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COMPARATIVE EFFECTS OF LOADED AND UNLOADED SIT TO STAND STRENGTHENING EXERCISES ON MUSCLE STRENGTH AND ENERGY EXPENDITURE IN CHILDREN WITH CEREBRAL PALSY

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ABSTRACT

Background: Cerebral palsy (CP), a non-progressive disorder, undergo mishap to developing brain and it affect person's mobility, balance and posture. In Spastic diplegic CP children, muscle stiffness mainly affect the legs, with the arms less or not affected at all.

Objective: To find out the effects of loaded and unloaded sit to stand strengthening exercises on muscle strength and energy expenditure in children with cerebral palsy.

Methods: 28 children with Diplegic CP aged 6-12 years were randomly allocated into two groups.Group A received baseline lower limb stretchings with loaded STS strengthening exercises while Group B received baseline lower limb stretchings with unloaded sit to stand strengthening exercises and training session was 15 minutes per set, 3 sets/day, 3 days a week for total 6 weeks.Outcome measure tools included Bag method of Modified Sphygmomanometer for muscle strength, Physiological Cost Index Formula for energy expenditure and Functional Strength Test for functional strength and readings were taken before and after 6 weeks of intervention. Data were analyzed using SPSS version 25.

Results: Out of 28 subjects, 14 (50%) in each of the two groups. Overall, 21 males and 7 females with mean age 8.54±1.688. Significant difference was noted in lower limb muscle strength of both groups post treatment ($P<0.05$) and also in within group analysis of lower limb muscle strength and functional strength of both groups. No significant difference was seen in physiological cost index as well as for functional strength test of both groups post intervention (P value > 0.05).

Conclusions: It was concluded that significant improvement was observed in the muscle strength of loaded exercise group while physiological cost index and functional strength remained equally significant in both groups.

Keywords: Cerebral Palsy, Energy Expenditure, Muscle Strength, Sphygmomanometer.

Trial Registration: NCT, NCT06190418, *https://classic.clinicaltrials.gov/ct2/show/NCT06190418*

INTRODUCTION

Cerebral palsy previously known as little's disease, is non progressive nervous disorder, any trauma occurred during pre-natal or post-natal period. Cerebral palsy further leads to chronic physical abnormalities. Many risk factors are present that lead to cerebral palsy, includes immature birth and low birth weight etc (1). According to treatment, CP is divided into two types: functional abilities & clinical signs. There are three types of clinical sign: Spastic Diplegic CP, Dyskinetic CP, Mixed CP (2).A static injury to the brain that occurs during gestation or during the initial two years of life is the cause of cerebral palsy (CP), which frequently shows movement problems including spasticity and contractures as well as musculoskeletal difficulties. The most prevalent cause of physical disabilities in developed countries is acquired cerebral palsy. At least 80% of cerebral palsy children live into their sixth decade and there are an estimated 17 million people living with the condition worldwide (3).little's disease is upper motor neuron lesion, it has positive features of spasticity, hyper-reflexia, bebinski sign. Initially cerebral palsy child is low tone and have no musculoskeletal abnormalities at birth and with the passage of time child starts to develop secondary abnormalities i.e: scoliosis, hip contracture etc (4) Cerebral palsy is an umbrella term, mainly affect gross motor functions that hinders locomotion. Due to defect in motor functions of cerebral palsy children, energy consumption during walking is increased. Energy cost is energy consumed per mile while energy consumption is energy used per unit time, both these terms fall in energy expenditure. Cerebral palsy children as well as adults have high energy cost than typically developing child. Due to high energy cost, CP child are limited to participate in activities (5)

In cerebral palsy, there is lesion in Pyramidal, Corticospinal tract, that will affect isolated voluntary motor control in children as well as their muscular strength and endurance (6). For load determination, 1RM of loaded sit to stand exercises in spastic diplegic cerebral palsy children, they use body vest and load weights were specially formed. loaded STS exercises was reliable for (FST) functional strength tests. Sit to stand is the most demanding task used in daily routine, it bring some bio-mechanical changings in body and shift the center of mass higher and forward. To avoid secondary complications like contractures of joints, low backache etc it is important to invent effective exercises with low load (7). All lower limb muscles of Cerebral palsy children are weak and small rather than spastic. Children with cerebral palsy can have their muscle strength assessed with reliability, and those who take part in strengthening programme show improvements in their function as well as increases in muscle power (8)Sit to stand activity is very important pre requisite for functional activities. It is a bio-mechanical demanding task that requires neuromuscular coordination, muscle strength & postural control. Spastic cerebral palsy children with disabilities need adequate time for sit to stand performance as compared to cerebral palsy children without disabilities, this is due to increased extension phase (9) Energy expenditure for cerebral palsy children is affected by many factors. Injury to the immature brain affects the pattern of movement and motor function. These patterns totally change the energy requirement for cerebral palsy children. Energy requirement for a cerebral palsy children is very important because early nutrition management is important component for healthy development of child (10) Although cerebral palsy is a non progressive disease but mobility and musculoskeletal related problems progress with the passage of time. To deal with these kind of problems, progressive functional training is used (11)

