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Remote Ischemic Conditioning Combined with Bimanual Task Training for Motor Skill Acquisition in Children with Unilateral Cerebral Palsy: A Randomized Controlled Trial

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Abstract Cerebral palsy presents diverse neurodevelopmental challenges, often accompanied by epilepsy and musculoskeletal issues. Lesions to UMN further affect with CST pathways, causing difficulty and paralysis. Injuries affecting children with impaired motor function may benefit from ischemic conditioning and bimanual training. **Purpose:** To evaluate how bimanual task training with ischemic conditioning might enhance motor abilities and task performance in children with unilateral cerebral palsy. Finding efficient rehabilitation techniques that improve functional outcomes in this population was the aim. **Methods:** In this 4-month randomized controlled experiment, 22 children with unilateral cerebral palsy (UCP), ages 8 to 16, were examined to determine benefits of bimanual task training in combination with ischemic conditioning and a sham intervention. 3 Manual Ability Classification System (MACS) levels and the ability to stack three cups in under a minute were requirements for inclusion. Blood pressure was periodically taken throughout 45-minute intervention, and cycles of pressure cuff inflation and deflation lasted five minutes each. Assisting Hand Assessment (AHA) ratings, goal synchronization, and Total task duration were among findings that were statistically analyzed using SPSS version 26. **Results:** Both of intervention groups demonstrated improved motor function and skill acquisition despite minor demographic differences. These outcomes show how therapies had a major effect on improving motor function. When given both ischemic conditioning and bimanual task training, children with UCP demonstrated improved performance on bimanual tasks. The results suggest that these interventions can enhance task efficiency and cognitive function in this population, even if not all variables exhibited statistically significant differences. **Discussion:** This study shows that bimanual task training and ischemic conditioning both greatly enhance motor function and task efficiency in children with unilateral cerebral palsy. According to these results, combining the two approaches may improve rehabilitation results and offer insightful information for future study and clinical use.

Keywords: Ischemic conditioning, Bimanual task training, Unilateral Cerebral Palsy

1. Introduction

Cerebral Palsy describes as a range of neurodevelopmental problems, the main ones being associated with impairments in posture and motion (1, 2). The initial disruption to normal brain structure and function may eventually result in modifications or additional symptoms, cerebral palsy is currently defined as a permanent condition (3). Unilateral spastic cerebral palsy (CP) is typically caused by middle cerebral artery infarction, hemi-brain atrophy, periventricular lesions, brain malformation, or post hemorrhagic porencephaly; these diseases commonly compromise the integrity of the motor areas and Corticospinal tract (CST) (4).

The complication to CST and other developing motor pathways indicated earlier causes difficulty in upper extremities performing actions (1). Children with cerebral palsy, age 6-15, apply fingertip force less quickly, with less coordination than others who are usually developing (5). The central nervous system (CNS) contains Upper Motor Neurons (UMNs) that regulate movement. These UMNs include corticospinal and corticobulbar tracts that make up the pyramidal tract. Cerebral

palsy can result from injuries to UMNs (6). Movement is regulated by (UMNs) through tracts; pyramidal tract serves as a direct link between cerebral cortex and spinal cord (7).

The pyramidal tract pathways are important to understand UMN lesions since lesion's location in relation to pyramidal decussation affects its symptoms. When a lesion occurs in right corticospinal tract prior to crossing, left hemisphere experiences muscle weakness and stiffness. This is because lesions rostral to decussation induce contralateral symptoms (8). Unilateral lesions may not cause major impairment, however bilateral UMN lesions can cause problems (9).

Studies have shown that children who have been diagnosed with cerebral palsy (CP) may face difficulties when trying to perform complex tasks that require exact command of voluntary motions, such as gripping and reaching, using their affected limbs. These movements are accompanied through atypical inhibition and excitation patterns in muscle activity (10). Normally growing adults and children use muscular activities to make smooth and graceful reaching motions when interacting with objects in their environment. However, limb that is dominant usually demonstrates greater synchronization compared to non-dominant limb due to asymmetrical nature of governing these interactions (11).

