The Egyptian Journal of Hospital Medicine (October 2022) Vol. 89, Page 4507- 4515

Shoulder Joint Angle and Forward Reaching Speed in Hemiparetic Cerebral Palsy Children

Riham MR. Mahmoud[1], Kaled A. Olama[2], Nanees E. Mohamed[2]*
[1]Department of Physical Therapy, Al-Mataria Teaching Hospital, Cairo, Egypt
[2]Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Cairo, Egypt
***Corresponding Author**: Nanees Essam Mohamed, **Mobile**: +201115960603, **Email**: nanessam2015@cu.edu.eg

ABSTRACT

Background: Different daily activities depend on proper forward reach. Doing functional activities bilaterally may improve daily performance.

Objective: The aims of the current study are to determine if the bilateral forward reaching task can alter the shoulder joint flexion angle and the reaching speed of non-affected and affected upper limbs and to detect the relation between shoulder flexion angle and reaching speed in hemiparetic cerebral palsied children.

Patients and Methods: A total of 50 hemiparetic cerebral palsy children, 52% boys, their ages ranged from 6 to 10 years participated in this study. From an erect sitting position, they were asked to forward reach a ball fixed on a table in front of them. Three different measurements were done, the first two times by the non-affected and the affected limbs separately then the third time by using both limbs at the same time. All measurements were photographed then kinovea software was used to measure the joint angle and speed during unilateral and bilateral forward reaching tasks.

Results: The results of the joint angle and speed showed significant change in both limbs in bilateral task compared with that in unilateral task (p=0.0001). There was a negative correlation (r= -0.59, p=0.0001) between joint angle and speed in unilateral task of the affected limb. Less negative correlation (r= -0.45, p=0.001) was observed between joint angle and speed in bilateral task of the affected limb.

Conclusion: The better outcomes were gained when the task done bilaterally and there was an inverse relationship between the joint angle and the speed of movement of the affected limb of hemiparetic cerebral palsy children during forward reaching activity.

Keywords: Bilateral tasks, Cerebral palsy, Forward reaching function, Hemiparesis, Shoulder Joint Angle.

INTRODUCTION

Reaching skill is essential in daily tasks and activities done from sitting and standing positions [(1)]. Functional arm reaching is multilinked joints where shoulder and elbow were prime movers of the limb so the hand reaches the target position [(2)]. Reaching develops from early jerky and tortuous motion to more smooth and coordinated movement [(3)], during mid-childhood from (5-10) years, there is an accurate and less variable adjustment of the reaching movement to any changes of target position [(2)].

Cerebral palsy (CP) is a group of non-progressive impairment syndromes due to lesions or abnormalities in early developed fetus/infant's brain. There are heterogeneous symptoms including sensorimotor, cognitive, and social aspects [(4)]. In hemiplegic CP the muscle tone and movement of one body's side are affected where the upper limb is more affected than the lower limb. Children with hemiparetic CP show limited performance of activities that depend on the coordination of both upper limbs. They always depend on the unaffected limb in their activities. So the less used affected limb lacks the opportunity to learn and develop, making a larger gap with normal children [(5)].

Mild to moderate spastic hemiparetic CP children can perform unilateral and bilateral reach activities at speed however most of them did not fully extend the more affected arm. They depended on different way of reaching with the more affected upper limb compared to the less affected. There was a segmental coordination of shoulder flexion and elbow movement with more trunk contribution to compensate the decreased elbow and shoulder excursion [(6)].

Goniometer clinically used to measure joints range of motion (ROM). In spite of, it is easily used and less expensive, a little bit it has some degree of error especially when dealing with a complex joint like the shoulder complex. Recently, Kinovea software was widely used for analyzing motion, and measuring the position, velocity, and acceleration of the limbs motion[(7)]. Kinovea software (GPLv2 license) is free 2D motion analysis, portable, easily used and require little training, saving time and less expensive with no sensors needed for analysis. It permits frame by frame measuring of different temporal and spatial parameters[(8)].

Furuya *et al.* [(9)] studied the impact of three angles of shoulder flexion (60°, 90° and 120°) on the reach trajectory of more affected hand in children with spastic CP. Mild cases straightly and smoothly moved at the three shoulder flexion angles while in severe CP more outward deviation in the trajectory seen in greater shoulder angles.

Some studies investigated the upper limb spatiotemporal and kinematics parameters during unilateral reaching with hemiparetic side [(10,11,12)], others investigated both sides [(13,6)]. However, some studies investigated them for the affected upper extremity

Received:16/5/2022
Acepted:21/7/2022

during uni- and bilateral activities [14-17]. To our knowledge, only study done by **Steenbergen *et al.*** [18] investigated the spatiotemporal and kinematics parameters during uni- and bilateral tasks of both less and more affected limbs of spastic hemiparetic children but they used small sample of 6 subjects with age ranged from (14.5-18.7 years).

