

## Muscle Performance as Predictors of Standing Ability in Children with Spastic Diplegic Cerebral Palsy

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### Abstract

**Aim of the Study:** The aim of the study was to determine the relationship between the performance of six therapeutic exercises and muscle strength with standing ability in children with spastic diplegic cerebral palsy.

**Methodology:** 50 subjects with spastic CP with ability to stand with one finger support or without support were randomly selected. The total standing duration without support or with one finger support was recorded using stop watch. Then the performance of six therapeutic exercises of kneel stand, quadruped arm/leg lift, unilateral bridging, upper trunk extension, lower trunk extension, leg press exercises were taken. Maximum isometric muscle strength of lower trunk extensor, hip abductor, hip extensor, knee extensor, ankle plantar flexor was measured using modified sphygmomanometer. Muscle length of hamstring and hip adductor was measured using goniometer.

**Data Analysis:** Data were analyzed using Pearson Correlation to find the correlation between each independent variable with standing ability. Multi Variant analysis and Linear Regression were done between standing ability and performance of therapeutic exercises as well as muscle strength. P value will be set at 0.05 for a calculation.

**Results and Conclusion:** The findings of the present study shows that a relationship exists between standing ability and exercise performance of kneel stand, quadruped arm/leg lift, unilateral bridging, upper trunk extension, lower trunk extension and leg press. The study also shows a relationship between strength of lower trunk extensor, hip abductor, hip extensor, knee extensor and plantar flexor of children with spastic diplegic cerebral palsy. This experiment suggests subjects who perform better in the above functions also have better standing abilities. More the strength of the above mentioned muscles the more the standing abilities.

**Keywords:** Muscle Performance; Predictors; Standing Ability; Spastic Diplegic Cerebral Palsy

### Introduction

Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behavior and secondary musculoskeletal problems [1]. The motor type is usually described as spastic, dyskinetic, ataxic, hypotonic or mixed [2-4]. CP is a common problem, the worldwide incidence being 2 to 2.5 per 1000 live births [5,6].

The primary type of CP that results from prematurity is spastic diplegia, which account for 40% to 60% of all cases [7,8]. In spastic CP the common clinical problems include abnormal muscles tone, bone deformity, muscle weakness, limited joint range of motion and

reduced isolated muscle control [9,10]. The ability to stand upright is an important precursor for the initiation of other activities of daily living. So promoting standing ability is one of the important therapeutic goals in the treatment of cerebral palsy children. Postural control requires a complex interaction of musculoskeletal and neural system. Musculoskeletal components include joint range of motion, spinal flexibility, muscle properties and biomechanical relationship among linked body segments. The ability to maintain stability in the erect standing posture is a skill that the CNS learns using information from passive biomechanical elements, sensory systems and muscles [11]. Children with CP have been documented to have poorer standing abilities as compared to typically developing peers [12].

The ideal alignment in stance requires minimal muscular effort to sustain the vertical position. The muscles that are activated during the control of quiet stance are gastrocnemius, soleus, iliopsoas, abdominals, erector spinae [13]. EMG studies also show that the longissimus dorsi, rotator neck extensors and back extensors muscles exhibit activity during standing.

In crouch posture, the Line of gravity (LoG) passes posterior to the knee joint axes. The posterior location of the LoG creates an external flexion moment at the knees that must be balanced by an internal extension moment created by activity of the quadriceps muscles in order to maintain the erect position. As knee flexion in the upright stance is accompanied by hip flexion and ankle dorsiflexion, the location of the LoG also will be altered in relation to these joint axes. At the hip, hip extensors and at the ankle gastro-soleus muscle activity are required to balance extension-flexion and extension-dorsiflexion respectively [14]. The nature of the relationship between strength and function is of considerable relevance to clinical practice.

### Aim of the Study

The aim of the study is to determine the relationship between the performance of six therapeutic exercises and muscle strength with standing ability in children with spastic diplegic cerebral palsy.

### Methodology

**Study design:** Non experimental, Relationship study.

**Sample population:** Spastic diplegics CP with age group 3 - 13 yrs from Paediatrics Physiotherapy unit, SVNIRTAR, Cuttack who fulfilled the criteria were randomly taken for the study.

**Sample size:** 50 subjects.

**Sampling technique:** Simple random sampling.

**Inclusion criteria:** Spastic CP with ability to stand with one finger support or without support.

**Exclusion criteria:** Contracture of adductors, hamstring and tendoachilles, presence of involuntary movement, spasticity more than 2 by Modified Ashworth Scale (MAS).

### Procedure

After thorough assessment children who met the inclusion and exclusion criteria were included as participants by simple random sampling. Prior to the participation of the study a written consent was taken from parents or caregivers of the children after explaining the purpose of the study. The total standing duration without support or with one finger support was recorded using stop watch. Then the performance of six therapeutic exercises was taken. Maximum isometric muscle strength of lower trunk extensor, hip abductor, hip extensor, knee extensor, ankle plantar flexor was measured using modified sphygmomanometer. Muscle length of hamstring and hip abductor was measured using goniometer.

### Measurement of Performance of Therapeutic Exercises

**Unilateral bridging:** Unilateral bridging was performed in supine lying on each side and the duration of hold of this position was recorded. Distance of lift was measured using scale as the distance between the ASIS and the couch after lift.

**Leg Press:** The amount of weight the subjects can press only once so that the knee was fully extended was taken as one repetition maximum (RM). 1RM was considered to be a valid measure and is usually performed through leg press and bench press for upper limb and lower limb respectively [15].

**Upper trunk extension:** The subjects were in prone on the couch. Both the hands were placed under the thighs. A coin was placed on the couch in line with the subjects eyes. By focusing the coin, the subjects were asked to lift the upper trunk. The subjects were instructed to lift the upper body off the couch, in a controlled manner and hold the position. A ruler was placed on the couch in front of the subjects and the distance from the couch to the subjects' sternum level was measured.

**Lower trunk extension:** The subjects were in trunk prone lying position with hip and knee out of the couch in 90 - 90 positions supported on a stool. From this position the subjects were asked to extend both the thighs. The linear distance between the lateral epicondyle of femur and the supporting surface was measured using scale.