The significance of this study was to determine how the sit-to-stand (STS) training with variable loads will impact the muscular strength of lower extremity along with the change in the functional

status of the child as improved muscle strength are supposed to be associated with the lower energy expenditure for independent ambulation.

Gross motor function has received sufficient attention in the literature, although there is still room to focus on energy expenditure in spastic diplegic cerebral palsy. Current study focused on energy expenditure because mobility is improved when energy consumption is low.

HYPOTHESIS

1.1.1 Null Hypothesis: Loaded and unloaded sit to stand exercises has no effect on muscular strength and energy expenditure in cerebral palsy children

1.1.2 Alternate Hypothesis: Loaded and unloaded sit to stand exercises has effect on muscular strength and energy expenditure in cerebral palsy children

MATERIALS AND METHODS

Study design and participants

The study was structured as a Randomized Clinical Trial and determined its sample size through the use of Epi tool software. This calculation, factoring in a 10% attrition rate, yielded a total sample size of 28 participants. To collect data, the researchers utilized a non-probability convenience sampling technique, conducting the study at specific location: District Head quarter, Hafizabad. The study's duration spanned six band exclusion criteria were established. Inclusion criteria comprised children aged 6 to 12 years diagnosed with diplegic cerebral palsy. Children with GMFCS level I,II and those who independently stand up from chair and stay stand for more than 5 seconds without falling were included (12).

Exclusion criteria were also defined to ensure the integrity of the study. Children scheduled orthopedic interventions and conditions within past six months were excluded. Children with epileptic history and lower limb contractures were excluded. Children who are unable to follow verbal command were not included in this study. These stringent criteria aimed to maintain the homogeneity of the sample and enhance the validity of the findings.

Intervention Protocol

Experimental Group (Loaded Sit to stand Strengthening exercises)

This group was provided with baseline stretchings of lower limb muscles like hip flexors, hamstring muscles and dorsiflexors. After baseline stretchings of lower limb muscles, this group was provided with loaded sit to stand exercises. This load was provided on the basis of 50% of 1 Repetition Maximum (1RM) of each child. The maximal load carried by a child 1 time, to stand up from a seated position without falling is known as 1 Repetition Maximum. The standardized loaded Sit to stand test has high test-retest and inter rater reliability (ICC=.94) for children with spastic diplegia (13). Patient wore the loaded west and weight was added into the loaded west and patient have performed loaded sit to stand exercises for 15 minutes in each session (7). This training session was conducted for 15 minutes per set, 3 sets per day, 3 days in a week for total 6 weeks (12). Pre and post assessment readings were taken, for energy expenditure, physiological cost index formula was used. Bag method of modified sphygmomanometer was used to measure lower limb muscular strength while functional strength was measure by performing functional strength test.

Experimental Group (Unloaded Sit to stand Strengthening exercises)