The present study aimed to assess forward reaching function in children with hemiparetic CP to: 1) determine if the bilateral forward reaching task can alter the shoulder joint flexion angle and the reaching speed of non-affected and affected upper extremities; 2) assess the relationship between the shoulder flexion angle and the reaching speed.

PATIENTS AND METHODS

Study design: A cross sectional study was conducted from November 2021 to March 2022.

Subjects:

A total of 50 hemiparetic CP children, of both sexes, selected from the Faculty of Physical Therapy, Cairo University (outpatient clinic) and privet clinics. The inclusion criteria stipulated that: (1) All children aged 6–10 years; (2) They can sit without support and do forward reaching by each side; (3) Their upper limb spasticity was mild to moderate, graded 1, 1+, 2 on modified Ashworth scale [19]; (4) They had levels I/II at gross motor functional classification system (GMFCS) [20]; (5) They had levels I/II at manual ability classification system (MACS) [21]; (6) They abled to understand instructions and orders.

Children were excluded from this study if they manifested in their upper extremities (1) any limited joint motion resulting from dermatological problem, or muscle contracture; (2) structural deformity; (3) unhealed fracture; (4) recent surgery, or (5) recent Botox injection, also if they had visual and hearing deficits or received anticonvulsant drugs.

Sample size calculation:

Estimated sample was calculated by G*Power software 3.0.10. The (α level) was 0.05, the power=0.95, and an effect size=0.50 that showed a total sample size of 45 subjects. To overcome any dropout, 50 children were selected. **Figure 1** shows the flow chart for the recruitment process.

For all fifty participated children, the shoulder joint flexion angle in degrees and forward reaching speed in meter/second were measured for both non-affected and affected sides during unilateral and bilateral forward reaching. The study was carried out at the outpatient clinic of Faculty of Physical Therapy, Cairo University.