**Kneel standing:** The subjects were instructed to bear weight on both the knees by keeping the trunk as erect as possible. The subjects were instructed to maintain the position as much as possible. Duration of hold of kneel standing was recorded.

**Quadruped arm and leg lift:** Subjects were asked to maintain quadruped position. From this position the subjects were asked to lift contralateral upper and lower extremity simultaneously. It was repeated on both the sides. Duration of hold was recorded for both the sides.

### Measurement of Isometric Muscle Strength

Lower Trunk Extensors were tested in trunk prone lying position with hip and knee out of the couch in 90 - 90 position supported on a stool. From this position the subjects were asked to extend both the thighs. The inflated cuff was placed at the sacral region and fixed in stable position with belt. From this position the subjects were asked to lift lower trunk.

Hip Extensors were tested in prone position, with the hip in 15 degree of extension and the knee in 90 degree of flexion. The subjects were allowed to hold on to the sides of the table with both the hands. The cuff of modified sphygmomanometer was kept 1 inch above the mid-thigh, so that there was maximum activation. Belt was tied to fix the cuff in stable position. The subjects were asked to push the cuff by extending the hip.

Hip Abductors were tested in the supine position, with the hip in neutral position. The opposite leg was flexed. The cuff of sphygmomanometer was placed in a fixed position on the lateral femoral condyle and the subjects were asked to exert a maximum effort against the cuff in fixed position.

Knee Extensors were measured in sitting on the quadriceps exercise table which was adjusted with their knee in 30 of flexion. The cuff was tied anteriorly 5 cm proximal to lateral malleolus. The subjects were asked to straighten the knee as forcefully as possible.

Ankle Plantar Flexors were measured supine lying position with their foot in plantigrade position. The cuff of the modified sphygmomanometer was kept below the sole of foot in the region of metatarsal. Subjects were asked to plantar flex their ankle as forcefully as possible.

The processes were performed a total of 3 times with a 5 seconds resting period between each repetitions. The mean of 3 was taken and the same was repeated for the other side.

### Measurement of Muscle Length

Hamstring Length were measured by 90 - 90 test.

Hip Adductor Length was measured in supine lying position with the opposite hip in neutral and pelvis was stabilized to prevent rotation and pelvic tilting. The passive hip abduction range of motion was measured by using goniometer.

**Data Collection**

The total standing duration of the subjects were taken. Then the performance of kneel stand, quadruped arm/leg lift, unilateral bridging, upper trunk extension, lower trunk extension, leg press exercises were taken. Measurement of isometric muscle strength for lower trunk extensor, hip abductor, hip extensor, knee extensor, plantar flexor and muscle length of hamstring, hip adductor were taken.

Data of all variables were recorded in master sheet.

**Data Analysis**

Analysis was performed using SPSS package 16 version.

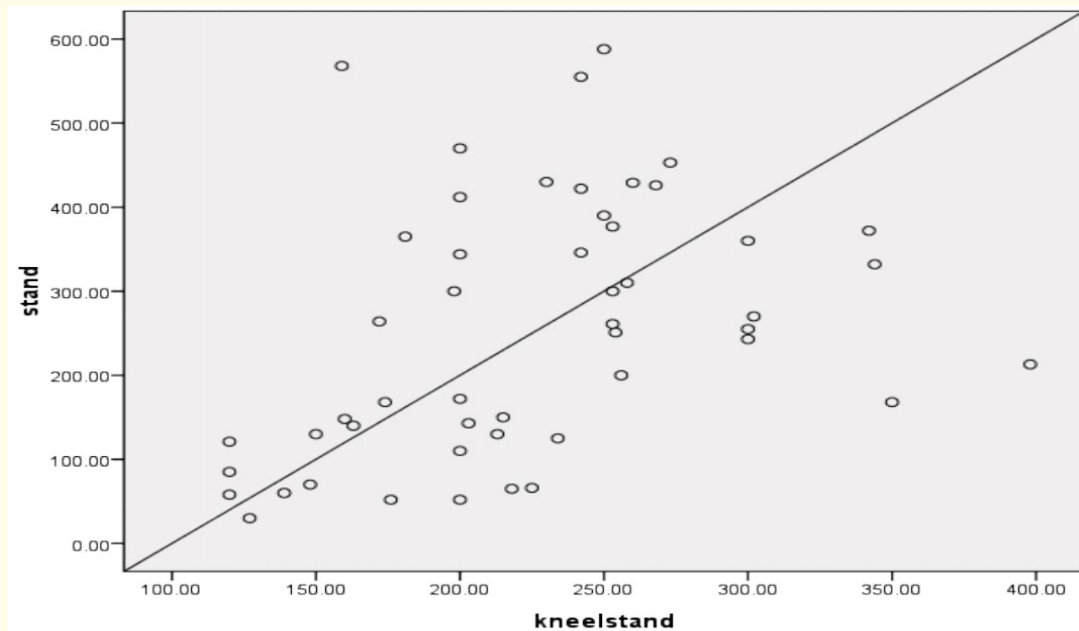
Data were analyzed using Pearson Correlation to find the correlation between each independent variable with standing ability. Multi Variant analysis and Linear Regression were done between standing ability and performance of therapeutic exercises as well as muscle strength. P value will be set at 0.05 for a calculation.