By utilizing a blood pressure cuff to induce ischemia and reperfusion in a distant limb, remote ischemic conditioning (RIC) increases the target organ's resistance to additional ischemic events. This technique uses distant tissue conditioning to activate cellular defensive mechanisms (12). With its significant cardio protective effects, Remote Ischemic Conditioning (RIC) shields tissues and organs from damage caused by prolonged ischemia by using brief cycles of reduced and restored blood flow (13). Learning motor skills may be enhanced by combining remote ischemic conditioning (RIC) with task-specific training. To validate its advantages for children with unilateral cerebral palsy (UCP), more study is necessary (14).

In order to construct pyramids, participants stacked and unstacked cups, paying close attention to speed, gentle handling, and utilizing both hands. Errors were fixed and times were noted. They were split up into groups, one of which watched and spoke about methods (15). 5.8% to 15.3% of elderly Thais have trouble using their hands. To improve aging interventions, more research is required into the mental and physical aspects of activities like cup stacking (16). Kinematic analysis is used to evaluate the effects of a five-week cup stacking intervention on upper limb coordination, demonstrating the intervention's benefits in physical education (17).

According to research, less feedback can enhance timing while more feedback can impede the development of motor skills by developing dependency. Simultaneous feedback emphasizes the importance of practice situations that resemble exam scenarios and helps with learning complex tasks and transfer performance (18). In order to provide a thorough and reliable method for measuring hand function in CP, the Observational Skills Assessment Score (OSAS) assesses the frequency and quality of hand use in bimanual tasks (19). In an effort to shed light on efficient long-term stroke recovery, it looks at the relationship between functional gains, pain, and the speed at which cups stack (20).

In 46 children with unilateral cerebral palsy (UCP), Surkar SM, Willson JD, Cassidy JM, et al. investigated bimanual training using Remote Ischemic Conditioning (RIC). RIC or sham conditioning was administered at random to the 8 to 16-year-old participants over 5 days of cup stacking instruction. Movement length, corticospinal excitability, spatiotemporal kinematics, and Assisting Hand Assessment were among results (12). According to Cherry-Allen KM, Gidday, individuals with chronic stroke who observed their spouses for 6 minutes were able to enhance their bimanual cup stacking abilities more quickly than those who observed for less time (21).

Shea, Wulf, and Whitacre (1999) discovered that, despite similar results, dyad practice was more effective than individual practice. To fully comprehend these advantages, more research was recommended. Several practice scenarios were evaluated, and then a retention test was conducted on the 48 inexperienced cup stackers in the study (15). In Moodley's study, which involved 60 seniors, cup stacking significantly improved plate tapping and reaction speeds in intervention group while having no apparent impact on memory or hand-eye coordination. The findings point to possible advantages for motor skills, indicating the need for more study (22).

Klevberg and Jahnsen examined hand use variations in bimanual activities by analyzing 166 children with unilateral cerebral palsy (CP). It was discovered that children with higher AHA-18 or Manual Ability Classification System (MACS) scores had more limits but also developed more quickly. Ages 6 to 13 saw majority reach stable performance limits, with impairments persisting even after (23). When bimanual training was added to regular therapy, as opposed to standard therapy alone, Ejaz, Tanveer, and Ahmad observed that thirty individuals with unilateral spastic cerebral palsy had a significant improvement in hand coordination and everyday activities (24).

Objectives

The objectives of this research are to compares the effects of ischemic conditioning and bimanual task training on skill acquisition in children with unilateral cerebral palsy with a Sham intervention. It aims to enhance bimanual skills and coordination in these children.

Rationale of Study

To help therapists choose most appropriate treatments by investigating advantages of combining ischemic conditioning with bimanual task training to enhance skill development.

Impact of Study

The study investigates how to enhance the acquisition of skills in children with cerebral palsy by combining ischemic conditioning with bimanual task training. By encouraging brain adaptation and synaptic plasticity by temporary blood flow restriction, this strategy seeks to improve neuroplasticity, which will improve motor function and performance on daily activities.

Research Gap

Even while bimanual task training and ischemic conditioning are useful for enhancing motor abilities in children with unilateral cerebral palsy, their combined effects have not received enough attention. The majority of research focuses on single treatments with limited follow-ups. This study investigates synergistic effects of combining these interventions on skill acquisition outcomes through a randomized control trial.