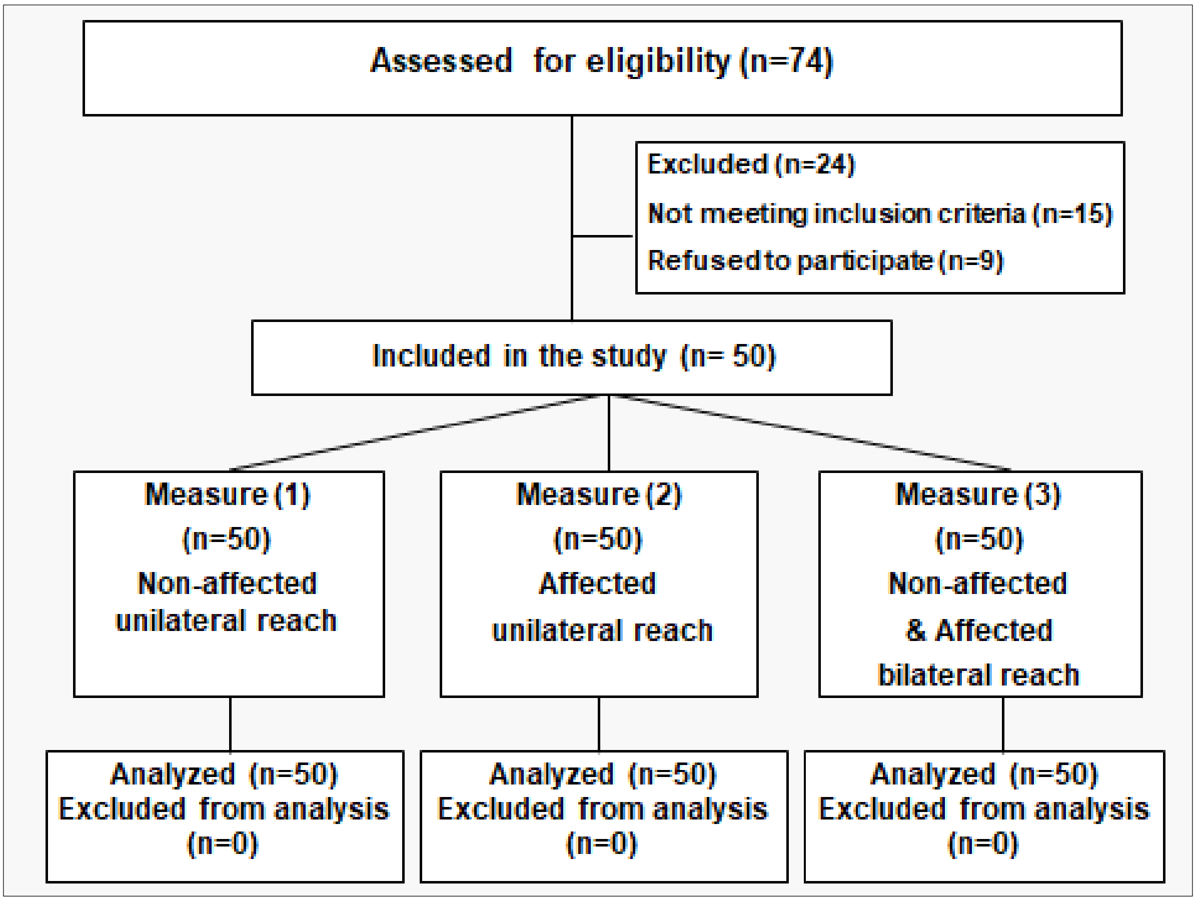

Figure (1): Flow chart for recruitment of the participants.

Procedures:

Before conducting the study, the aim and protocol of this study were described for all guardians of recruited children, who signed the consent form of acceptance for participation. The assessment and analysis were done by one trained researcher.

Assessment for eligibility of subjects:

Detailed medical and clinical histories were taken for each child and recorded in a recording data sheet. Physical examination was done to include children in the study according to selected criteria.

Measurement for forward reaching:

Forward reaching from sitting position was assessed for 50 hemiparetic CP children. The assessment was done individually in a calm room to avoid any distraction to the child during the measurements. Three measurements were applied for each child. The first measurement was done for the non-affected side, the second for the affected limb and the third for both non-affected and affected limbs together to determine the effect of the non-affected side on affected performance [(14)].

All participants were instructed to wear light clothes for perfect determination of the selected bony landmarks and to allow easily forward reaching motion without any restrictions [(7)]. Before photographing the motion, an adjustable chair and table were positioned at the center of the examination room. Two tripod stands, 80 centimeters height, were placed at a distance of 1.5 meters away from the child's feet one on each side of the lower limbs [(7)]. Two cameras (BenqFfI.8) were placed on the tripod stands.

The anatomical landmarks were determined for shoulder flexion to be at the lateral side of the center of the humeral head nearly under the acromion process (fulcrum), along the mid-shaft of the humerus at the same line of the greater tuberosity and lateral epicondyle of the humerus, along the midline of the thorax, on wrist at ulnar styloid process and greater tubercle at hip joint [(7)]. An adhesive marker dots (3cm and 1.5cm diameter) placed on preselected anatomical landmarks. Thereafter, the distance was measured individually between the axilla and the middle finger tip (using the affected arm). The place of the table adjusted individually to ensure standardized reaches distance. A stationary object (small colored ball, 7cm diameter) fixed on a standardized position on the table from the child's midline [(14,22)].

After that, the examiner explained and demonstrated the forward reaching tasks to each child. Each child did every task 3 times to be familiar with the measured movement, before start any recording [(2,7)]. To ensure that the child didn't lean the trunk forward during the motions, the trunk stabilized on the chair by straps to maintain an erect posture.

Children's started position of the tasks emphasized seated with erect back and 90 degrees flexion at knees and hips [(17)], with hands placed on the surface of the table directly in front of them with approximately 90° elbow flexion and slight pronation of the forearm [(14)].

The forward reaching tasks included extending the elbow/s to touch or catch the stationary ball on the table at the child's midline and then allowing the hand/s to reassume the started position. Each child was asked to reach as much as he/she can without lowering the arm or leaning the trunk forward. The same procedure was applied by the same participant for all measurements [(14)].

All participated children had undergone three measurements. The first measurement for unilateral forward reaching of the non-affected side, the second for unilateral forward reaching of the affected side and the third for bilateral forward reaching of both non-affected and affected limbs together. The tasks were done randomly at preferred speed. Each task was done by each child 3 times consecutively with approximately 10 seconds of rest between trials [(14)].

Only one camera placed on the measure side used for unilateral tasks while for bilateral task two cameras, one in each side, was used for photographing the motion.

Analysis using Kinovea software:

Kinovea is a valid, precise and reliable computer program for measuring angles and distances [(23)]. Kinovea software (version 0.8.25) (http://www.kinovea.org/) used to perform the 2-D analysis of the shoulder joint flexion angle and the forward reaching speed of all measurements.