**Results**

**Pearson Correlation and Linear Regression**

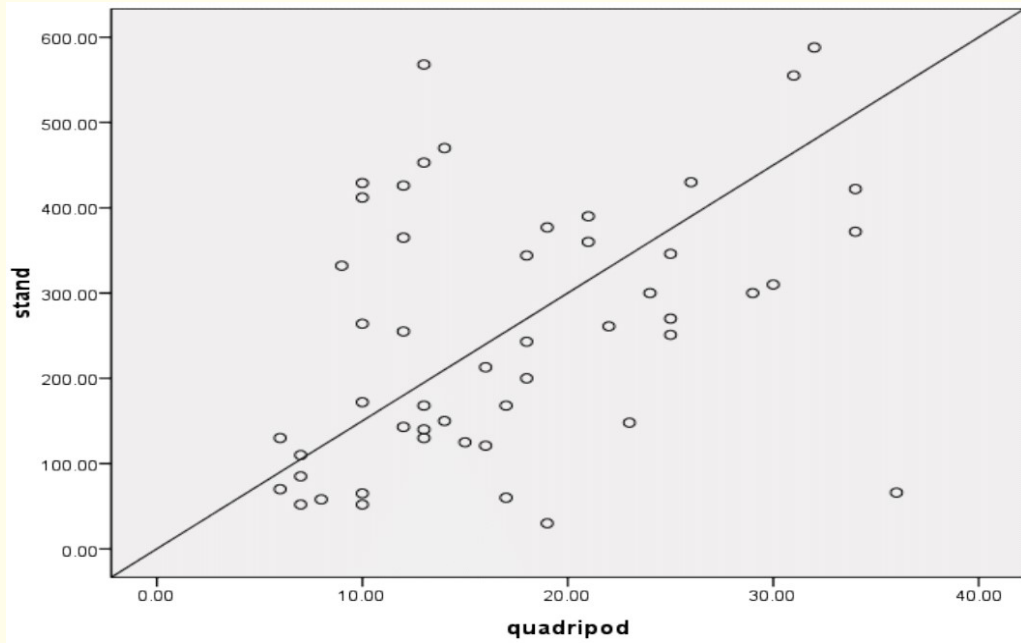
Linear regression analysis was done between standing ability and kneel stand, quadruped arm/leg lift, unilateral bridging, upper trunk extension, lower trunk extension, leg press showed  $r = 0.788$  ( $p = 0.000$ ).

Graph 1 illustrates the scatter plot diagram with best fit line showing correlation between standing ability and kneel stand with Pearson’s correlation coefficient having values  $r = 0.387$ ,  $p = 0.01$ . Linear regression analysis between standing ability and kneel stand showed that one second of kneel stand increases standing ability by .20 seconds.



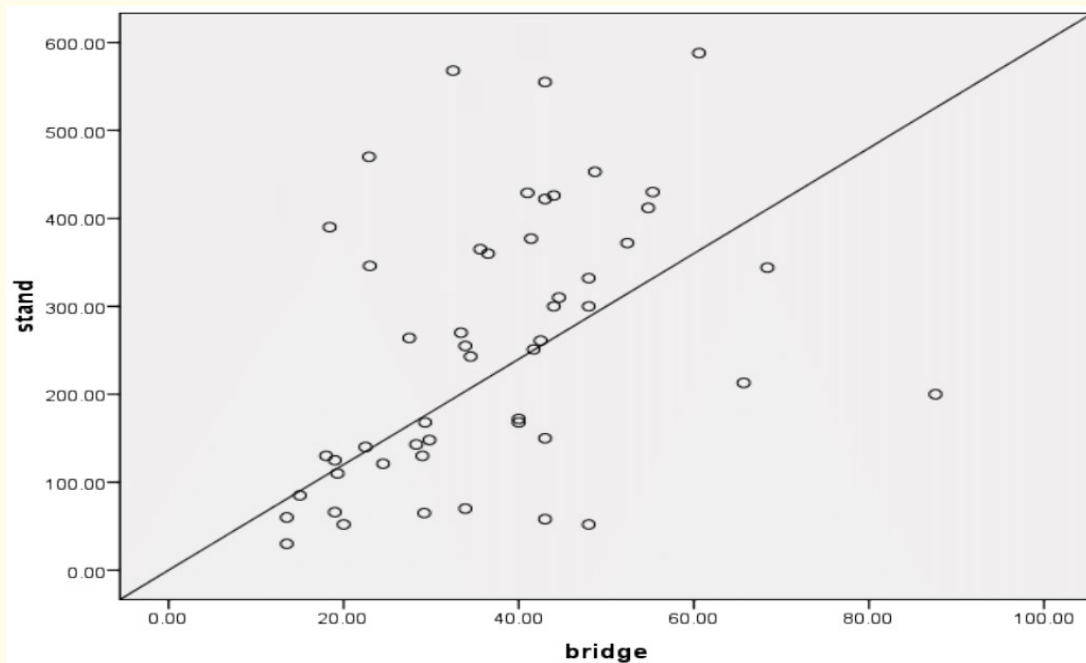
**Graph 1: Kneel stand.**

Graph 2 illustrates the scatter plot diagram with best fit line showing correlation between standing ability and quadruped arm/leg lift with Pearson’s correlation coefficient having values  $r = 0.390$ ,  $p = 0.01$ . Linear regression analysis between standing ability and quadruped arm/leg lift showed that one second of quadruped arm/leg lift increases standing ability by 5.41 seconds.