2. Methodology

The purpose of this randomized controlled research was to assess how well ischemic conditioning when combined with bimanual task training can help children with unilateral cerebral palsy acquire new skills. After receiving ethical approval, the study was carried out at Children Hospital in Faisalabad, Pakistan, for a period of 4 months. The outcome assessor was blinded to the assignment of participants, who were chosen through purposive selection, and randomly allocated to either the ischemic conditioning group or the sham intervention group. The study comprised 22 individuals in total. In order to ensure a consistent and accurate selection procedure, a 10-item screening form was used to identify suitable participants. The form assessed bimanual coordination impairments, educational placement, developmental challenges, and Manual Ability Classification System levels.

Inclusion Criteria

- Children identified as having unilateral cerebral palsy (UCP) (12)
- Children with age: 8-16 years (12)
- Children having Levels I through III of the Manual Ability Classification System (MACS) (25)
- Children who are capable of stacking three cups in about a minute (26)
- Mainstream in school (12)

Exclusion Criteria

- Children experiencing from other developmental abnormalities like autism, ADHD, and developmental coordination issues (12)
- Children lacking an active motor threshold (27)
- Children who have been identified as having cardiorespiratory, metabolic, or vascular diseases (12)
- Children with hydrocephalus and neoplasm (12)
- Children who have either obtained or are presently acquiring other adjunct therapies, like TDs and RTMs, within the last six months (12)
- Children who are currently using anti-seizures medication and have had active seizures or seizures within last two years (12)
- Children with devices for medical care that are incompatible and implants made of metal (28)

Figure 1 Remote Ischemic conditioning

Figure 2 Bimanual Speed Stacking Task

Bimanual coordination and hand function will be assessed using Assisting Hand Assessment (AHA) 5.0. A physical therapist administers this evaluation, which has a score range of 1 (no arm use) to 4 (effective arm use). A considerable improvement is indicated by a 5-point difference on AHA scale. By measuring timing difference between affected and unaffected arms, goal synchronization sheds light on motor coordination. A thorough assessment of motor performance is provided by total task duration, which measures amount of time from beginning of hand movement to end of activity. The caregivers of participants gave their informed consent after being fully informed about all study's benefits and risks. The AHA question scale, BP equipment, stopwatches, and video recordings were all used in data gathering process. 5 times a week for 6 weeks, participants received therapy in either ischemic conditioning or sham intervention groups, which were assigned at random. Cycles of cuff inflation and bimanual cup stacking were part of ischemic conditioning, whereas sham group experienced same training without artery constriction. The effectiveness of interventions was ascertained by recording and analyzing speed stacking tasks, AHA evaluations, measurements of aim synchronization, and overall task time. The effect on motor function and skill acquisition was assessed five days after treatment, and results served as a basis for further clinical procedures.

ETHICAL CONSIDERATION

The University of Faisalabad granted ethical approval for the study, and The Children's Hospital Faisalabad provided its consent. Informed written consent has been submitted by participants and their guardians, confirming compliance with ethical standards. Strict coding and safe storage practices were used to protect data confidentiality, and the study's activities were planned with participant safety and no disruption in consideration.