For measuring the shoulder joint flexion angle by using Kinovea software the fulcrum point (angle's vertex) determined by the marker dot at the lateral side of the center of the humeral head nearly under the acromion process. The fixed side determined by the distance between the fulcrum point and the marker dot at the greater tubercle at the hip joint, and the other angle's side determined by the distance between the fulcrum point and the marker dot at the wrist at ulnar styloid process [(7)].

Tracking of the motion was measured to detect the speed of forward reaching. The tracking pathway was achieved by the insertion of tracking marker from the beginning position, the first point, hand on table to the second point which was hand or finger reach the ball [(8)].

For each child, the mean of each 3 measures of shoulder joint angle in degrees and forward reaching speed in meter/second were taken for both non-affected and affected sides during unilateral and bilateral forward reaching.

Ethical consent:

The Faculty of Physical Therapy at Cairo University's ethics committee gave its approval to the study's procedure (No:P.T.REC/012/003847). A signed consent form was obtained from each guardian before the study. This work has been carried out following the Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 25 for Windows® (IBM SPSS Inc, Chicago, IL, USA).

Descriptive statistics, mean and standard deviation, were conducted for the mean age of the participants. The frequency distribution was used to represent sex, affected side, spasticity grades, GMFCS, and MACS distribution. Paired t-test was conducted for joint angles and speed to compare unilateral by bilateral tasks of affected and non-affected limbs. The relation between joint angle and speed was determined by Pearson Correlation Coefficient. P value $\leq$ 0.05 was considered significant.

RESULTS

Participants' mean age was 7.65 (SD 1.16) years. The baseline data are illustrated in **Table 1**.

Table (1): Participants' baseline characteristics.

Variable		Frequency	Percent age
Gender	Girls	24	48%
	Boys	26	52%
Affected side	Right limb	26	52%
	Left limb	24	48%
Spasticity grades	Grade I	15	30%
	Grade I+	19	38%
	Grade II	16	32%
Gross motor functional classification system	Level I	34	68%
	Level II	16	32%
Manual ability classification system	Level I	22	44%
	Level II	28	56%

Comparison of mean values of the shoulder joint flexion angle of non-affected limb between unilateral and bilateral forward reaching tasks revealed that there was a significant decrease of the non-affected limb joint angle in bilateral compared with that in unilateral task (P $\leq$0.001) while for the affected limb a significant increase of joint angle in bilateral task was shown (P $\leq$0.001) (**Table 2**).

By comparing the mean values of the forward reaching speed of non-affected limb between unilateral and bilateral tasks the results showed a significant increase of non-affected limb speed in bilateral task compared with that in unilateral (P $\leq$0.001). For affected limb, a significant decrease of speed in bilateral task was shown (P $\leq$0.001) (**Table 2**).

Table (2): Comparison of shoulder joint flexion angle and reaching speed of both non-affected and affected limbs between unilateral and bilateral forward reaching tasks.

Hemiparetic cerebral palsy children (n=50)		Unilateral	Bilateral	MD	t-value	P-value
		Mean ± SD	**Mean ± SD**			
Non-affected limb	**Joint angle (degrees)**	79.46 ± 8.69	68.52 ± 8.99	10.94	12.46	0.0001*
	Speed (meter/second)	0.07 ± 0.02	0.11 ± 0.05	-0.04	-5.21	0.0001*
Affected limb	**Joint angle (degrees)**	65.48 ± 10.66	74.38 ± 9.39	-8.9	-12.47	0.0001*
	Speed (meter/second)	0.18 ± 0.13	0.13 ± 0.11	0.05	7.71	0.0001*

SD: Standard deviation; MD: Mean difference; t value: Paired t value; p value: Probability value; *: Significant at alpha level 0.05.

The correlation between shoulder joint flexion angle and forward reaching speed of the non-affected upper limb was small negative non-significant correlation in unilateral task (r=-0.18, P=0.19) (**Figure 2**) and bilateral task (r=-0.08, P=0.54) (**Figure 3**).

