-cancelling devices to enhance their effectiveness in real-world use[3]. The contrast with Pathak's study, which reported positive outcomes using an active tremor cancellation device for essential tremors, suggests that differences in tremor characteristics and device design may explain the varied results[16].

This study, despite its valuable insights, presented several limitations that warrant attention in future research. The small sample size of eight participants may have constrained the generalizability and statistical power of the findings. Additionally, potential biases such as variability in individual tremor patterns and the time required for participants to acclimate to the device could have affected the perceived effectiveness of the smart spoon during the trial. Furthermore, the short duration of the study did not facilitate an assessment of long-term usability and adaptation, both of which are crucial for comprehending the practical advantages of assistive devices.

The overall interpretation of these findings suggests that while the smart spoon's current design was ineffective in reducing spillage, it underscores the need for improvements. The observed significant increase in spillage when using the smart spoon may be attributed to factors such as user adaptation challenges, device ergonomics, partial tremor cancellation, and task complexity. Addressing these through design improvements, user training, and controlled experimental conditions will be crucial to optimising the smart spoon's efficacy and reducing spillage in Parkinson's disease patients[19,20]. This interpretation should be viewed cautiously due to the limitations in sample size and study design. The result aligns with other studies that underscore the importance of personalised assistive technologies, yet they differ from some studies that found more effective solutions with different technological approaches. Further research should include a larger and more varied sample size to explore the spoon's effectiveness across varying levels of tremor severity and types of tremors. Incorporating longer study durations would help evaluate the impact of device use over time, including any potential improvements in user proficiency and satisfaction.

The generalizability of these findings is currently limited due to the small and specific study sample. Future studies should aim to include a broader population of PD patients to better understand the applicability of the findings across different demographics and severities of PD. This study was conducted without external funding, and no funder influenced the findings' design, implementation, or reporting. The insights gained from this study provide a foundation for future research aimed at refining the design of assistive devices for people with Parkinson's disease and ensuring their effectiveness in daily life activities.

6. Conclusion

The current design of the smart spoon does not significantly reduce food spillage during eating tasks for individuals with Parkinson's disease. This suggests that while technology aims to assist users with motor control challenges, further refinement and development of the device are necessary.

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