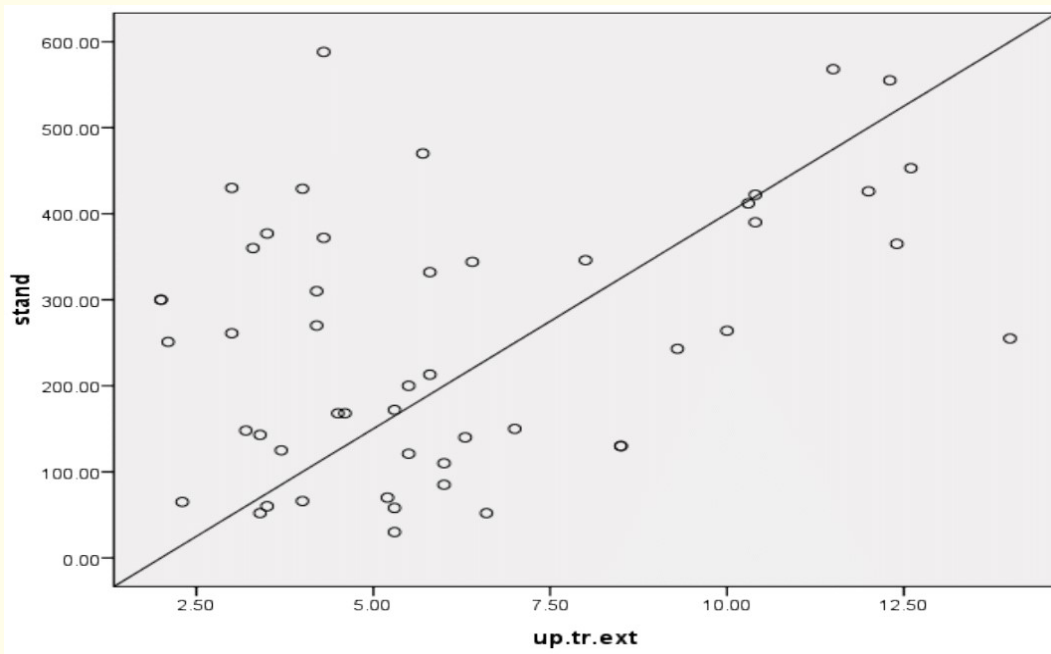
**Graph 2:** *Quadruped arm/leg lift.*

Graph 3 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and unilateral bridging with Pearson's correlation coefficient having values  $r = 0.417$ ,  $p = 0.01$ . Linear regression analysis between standing ability and unilateral bridging showed that one second of unilateral bridging increases standing ability by 2.66 seconds.



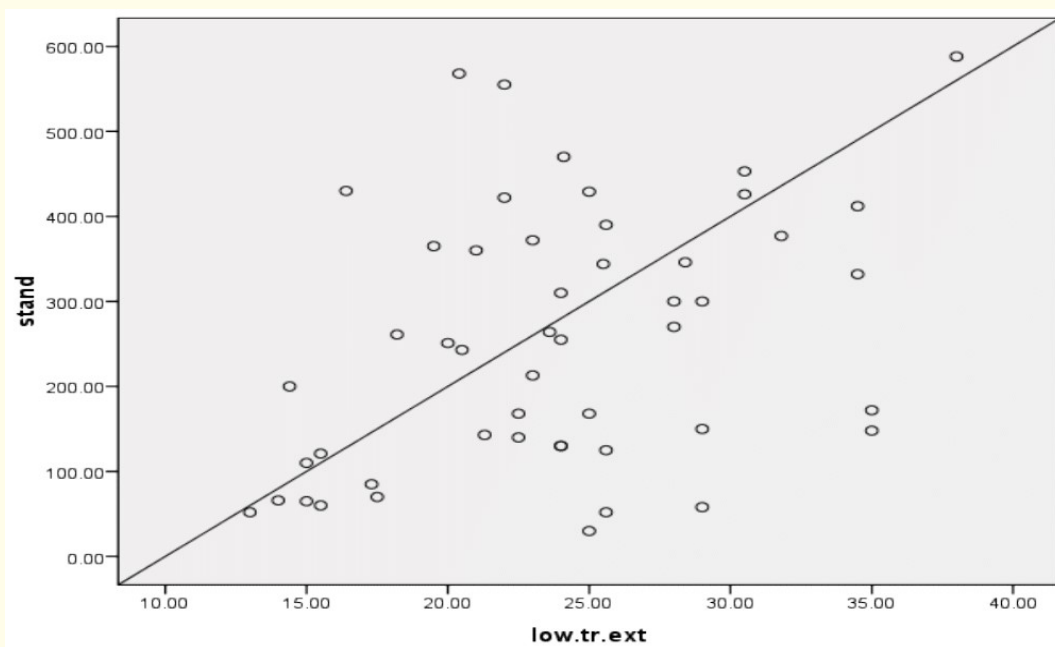
**Graph 3:** *Unilateral bridging.*

Graph 4 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and upper trunk extension with Pearson's correlation coefficient having values  $r = 0.377$ ,  $p = 0.01$ . Linear regression analysis between standing ability and upper trunk extension showed that one cm of upper trunk extension increases standing ability by 18.7 seconds.



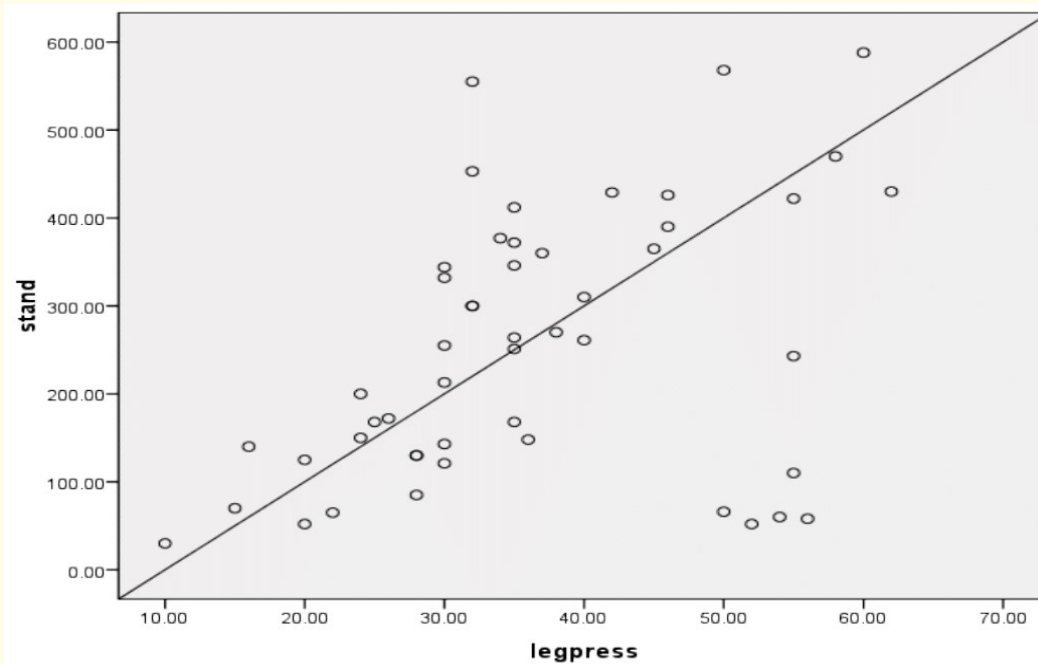
**Graph 4:** Upper trunk extension.