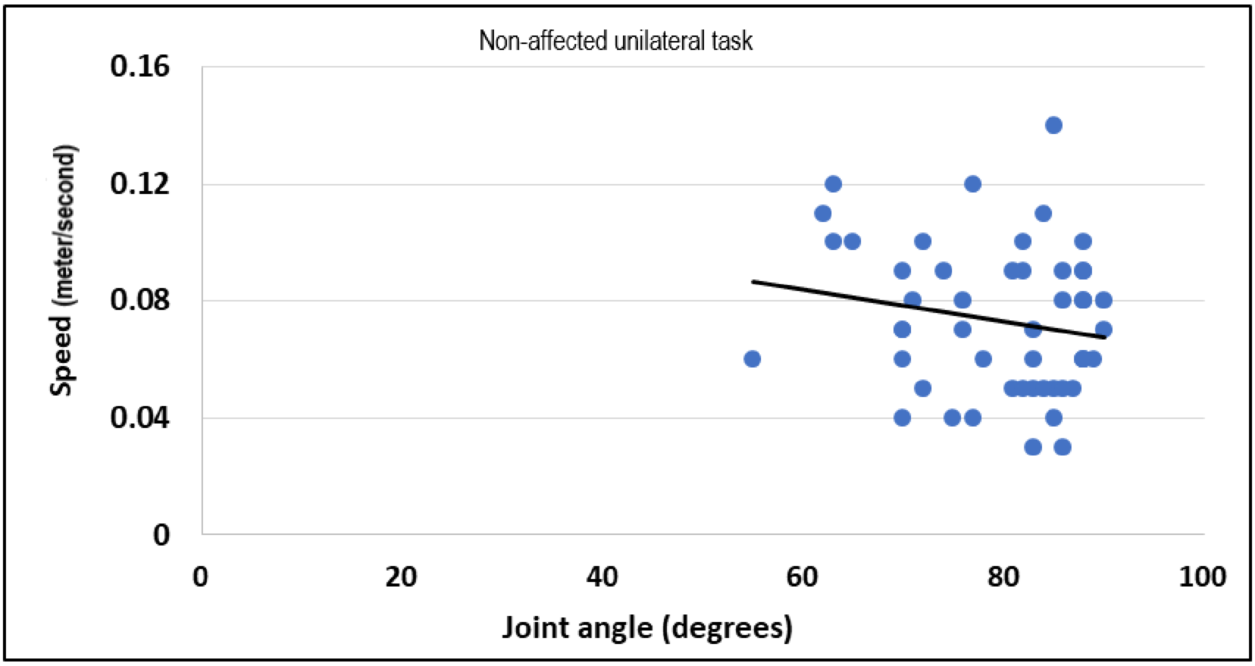

Figure (2): Correlation between joint angle and speed in unilateral task of the non-affected limb.

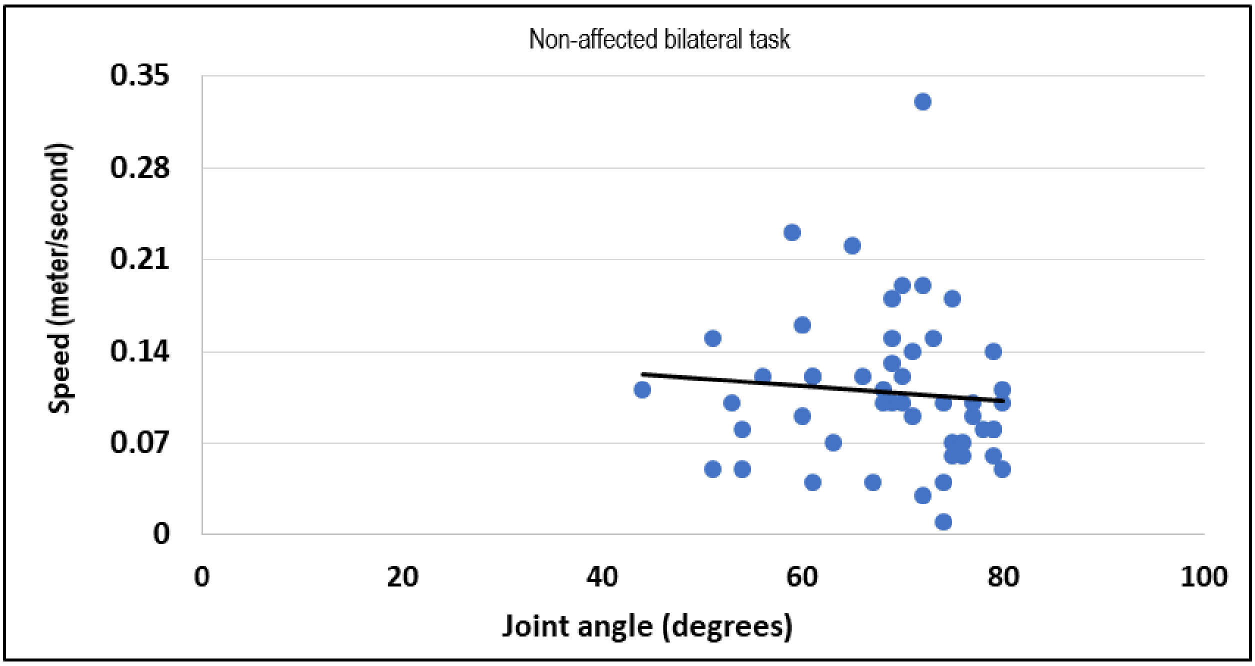

Figure (3): Correlation between joint angle and speed in bilateral task of the non-affected limb.