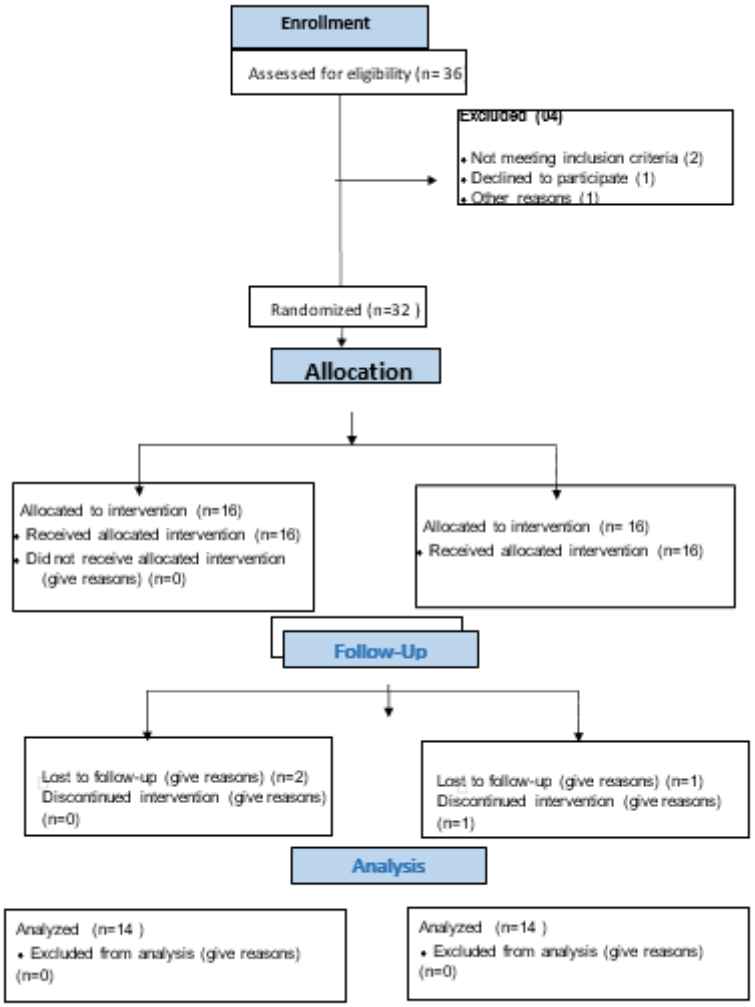
This group was provided with baseline stretchings of lower limb muscles like hip flexors, hamstring muscles and dorsiflexors. After baseline stretchings of lower limb muscles, this group was provided with unloaded sit to stand exercises. This training session was conducted for 15 minutes, 3 sets per day, 3 days in a week for total 6 weeks (12). Pre and post assessment readings were taken. Bag method of modified sphygmomanometer was used to measure lower limb muscular strength while functional strength was measure by performing functional strength test and for energy expenditure, physiological cost index formula was used.

Data Analysis Procedure:
The data was analyzed by using SPSS for version 25. Statistical significance was be set at p- value ≤ 0.05. Normality of the data was assessed using the Shapiro-Wilk test, if the p-value was found to be greater than 0.05, the data was considered to be distributed normally, and parametric tests were applied. Conversely, if the p-value was less than 0.05, non- parametric tests were used.

Descriptive statistics utilized frequency tables, pie charts, and bar charts to display a summary of group measurements taken over time.

When comparing differences between groups, the normality of the data was assessed using the Shapiro-Wilk test. Depending on the results, either parametric or non-parametric tests were selected for within-group or between- group comparisons

Figure No. 1: CONSORT Diagram



RESULTS

Baseline characteristics & Demographic Features

The results showed that the mean age of the participants in Loaded Exercise was 9.21±1.528 while in Unloaded Exercise was 7.86±1.610. However, about the gender distribution, a greater frequency distribution of boys were observed in both groups, suggesting higher prevalence of diplegic cerebral palsy in boys as compared to girls, as supported by different studies.

Table No 1. Baseline demographic data of both Groups.

Variables	Sub-category	Total Population	Loaded Exercise (Group A)	Unloaded Exercise (Group B)
Age		28	9.21±1.528	7.86±1.610
Gender	Male	21	12	9
	Female	7	2	5
Family history	Yes	15	5	10
	No	13	9	4
Socioeconomic Status	Upper Class	2	1	1
	Middle Class	13	9	4
	Lower Class	13	4	9
GMFCS	Level I	2	1	1
	Level II	26	13	13
Birth Asphyxia	Yes	19	9	10
	No	9	5	4
Pregnancy Complications	Preclampsia	21	12	9
	Others	7	2	5
Cousin Marriage	Yes	18	9	9
	No	10	5	5

Table 2: Within group Analysis using Wilcoxon-rank test

A: Left Lower Limb Muscles

Groups		Treatment	Mean±SD	Median	Mean Rank	Z Score	P value
Loaded Sit to Stand Exercise Group	**Left Hip Flexors**	Pre Treatment	53.57±13.927	50.00	7.50	-3.359	0.00
		Post Treatment	68.93±13.613	70.00	0.00		
	Left Hamstring Muscle	Pre Treatment	46.43±10.818	45.00	7.50	-3.346	0.00
		Post Treatment	59.79±11.423	60.00	0.00		
	Left Dorsiflexor muscle	Pre Treatment	32.86±4.688	30.00	7.50	-3.439	0.00
		Post Treatment	44.00±6.805	40.00	0.00		
Unloaded Sit to Stand Exercise Group	**Left Hip Flexors**	Pre Treatment	53.57±13.927	50.00	7.50	-3.359	0.00
		Post Treatment	68.93±13.613	70.00	0.00		
	Left Hamstring Muscle	Pre Treatment	46.43±10.818	45.00	7.00	-3.346	0.00
		Post Treatment	59.79±11.423	60.00	0.00		
	Left Dorsiflexor	Pre Treatment	32.86±4.688	30.00	7.50	-3.439	0.00

	muscle	Post Treatment	44.00±6.805	40.00	0.00		

B: Right lower limb muscles:

Groups		**Treatment**	**Mean±SD**	**Median**	**Mean Rank**	**Z Score**	**P value**
Loaded Sit to Stand Exercise Group	**Right Hip Flexors**	Pre Treatment	67.93±12.468	60.50	7.50	-3.313	0.001
		Post Treatment	106.93±13.194	109.50	0.00		
	Right Hamstring Muscle	Pre Treatment	57.14±7.263	60.00	7.50	-3.334	0.001
		Post Treatment	88.64±12.947	90.00	0.00		
	Right Dorsiflexor muscle	Pre Treatment	41.57±3.610	40.00	7.50	-3.330	0.001
		Post Treatment	68.64±6.846	70.00	0.00		
Unloaded Sit to Stand Exercise Group	**Right Hip Flexors**	Pre Treatment	62.64±12.314	60.00	7.50	-3.334	0.001
		Post Treatment	77.64±14.468	80.00	0.00		
	Right Hamstring Muscle	Pre Treatment	57.86±9.945	60.00	7.00	-3.209	0.001
		Post Treatment	69.64±11.426	70.00	0.00		
	Right Dorsiflexor muscle	Pre Treatment	39.50±4.848	40.00	7.50	-3.370	0.001
		Post Treatment	51.50±5.460	50.00	0.00		

Table 3: Within group Analysis using Wilcoxon-rank test

C: Physiological Cost Index

Groups	**Treatment**	**Mean±SD**	**Median**	**Mean Rank**	**Z Score**	**P value**
Loaded Sit to Stand Exercise Group	Pre Treatment	5.77±2.382	5.37	2.00	-3.045	0.002
	Post Treatment	4.23±1.481	4.26	4.82		
Unloaded Sit to Stand Exercise Group	Pre Treatment	5.43±1.491	5.06	2.75	-2.605	0.009
	Post Treatment	4.42±1.505	4.58	9.40		

Table 4: Within group Analysis using Paired Sample t test

D: Functional Strength Test:

Groups		**Treatment**	**Mean±SD**	**P value**
Loaded Sit to Stand Exercise	**Lateral Step Up Test**	Pre Treatment	11.32±1.539	0.000

Group		Post Treatment	15.21±2.517	
	Sit to Stand	Pre Treatment	13.43±2.848	0.000
		Post Treatment	18.07±3.990	
	Stand from half kneel without using arms	Pre Treatment	10.79±2.082	0.000
		Post Treatment	14.93±3.198	
Unloaded Sit to Stand Exercise Group	**Lateral Step Up Test**	Pre Treatment	11.11±1.831	0.000
		Post Treatment	13.96±2.333	
	Sit to Stand	Pre Treatment	12.64±2.098	0.000
		Post Treatment	15.07±2.731	
	Stand from half kneel without using arms	Pre Treatment	10.86±1.875	0.000
		Post Treatment	12.86±2.107	

Table 5: Between group Analysis (Mann Whitney U test)

Lower limb muscles

	Treatment	**Mean±SD**	**Median**	**Mean Rank**	**Z Score**	**P value**
Right Hip Flexors	Loaded Group	106.93±13.194	109.50	20.50	-3.904	0.00
	Unloaded Group	77.64±14.468	80.00	8.50		
Right Hamstring Muscle	Loaded Group	88.64±12.947	90.00	19.54	-3.288	0.001
	Unloaded Group	69.64±11.426	70.00	8.50		
Right Dorsiflexor muscle	Loaded Group	68.64±6.846	70.00	21.07	-4.306	0.00
	Unloaded Group	51.50±5.460	50.00	7.93		
Left Hip Flexors	Loaded Group	95.36±10.924	96.50	20.57	-3.946	0.00
	Unloaded Group	68.93±13.613	70.00	8.43		
Left Hamstring Muscle	Loaded Group	82.57±13.665	80.00	20.54	-3.951	0.00
	Unloaded Group	59.79±11.423	60.00	8.46		
Left Dorsiflexor muscle	Loaded Group	58.79±5.147	60.00	20.68	-4.121	0.00
	Unloaded Group	44.00±6.805	40.00	8.32		