Graph 5 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and lower trunk extension with Pearson’s correlation coefficient is having values  $r = 0.364$ ,  $p = 0.01$ . Linear regression analysis between standing ability and lower trunk extension showed that one cm of lower trunk extension increases standing ability by 6 seconds.



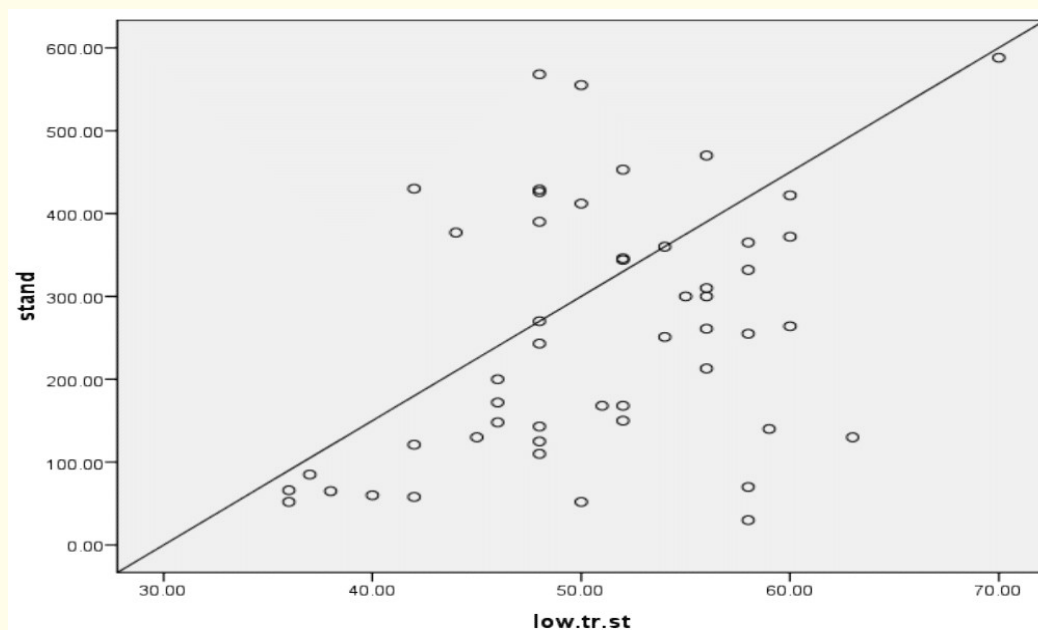
**Graph 5:** Lower trunk extension.

Graph 6 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and leg press with Pearson’s correlation coefficient having values  $r = 0.415$ ,  $p = 0.01$ . Linear regression analysis between standing ability and leg press showed that one kg of leg press increases standing ability by 3.5 seconds.



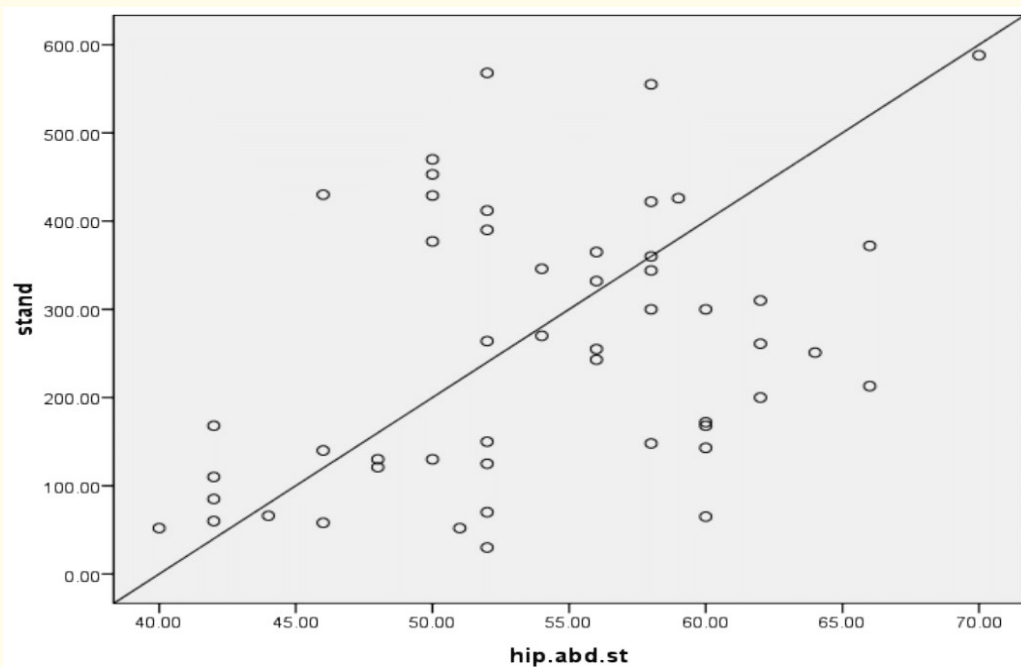
**Graph 6:** Leg press.

Graph 7 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and lower trunk extensor strength with Pearson’s correlation coefficient having values  $r = 0.383$ ,  $p = 0.01$ . Linear regression analysis between standing ability and lower trunk extensor strength showed that one mmhg of lower trunk extensor strength increases standing ability by .28 seconds.