FOLLOW UP

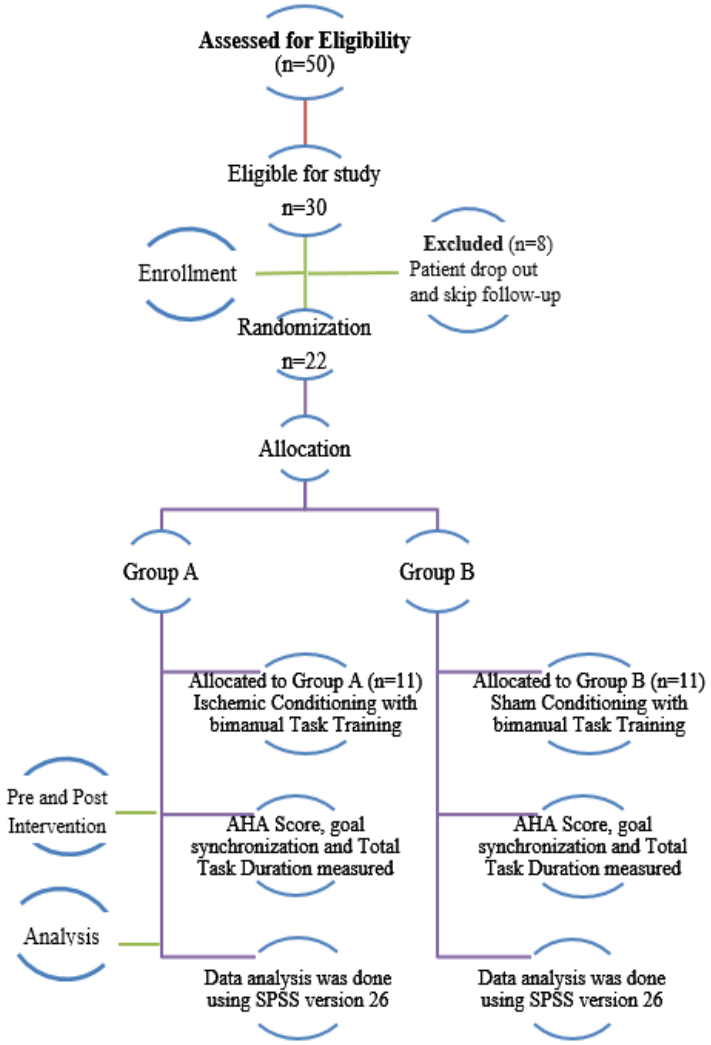
Five days later, at baseline and following the end of the fifth treatment session, follow-up measurements were carried out. These evaluations played an essential part in determining how well ischemic conditioning and bimanual task training performed for children with unilateral cerebral palsy (UCP). Nine trials were used to carefully document the primary outcomes, such as movement time, and video recordings were used to ensure accuracy and transparency. Secondary outcomes included more information about bimanual coordination and motor performance. These included the Assisting Hand Assessment (AHA), goal synchronization, and overall activity duration. Subsequent clinical methods for children with UCP will be dependent on the extensive review of the interventions' effects on learning skills and motor function made possible by these follow-up tests.

STATISTICAL ANALYSIS

Using SPSS version 26 on Windows, a statistical analysis of bimanual task function was performed in two groups (Ischemic Conditioning with Bimanual Task Training vs. Sham Conditioning with Bimanual Task Training) in order to determine the significance of the interventions. To determine whether to use parametric or non-parametric approaches, the Shapiro-Wilk test was used to test the initial data's normality. While the AHA Score, with a p-value > 0.05, enabled parametric testing, non-parametric analysis was required for variables with non-normal distributions ($p < 0.05$), such as goal synchronization and task

time. Clinical decision-making pertaining to bimanual task rehabilitation is facilitated by the thorough analysis of the study, which provides insightful information about treatment efficacy.

CONSORT FLOW DIAGRAM



3. Results and Discussion

22 of the 50 screened participants; split into two groups of 11; completed the research. Group B had Sham Conditioning, while Group A underwent Ischemic Conditioning with bimanual Task Training.

Interpretation of Normality Tests on pretest variables

Table 1 Tests of Normality on pretest variables

Tests of Normality						
	Kolmogorov-Smirnov[a]			**Shapiro-Wilk**		
	Statistic	df	Sig.	Statistic	df	Sig.
Goal synchronisation (PRE Intervention)	.259	22	.000	.788	22	.000
TOTAL AHA score (PRE Intervention)	.215	22	.009	.860	22	.005
Total Task Duration (PRE Intervention)	.313	22	.000	.746	22	.000

Non-parametric statistical tests are required because the tests for "Goal Synchronization (PRE Intervention)," "Total AHA score (PRE Intervention)," and "Total Task Duration (PRE Intervention)" reveal substantial deviations from normal distribution.

Non-Parametric Tests finding of Ischemic Conditioning Combined with Bimanual Task Training Group

Within-group Analysis (Wilcoxon Signed Ranks Test) of RIC + Bimanual Task Training

Table 2 Wilcoxon Signed Ranks Test

Ranks				
		N	Mean Rank	Sum of Ranks
Goal synchronisation (POST Intervention) - Goal synchronisation (PRE Intervention)	Negative Ranks	7[a]	5.29	37.00
	Positive Ranks	2[b]	4.00	8.00
	Ties	2[c]		
	Total	11		
TOTAL AHA score (POST Intervention) - TOTAL AHA score (PRE Intervention)	Negative Ranks	0[d]	.00	.00
	Positive Ranks	11[e]	6.00	66.00
	Ties	0[f]		
	Total	11		
Total Task Duration (POST intervention) - Total Task Duration (PRE Intervention)	Negative Ranks	4[g]	2.50	10.00
	Positive Ranks	0[h]	.00	.00
	Ties	7[i]		
	Total	11		

Based on Wilcoxon Signed Ranks Test, all 11 observations had a higher TOTAL AHA score, indicating a significant improvement in goal synchronization and cognitive function following intervention. 7 of 11 cases had a drop in goal synchronization, two had an improvement, and 2 had no change at all. Four examples had a decrease in total task duration, whereas seven cases exhibited no discernible change, indicating a favorable impact on task efficiency.