While the correlation between joint angle and speed in unilateral task of the affected limb was large negative significant correlation (r=-0.59, P=0.0001), the regression equation was y= -0.0074 x ± 0.6688 (**Figure 4**). Also for bilateral task was medium negative significant correlation (r=-0.45, P=0.001), the regression equation was y= -0.0056 x ± 0.5529 (**Figure 5**). Where the speed represented by (Y) symbol and (X) represented the angle.

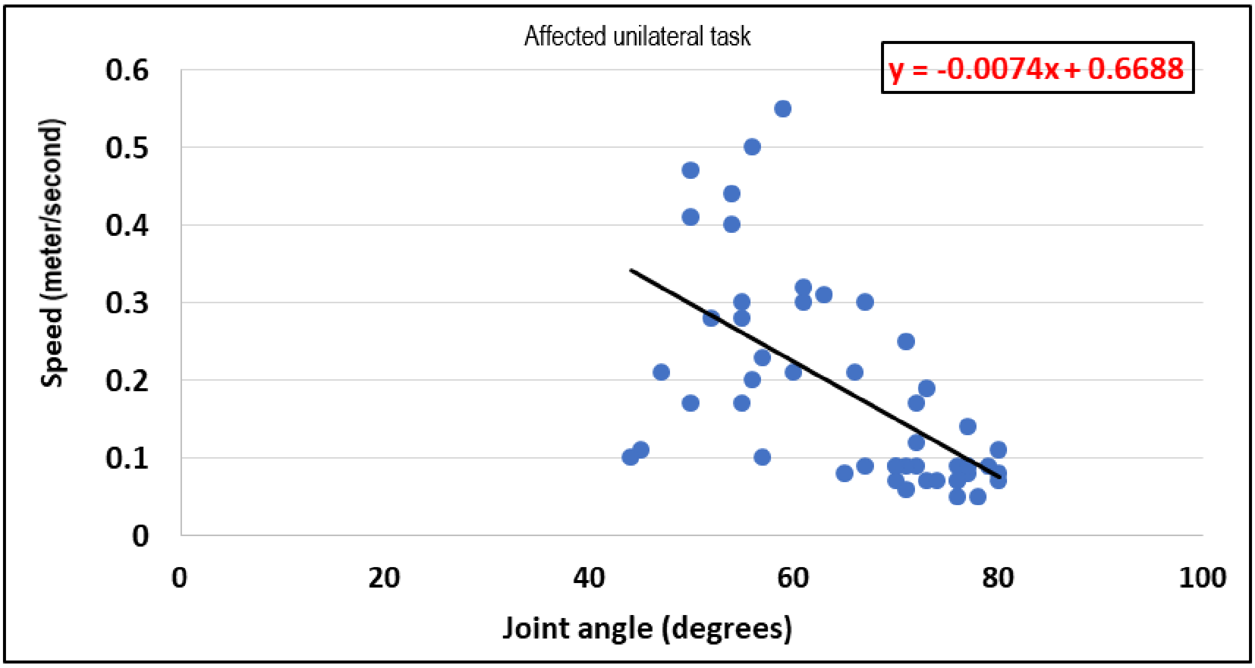

Figure (4): Correlation between joint angle and speed in unilateral task of the affected limb.