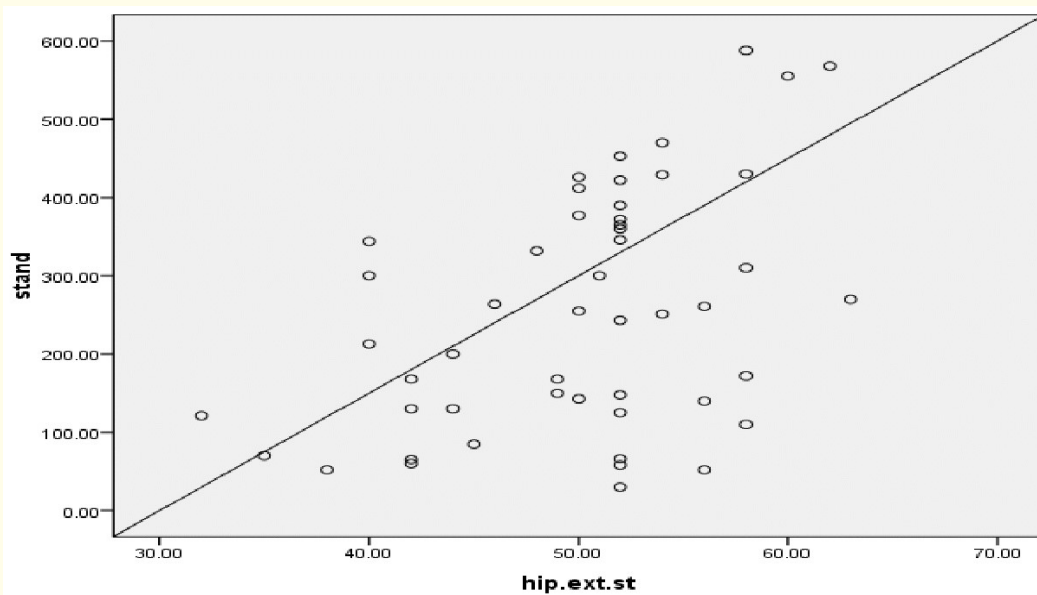
**Graph 7:** Lower trunk extensor strength.

Graph 8 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and hip abductor strength with Pearson’s correlation coefficient having values  $r = 0.386$ ,  $p = 0.01$ . Linear regression analysis between standing ability and hip abductor strength showed that one mmhg of hip abductor strength increases standing ability by 2.5 seconds.



**Graph 8:** Hip abductor strength.

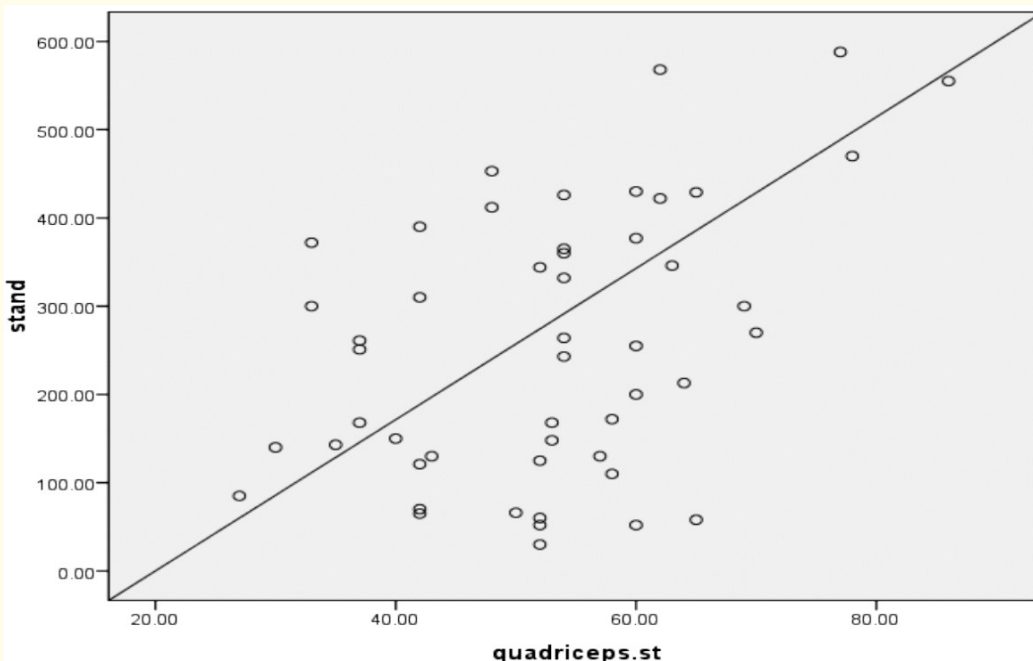
Graph 9 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and hip extensor strength with Pearson’s correlation coefficient having values  $r = 0.447$ ,  $p = 0.01$ . Linear regression analysis between standing ability and hip extensor strength showed that one mmhg of hip extensor strength increases standing ability by 5.6 seconds.



**Graph 9:** Hip extensor strength.

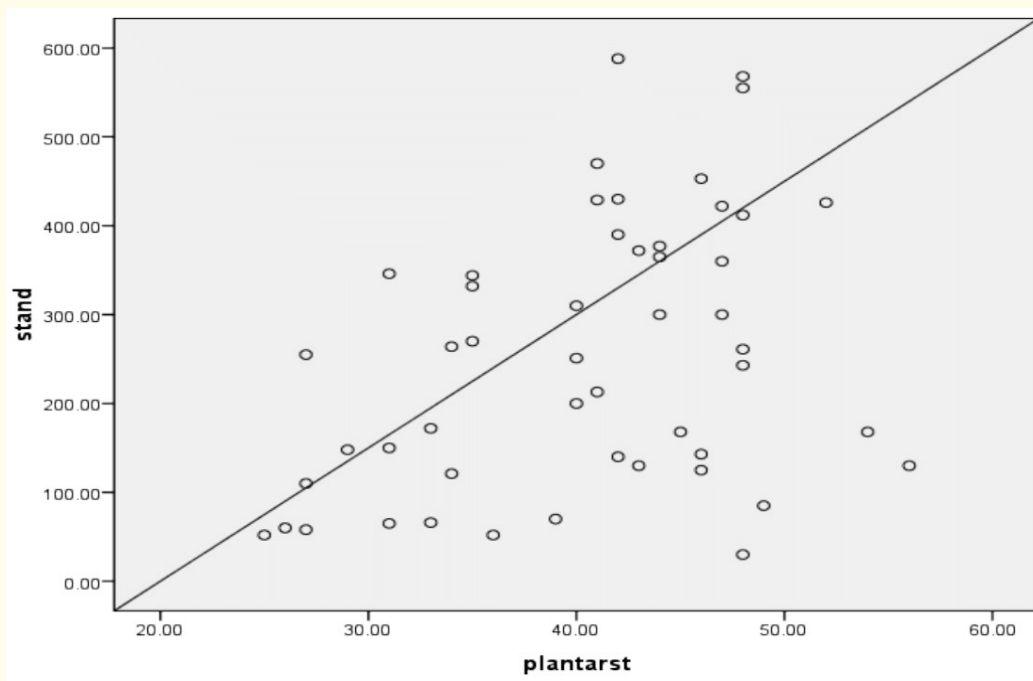
Graph 10 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and quadriceps strength with Pearson’s correlation coefficient having values  $r = 0.430$ ,  $p = 0.01$ . Linear regression analysis between standing ability and quadriceps strength showed that one mmhg of quadriceps strength increases standing ability by 4 seconds.