Table 2.1 Wilcoxon Test Statistics

Test Statistics			
	Goal synchronisation (POST Intervention) - Goal synchronisation (PRE Intervention)	TOTAL AHA score (POST Intervention) - TOTAL AHA score (PRE Intervention)	Total Task Duration (POST intervention) - Total Task Duration (PRE Intervention)
Z	-1.811[b]	-2.937[c]	-1.890[b]
Asymp. Sig. (2-tailed)	.070	.003	.059

With Z-scores of -1.811, -2.937, and -1.890, respectively, the Wilcoxon Signed Ranks Test reveals lower post-intervention values for goal synchronization, TOTAL AHA score, and Total Task Duration. The TOTAL AHA score showed significant improvements ($p = 0.003$), but not Total Task Duration ($p = 0.059$) or goal synchronization ($p = 0.070$).

Non-Parametric Wilcoxon Test on Sham Combined with Bimanual Task Training Group

Within-Group Analysis (Wilcoxon Signed Ranks Test) of Sham + Bimanual Task Training

Table 3 Wilcoxon Signed Ranks Test

Ranks				
		N	Mean Rank	Sum of Ranks
Goal synchronisation (POST Intervention) - Goal synchronisation (PRE Intervention)	Negative Ranks	6[a]	3.50	21.00
	Positive Ranks	0[b]	.00	.00
	Ties	5[c]		
	Total	11		
TOTAL AHA score (POST Intervention) - TOTAL AHA score	Negative Ranks	2[d]	3.00	6.00
	Positive Ranks	9[e]	6.67	60.00

(PRE Intervention)	Ties	0[f]		
	Total	11		
Total Task Duration (POST intervention) - Total Task Duration (PRE Intervention)	Negative Ranks	7[g]	4.00	28.00
	Positive Ranks	0[h]	.00	.00
	Ties	4[i]		
	Total	11		

54.5% of participants showed a drop in goal synchronization, according to intervention study, while 45.5% observed no change at all. 81.8% of participants noticed improvements in their overall AHA score, with no losses. Furthermore, 36.4% reported no change, and 63.6% reported a reduction in Total Task Duration. The AHA score and task length were both positively impacted by intervention, according to these results, impacts on goal synchronization were less consistent.

Table 3.1 Wilcoxon Test Statistics on Sham group variables

Test Statistics[a]			
	Goal synchronisation (POST Intervention) - Goal synchronisation (PRE Intervention)	TOTAL AHA score (POST Intervention) - TOTAL AHA score (PRE Intervention)	Total Task Duration (POST intervention) - Total Task Duration (PRE Intervention)
Z	-2.333[b]	-2.404[c]	-2.646[b]
Asymp. Sig. (2-tailed)	.020	.016	.008

Goal Synchronization (Z = -2.333, p = 0.020), Total AHA Score (Z = -2.404, p = 0.016), and Total Task Duration (Z = -2.646, p = 0.008) were three metrics that showed a significant improvement following the intervention. These results provide strong confidence in significant gains.

Total AHA Score

Between-Group Analysis (Mann Whitney U) of Total AHA Score

Table 4 Mann Whitney-U of Total AHA Score

Ranks				
	Group	N	Mean Rank	Sum of Ranks
TOTAL AHA score (PRE Intervention)	RIC + Bimanual Task	11	12.09	133.00
	Sham + Bimanual Task	11	10.91	120.00
	Total	22		
TOTAL AHA score (POST Intervention)	RIC + Bimanual Task	11	12.09	133.00
	Sham + Bimanual Task	11	10.91	120.00
	Total	22		

Table 4.5 shows the Mann Whitney U Test reading on Total AHA Score between group A and Group B. On pre-intervention, for group A, the mean rank was 12.09 and for group B, the mean rank was 10.9. However, post-intervention results of both group A and B remained unchanged.