Table 6: Between group Analysis (Mann Whitney U test) Physiological Cost Index:

		Mean±SD	Median	Mean Rank	Z Score	P value
Physiological Cost index	**Loaded Exercise Group**	4.23±1.481	4.26	13.86	-0.414	0.679
	Unloaded Exercise Group	4.42±1.505	4.58	15.14		

Table 7: Between group Analysis (Mann Whitney U test) Functional Strength Test:

		Mean±SD	P Value
Post Lateral Step Up Test	**Loaded Exercise Group**	15.21±2.517	0.185
	Unloaded Exercise Group	13.96±2.333	
Post Sit to Stand Test	**Loaded Exercise Group**	18.07±3.990	0.028
	Unloaded Exercise Group	15.07±2.731	
Post Stand from half kneel without using arms	**Loaded Exercise Group**	14.93±3.198	0.053
	Unloaded Exercise Group	12.86±2.107	

Wilcoxan test showed statistically significant difference in pre and post treatment assessment of both left and right lower limb muscular strength of both groups, as the p value<0.05. For physiological cost index, significant improvement was seen in pre treatment and post treatment assessment values of both loaded and unloaded group, as p value<0.05. Paired sample t test showed that functional strength was significantly improvement in post treatment as p value<0.05. Mann Whitney U test showed that as Z score for left dorsiflexors was -4.121, significant improvement was seen in post treatment of loaded group 58.79±5.147. As the Z score -4.306, in Mann Whitney U test clearly showed that right dorsiflexors muscular strength was significantly improved among all right lower limb muscles. As the Z score value for post treatment (-0.414) physiological cost index was greater than pre treatment (-0.230), so Mann Whitney U test showed clear improvement in post physiological cost index. Independent t test showed that no improvement was seen in Lateral Step Up Test among both groups while significant improvement among groups were observed in Sit to Stand Test and in Stand from half kneel without using arms as p value <0.05.

Discussion

This randomized clinical trial was conducted to determine the effects of loaded and unloaded STS strengthening exercises on muscle strength and energy expenditure in cerebral palsy children. For doing so loaded and unloaded sit to stand exercises was provided. The previous researches focus on selective gross motor functions of cerebral palsy children but current research focus on major group of lower limb muscles. Bag method of modified sphygmomanometer was used to measure muscular strength while physiological cost index to check energy expenditure. 28 diplegic cerebral palsy children were randomly selected and allocated into two groups: Group A was provided with baseline lower limb stretchings with loaded sit to stand exercises while Group B was provided with baseline lower limb stretchings with unloaded sit to stand exercises. Exercises was given 3 sets per day, 3 days in a week over a period of 6 weeks. This study concluded strength was improved

significantly in the group receiving loaded sit to stand exercise but not for functional strength and energy expenditure.

A Quasi experimental study by Malik AN. was conducted to determine whether the effects of strength training were more effective or loaded sit to stand (STS) on gross motor function in mild spastic diplegic children. Authors included 42 cerebral palsy children in contrast to current study, 28 participants were included. Authors included with GMFCS level I,II similar to current study, GMFCS level I,II were included. Authors, randomly allocated 42 participants into 2 groups, Group A received loaded STS exercises similar to current study while group B received strength training of hip and knee extensors in contrast to current study in which group B received unloaded STS exercises. Authors concluded that significant improvement was seen in within group analysis of loaded exercise group in coherence with current study, concluded that there is significant improvement seen in within group analysis of loaded exercise group (14)

A research was conducted by Safei et al. to determine the effects of loaded and unloaded sit-to-stand strengthening exercises on motor functions in spastic diplegia cerebral palsy patients. 24 subjects were randomly assigned into two groups, loaded STS strengthening exercises were given to interventional group while unloaded STS exercises were given to control group. Authors concluded that both unloaded STS and loaded STS exercises group does not show statistically significant difference in improving motor skills in spastic diplegic cerebral palsy in contrast to current study there is significant difference in muscle strength of cerebral palsy children (15)

Aye T, et al. conducted a study to determine whether strength training of hip and knee extensors improve gross motor function of CP children or not. Authors included GMFCS level I,II and 6 week strength training of hip extensors and knee extensors and concluded that there was great improvement seen in muscle strength and gross motor functions of cerebral palsy children in coherence with the current study that showed, significant difference in muscle strength of cerebral palsy children (16)