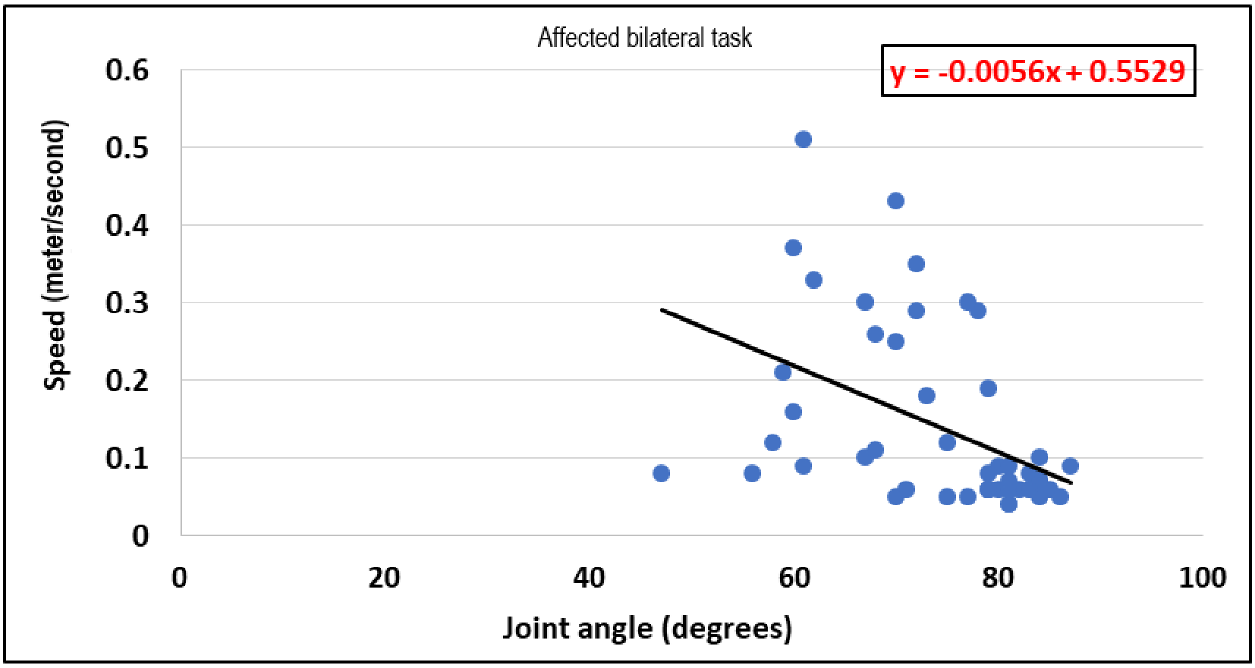

Figure (5): Correlation between joint angle and speed in bilateral task of the affected limb.

DISCUSSION

Reaching skill is mostly used in daily tasks and functional activities. Using upper extremities in different activities was limited in children with CP [(24)]. The hemiparetic upper extremity in children with unilateral spastic CP is nearly neglected. They almost preferred using the non-affected limb in unilateral activities. Including hemiparetic children in activities that emphasis bilateral reaching can encourage the movements of both arms and hands [(25)]. As the child practice more bilateral reaching tasks, the temporally and spatially coordinated movements were established [(5)]. So the present study compared the shoulder joint flexion angle and forward reaching speed of non-affected and affected limbs between unilateral and bilateral forward reaching tasks and studied if there is a relation between the shoulder flexion angle and the speed of forward reaching.

This study showed that in bilateral task the shoulder joint flexion angle of non-affected limb decreased and that of affected limb increased while the reaching speed of non-affected limb increased and that of affected limb decreased. There was an inverse relation between joint angle and speed of movement of the affected limb during forward reaching activity.

Results of the shoulder joint angle agree with systematic review of **Greaves *et al.*** [(26)] who found that bilateral activities are more complicated than unilateral one where both arms and hands movements had to coordinate temporally and spatially to accomplish the task. Daily activities required cooperation between both limbs, poor coordinated performance has a greatest functional impairment for children with unilateral CP.

The reaching movement in hemiplegic CP children was unlike that in normal developed group as they rarely reach with one movement unit that indicate less relied on feedforward strategy but used the feedback control strategy [6,27]. Children with hemiplegia had improper compensatory strategies and ROM as reduced shoulder flexion, and more trunk flexion [14]. Reaching with the affected limb had fewer excursions in both shoulder and elbow with less linearity and less coordinated movement and prolonged deceleration and motion time with more contribution from the trunk as compared to the least affected limb [13]. These findings indicate an interrupted motion strategy that may result from muscle weakness, abnormal muscle co-activation and disturbed sensorimotor processing in the arm.

This study finding agree with **Van Thiel and Steenbergen** [28] who reported that adaptation of the non-affected limb to the affected when doing a hitting movement strongly reduced between-arm-differences in bilateral activities. This explained by the proper transferring effect to the non-affected limb from the affected in bilateral activities that interfere with movement quality of the non-affected limb.

On the other hand, **Mackey *et al.*** [14] found that in bilateral reach activities the affected side joints ROM showed no change as compared with the unilateral one. This emphasis that the less affected side movement adjusted to more affected one. Bilateral training provides evidence for enhancing upper extremity functions in hemiparetic children. It may change in cortical representation of undamaged hemisphere [29].

Regarding the forward reaching speed, the study findings supported **Steenbergen *et al.*** [30] findings who stated that in spite of disturbed coordinated movements of spastic CP children observed during unilateral tasks, these children can coordinate the arms movements during bilateral activities because the unaffected limb adopted the time of the affected limb.