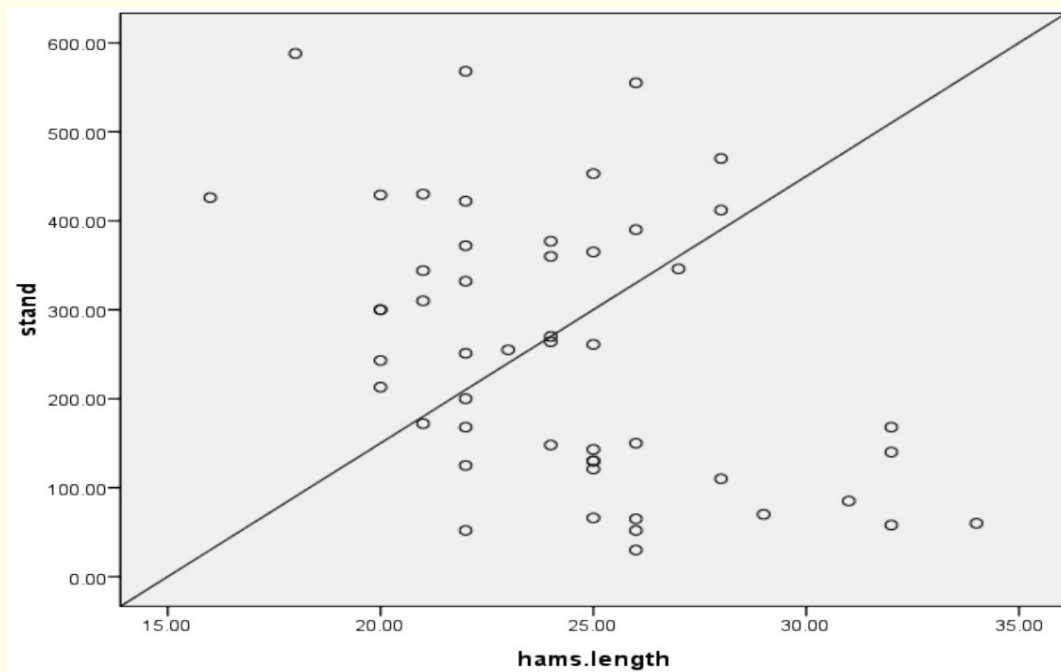
**Graph 10:** Knee extensor strength.

Graph 11 illustrates the scatter plot diagram with best fit line showing the correlation Between standing ability and plantar flexor strength with Pearson’s correlation coefficient having values  $r = 0.372$ ,  $p = 0.01$ . Linear regression analysis between standing ability and plantar flexor strength showed that one mmhg of plantar flexor strength increases standing ability by 5.5 seconds.



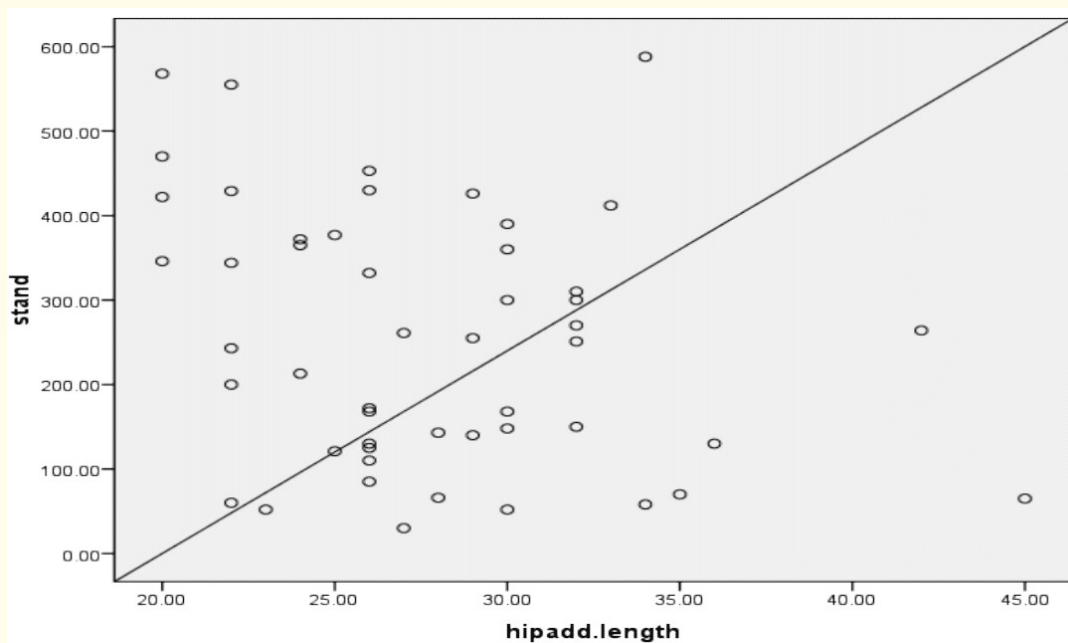
**Graph 11:** Plantar flexor strength.

Graph 12 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and hamstring length with Pearson’s correlation coefficient having values  $r = -0.437$ ,  $p = 0.01$ . Linear regression analysis between standing ability and hamstring length showed that one degree decreases in hamstring length increases standing ability by 6.1 seconds.



Graph 12: Hamstring length.

Graph 13 illustrates the scatter plot diagram with best fit line showing the correlation between standing ability and hip adductor length with Pearson’s correlation coefficient having values  $r = -0.274$ . Linear regression analysis between standing ability and hip adductor length showed that one degree increase in hip adductor length decreases standing ability by 2.6 seconds.