Table 4.1 Mann Whitney U test statistics between both groups

Test Statistics[a]		
	TOTAL AHA score (PRE Intervention)	TOTAL AHA score (POST Intervention)
Mann-Whitney U	54.000	54.000
Wilcoxon W	120.000	120.000
Z	-.431	-.428
Asymp. Sig. (2-tailed)	.666	.669
Exact Sig. [2*(1-tailed Sig.)]	.699[b]	.699[b]

When comparing the both groups for the effectiveness of results, the Mann Whitney U test statistics shows that P-value of post-intervention between both groups was 0.66, higher than 0.05, showing that there is no statistically significant difference between both groups in bimanual hand task improvement.

DISCUSSION

This study examined the effects of ischemic conditioning when combined with bimanual task training on development of skills in children with unilateral cerebral palsy, ages 8 to 16. Two groups of participants were created: one group received ischemic conditioning along with bimanual training, while the other group received sham conditioning along with bimanual training. The intervention was administered to both groups for five days consecutive at a rate of 15 trials per day, lasting between 10 and 35 minutes each. Monitoring vital signs and discomfort levels were among the safety precautions, and bimanual work performance was assessed using Assisting Hand Assessment Scale. Prior studies have demonstrated encouraging outcomes when concentrating on individual therapies such ischemic conditioning and bimanual training. By investigating combined effects of various techniques on skill enhancement, this study expands on earlier findings (12, 29).
In children with unilateral cerebral palsy, ischemic conditioning combined with bimanual task training led to significant improvements in goal synchronization, AHA scores, and task duration. Enhancing motor learning and functional outcomes may be more successfully achieved with this integrated approach than with separate therapies used in separately (9).

Bimanual task performance significantly improved, as indicated by total task durations and higher Assisting Hand Assessment (AHA) scores. Goal synchronization had conflicting results, too, with certain individuals displaying lower levels. In order to improve individualized rehabilitation plans for children with UCP, the study emphasizes necessity for more investigation to optimize and evaluate this combined strategy. The null hypothesis was accepted for a variety of reasons, including sample variability and insufficient sample size. Despite these negative findings, study offers insightful information and identifies areas that require more investigation. To improve knowledge and results, future research could investigate other approaches, improve measuring strategies, or deal with potential moderating variables. Even though there was no clear improvement, study highlights need for more research to fill in the gaps and increase the field's understanding. The study emphasizes necessity for ongoing research to fill up knowledge gaps and develop discipline even when conclusive evidence of improvement was not obtained.

4. Conclusion

Using bimanual task training and ischemia conditioning, study found that children with unilateral cerebral palsy showed significant improvements in their motor function and task performance. The results highlight need for more study to maximize these approaches, despite minor inconsistencies.

IMPLICATIONS ON PHYSIOTHERAPY PRACTICE

This research suggest that bimanual task training combined with ischemic conditioning may improve motor skills and task performance in children with unilateral cerebral palsy, offering physiotherapists a useful, evidence-based strategy. Faster skill development and better coordination could result from this dual intervention, directly assisting clinical objectives to boost independence for patients and reduce family stress. Physiotherapists can provide better therapy that targets both motor and cognitive problems by combining both approaches, which may enhance patients' and their families' quality of life.

STRENGTH

- In this study, children with unilateral cerebral palsy benefit from improved motor learning with Ischemic conditioning combined with bimanual task training.
- Ischemic Conditioning is affordable and useful; all you need is a blood pressure cuff along with modest technical knowledge.
- Safety precautions protect participant welfare and ethical norms. Examples of this include monitoring vital signs and suffering.

LIMITATIONS

- The results' limited applicability could be a result of extremely small sample size.
- A sample with a high degree of variability could cover up effects or correlations between variables.
- Patterns may be difficult to identify due to participant variability, including variations in age and health.

RECOMMENDATIONS

- To increase statistical power and generalizability, future studies should employ a larger, more varied sample.
- Accuracy will be improved by using more reliable and valid measurement tools.
- Examining other research techniques might produce deeper findings.

DIFFICULTIES

- Treatment plans and follow-up meetings became difficult for participants to commit to as a result of participant dropouts and participation problems.

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