Kusumoto Y, et al. conducted a study to evaluate the impact of loaded STS exercises at different speeds on walking in spastic diplegia patients. 16 spastic diplegic children with age 12 to 18 yrs, 8 children were included into one group which undergo low loaded sit to stand exercises while other 8 other children were included to other group which undergo loaded STS exercises. Loaded STS exercise group conducted their sessions at home for 15 min, 4 sets/day, 3–4 days/week, for total 6 weeks. Authors concluded that between group analysis showed that statistically significant difference was seen in physiological cost index of both groups in contrast to current study that showed, for between group analysis, there is no statistically significant difference in physiological cost index of both groups (7)

Dehghanizadeh M, et al. conducted a study to evaluate the effects of loaded STS resistance exercises on gross motor functions in spastic diplegic children. Authors included 20 spastic diplegic cerebral palsy children 5 to 12 years of age while current study includes 28 diplegic cerebral palsy children 6 to 12 years of age. Authors used MMT NICHOLAS apparatus to measure the isometric strength of hip and knee extensor and ankle plantar flexor while current study use bag method of modified sphygmomanometer to measure lower limb muscles strength. Authors concluded that loaded sit to stand resistance exercises showed improvement in lower extremity muscle strength similar to current study that shows muscles strength of lower extremity of loaded exercise group is improved (17)

A study was conducted by Thompson N et al. to determine muscular strength and walking capacity in diplegic cerebral palsy. Authors included 50 ambulatory spastic cerebral palsy, GMFCS level I,II,III and all lower limb muscles are targeted. Digital dynamometer was used to measure muscular strength in reference study while bag method of modified sphygmomanometer is used to measure the lower limb muscles strength in current study. Authors concluded that there is significant difference seen in muscle strength of experimental group in coherence with current study that shows lower limb muscle strength of loaded exercise group is improved (12)

Conclusion:
The study concluded that except for muscle strength which was improved in loaded sit to stand exercise group, no statistically significant improvement was observed between both groups for Energy Expenditure and functional strength. Although clinical improvement was observed.

Recommendations:
It is recommended to explore the dose-response relationship by varying the intensity and duration of loaded exercises. This could help determine the optimal parameters for maximizing strength gains while minimizing potential adverse effects. Future studies include a control group that receives no specific intervention. This would help control for natural development and account for any placebo effects. It is recommended to increase awareness within the community about the importance of regular physical activity for children with cerebral palsy. There is a need to provide educational resources to parents, caregivers, and teachers to enhance their understanding of the benefits and safety considerations of sit-to-stand strengthening exercises. If clinical demand is to enhance the muscle strength, it is recommended for clinicians to indulge sit to stand strengthening exercises especially the loaded ones.

Declerations

Ethical Approval and Consent to Participate
The study adhered to ethical standards and received approval from the Research and Ethics Committee (REC) of Riphah College of Rehabilitation and Allied Health Sciences, Riphah International University Lahore. The approval was granted under reference number REC/RCR & AHS/23/0729, ensuring that the research was conducted in accordance with ethical guidelines and principles. This endorsement underscored the commitment to safeguarding the welfare and rights of participants throughout the study.
Informed consent was obtained from the parents or legal guardians of all participating children before their inclusion in the study. Parents were provided with detailedinformation about the study objectives, procedures, potential risks, benefits, and their rights as participants. They were given ample time to review this information and ask any questions they might have had before providing their consent. Additionally, it wasemphasized that participation was voluntary, and parents had the freedom to withdraw their child from the study at any time without repercussions. This ethical practice ensured transparency, autonomy, and respect for the participants' rights and well-being throughout the research process.

Consent for Publications
All the authors have reviewed and approved the manuscript for publication. Additionally, all the participants included in the study have provided consent for their data to be published in the final manuscript.

Availability of Data and Materials
All the data and materials used and analyzed during the course of study are available from the corresponding author on reasonable request.

Competing Interests
All the authors declare that they have no competing interests.

Funding
No Funding was received.

Authors Contribution
"WR Physically conducted the study and collected data regarding the study, while the data was

analyzed and results were interpreted by **FK**. **MK** drafted theinitial manuscript and coordinated the writing process, while **UY and AM** provided critical revisions and contributed to the final version of the manuscript. **AT** managed the literature searches and provided additional data resources to respective group members. **NF** Conceptualized the study, designed the methodology, and supervised the project. All the authors read and approved the final manuscript".

Aknowledgements
Not Applicable

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