Steenbergen *et al.* [18] justified the asymmetry between affected and non-affected unilateral arm reaching in hemiparetic children to slow motion of the proximal musculature. In bilateral tasks they found that the affected limb cannot change its behavior under different conditions unlike the non-affected that change to cope with different constraints so it can adapt the reaching time of affected limb.

In children with spastic hemiplegic CP, the affected limb movement characterized by decreased velocity, weakness, inadequate coordination [24], and increased timing and variability [31]. Also, they have more striking movements that affect motion velocity of the limb as slowing time to reach peak angular velocity [14].

They have motor problems in affected and non-affected limbs. Motor difficulties depend mainly on brain lesion severity than spasticity itself. Also, inappropriate force, improper co-contraction, fatigue and weakened muscles can contribute to these difficulties. The compensation by reaching slowly aimed to accuracy and less variability, was associated with less trunk instability [27].

Coluccini *et al.* [6] showed decreased linear acceleration repeatability as the activity was occurred by affected side in high speed. Also, **Butler *et al.*** [10] found that children with spastic CP need more time to achieve reaching goal than normal developed children and added that as spasticity increased the reaching was faster than in less spasticity.

In agreement, **Kilbreath *et al.*** [32] concluded that post stroke patients do reaching task unilateral faster than bilateral due to the slowness in generating force and the muscle control during coordination of both limbs. **Mackey *et al.*** [14] reported that in bilateral tasks, time and speed of reaches vary in both limbs which may be due to the less affected limb used for obtaining object, so accelerating the activity, also because of its movement tried to cope the hemiparetic side.

In concordance with our results, **Van Thiel and Steenbergen** [28] showed asymmetry between the less and most affected limbs during unilateral reaching activities. Asymmetry obviously removed during bilateral activities because the less affected limb adjusted to the most affected.

In contrary, **Steenbergen *et al.*** [18] reported slower motion of the non-affected limb in bilateral tasks to adapt to affected limb speed. **Mackey *et al.*** [14] found in hemiplegic children no changes of peak velocities and timing of uni- and bilateral reaching task ($P>0.05$).

Results of the correlation supported finding of the study done by **Mailleux *et al.*** [16] that investigated the relation between sensorimotor disturbances and kinematic values of upper limbs in fifty children with hemiplegic CP. They reported large to medium correlations between decreased bilateral and unilateral functions and increased motion pathology and times ($r=-0.50$ to -0.87). Muscle with decreased power and increased tone had medium correlation with timing of motion. Moderate to high correlations obtained between the affect motor severity and the total motion pathology ($r=0.49$ to -0.73).

Correlation between affected upper extremity kinematic indices and bilateral activities in children with hemiplegic CP was studied by **Gaillard *et al.*** [17] who found a large negative correlation between bimanual application and kinematic disturbances of the affected upper limb and conclude that the bigger the total movement disturbance was, the smaller the bimanual function. Also, they showed a medium negative significant correlation between bimanual performance and shoulder flexion ($r=-0.48$, $P=0.019$). The correlation between the total deviation of the upper extremity movement and bimanual performance was medium negative non-significant correlation for the reach forwards task (r=-0.37, P=0.086).

The results of this study detected that, children with hemiparetic CP has deficit in the kinematic quality of reaching movement in both shoulder joint flexion angle and forward reaching speed. Better outcomes were gained when the task had done bilaterally as the movement become smoother and accurate (the accuracy of the affected limb improved) as the results founded that adjustment of the unaffected limb to the affected limb obviously decreased the differences in bilateral task. So the authors suggested that to improve these kinematic qualities had to encourage the reaching movement in bilateral way. Functional improvement can be achieved by considering the performance of the both sides.

Study weakness included that the other joints like elbow and wrist not considered while the maximum control of upper extremity motion depends on many joints' co-ordination of both temporal and spatial parameters that reflect in the end point kinematics. Further studies are very essential to determine if the limited ability of the affected limb to match the non-affected limb performance persists when using different challenging constraints (speed/time) with different daily tasks. Other studies should be done on the speed of reaching movement with and without using of compensatory strategies.

CONCLUSION

In conclusion, there was limitation of the shoulder joint flexion angle although there was increase of the speed of movement during unilateral forward reaching of the affected side in the hemiparetic CP children. However, the opposite happened in the unilateral forward reaching of the non-affected side. As the child doing the task bilaterally the joint angle increased and the speed of movement decrease of the affected limb and vice versa happened of the non-affected limb. There was inversely relationship between the joint angle and the speed of motion of the affected limb of hemiparetic CP children during forward reaching activity.

Conflict of interest: The authors declare no conflict of interest.

Sources of funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contribution: Authors contributed equally to the study.

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