Graph 13: Hip adductor length.

**Multi Variant Analysis between Standing Ability and Performance of Exercises, Muscle Strength**

Multi variant analysis reveals a total variability of 62% between standing ability and kneel stand, quadruped arm/leg lift, unilateral bridging, upper trunk extension, lower trunk extension, leg press.

Multi variant analysis reveals a total variability of 55% between standing ability and isometric strength of lower trunk extensor, hip abductor, hip extensor, knee extensor, plantar flexor and length of hamstring and hip adductor muscles.

### Discussion

Overall results of the present study showed that there was a significant correlation between duration of standing (with and without support) and performance of exercises like kneel stand, quadruped arm/leg lift, unilateral bridging, upper trunk extension, lower trunk extension, leg press.

There was also correlation between duration of standing (with and without support) and strength of lower trunk extensor, hip abductor, hip extensor, quadriceps, plantar flexor and hamstring and hip adductor length which was statistically significant.

### Relationship between Standing Ability and Performance of Therapeutic Exercises

The results of the present study support the finding that the performance of exercises like kneel stand, quadruped arm/leg lift, unilateral bridging, upper trunk extension, lower trunk extension and leg press can predict the standing ability of children with spastic diplegia. The total variance by multiple regressions showed 62% which was statistically significant. The maintenance of posture depends upon the integrity of CNS, visual, vestibular and musculoskeletal systems. The main functional goal of postural control is the postural orientation and postural equilibrium. Postural orientation involves the active control of body alignment and tone with respect to gravity, supporting surface, visual environment and internal references. Postural equilibrium is determined by the size of the supporting base, angle of motion, muscle strength and sensory information. So the main musculoskeletal prerequisites for maintenance erect standing includes the adequate range of motion and Muscle force, the size and quality of the base of support. As the base of support increases with supported standing the stability is also increased [16]. The muscles activated during normal standing include gastrocnemius, soleus, iliopsoas, gluteus medius, abdominals, erector spinae [13]. But in crouch posture the posterior location of the line of gravity creates an external flexion moment at knees and it is balanced by the internal extension moment created by quadriceps muscles to maintain erect posture. As previously said the knee flexion in the crouch posture alters the body alignment which is one of the prerequisite for standing. This knee flexion is accompanied by the hip and ankle dorsiflexion for maintenance of stability. Hip extensors are activated to create an internal extensor moment similarly plantar flexors are activated to create an internal plantar flexion moment to maintain erect posture [14].

### Relationship Between Standing Ability and Quadruped Arm/Leg Lift

In the current study performance of quadruped arm/leg lift is related to standing ability by 0.39 which supports the following studies, exercise involves the whole body and in this way it could prepare the muscular loop and slings for upright bipedal functional tasks [17].

During this exercise there is a high activity of the contralateral internal oblique and the ipsilateral external oblique. The contralateral internal oblique muscle was activated to balance the internal moments and lateral shear forces in association with ipsilateral external oblique to maintain a neutral pelvis and spine posture. In this way, the abdominal obliques and the back muscles i.e. ipsilateral lumbar part of iliocostalis lumborum work together with the contralateral thoracic part of iliocostalis lumborum. Lattismus dorsi also works symmetrically, to control the trunk irrespective of the movement or position of the upper limb the underlying reason could be the tensioning of the thoracolumbar fascia in a cranial direction. During this exercise gluteus maximus muscle works actively to prevent the flexion of the hips and thus preventing destabilization of the spine [18]. This study supports the results of the present study that the above mentioned muscles work together to maintain the body alignment during the exercise which is also required to maintain the body standing.

Ekstrom RA., *et al.* (2007) and Jull GA, Richardson GA (1994) also found that during this exercise, gluteus maximus along with longissimus thoracis and lumbar multifidus was activated on the side of the extended hip. It is also suggested that this exercise is a useful stabilization exercise for the clinic to control the lumbar spine in a neutral position [19,20].

Souza GM., *et al.* (2001) found that during quadruped arm/leg lift abdominal oblique muscle activity was greater than that of rectus abdominus similarly there was increased activity of erector spinae during lifting and lowering of the extremities for the need to prevent rotation of the pelvis and spine during the alternating motion of the extremities [21]. Activity of the gluteus maximus was maximal during ipsilateral leg raising and minimal during contralateral leg raising and lowering, indicating that this muscle did not contribute to pelvic stability during these phases. McGill SM (1998) stated that during this exercise ipsilateral extensor activity was activated when the contralateral arm was raised [22].

Pañego MM., *et al.* (2009) found that quadruped arm/leg lift exercise helps in stabilization of the core muscle especially abdominal muscle and back extensors [23]. Arokoski JP., *et al.* (1999) found results that during this exercise the lower paraspinal muscles along with gluteus maximus are activated [24].

Callaghan JP., *et al.* (1998) in his study resulted that the greater upper erector spinae muscle activity during the exercise. These studies support our finding that the muscles activated during the performance of this exercises is similar to the muscles activated during standing. It was also explained that these muscles are activated to maintain a neutral spine and it act as a preparatory phase to maintain a standing posture this is the reason behind the correlation between standing ability and performance of quadruped arm/leg lift [25].

### Relationship Between Standing Ability and Kneel Stand

In the present study kneel standing is related to standing ability by 0.38. During kneel stand, leg muscles are activated to stabilize the lower limb and pelvis. In this position the body is supported on the knees. The lower leg is relaxed and the body is stabilized on the knees. During kneel standing there is an interplay between the flexors and extensors of the knee to balance the femora vertically on the knees. The extensors of the hip and the flexors of the lumbar spine work more strongly to maintain the correct angle of pelvic tilt. Rectus femoris is stretched across the front of both the hip and the knee joint. During kneel standing the centre of gravity of the body is relatively lower than in the standing. Kneel standing is used to facilitate normal muscle tone as well as to facilitate normal movement from a kneeling to a standing position in children with cerebral palsy (CP).

Bobath K (1980) Kneel standing provides weight bearing at the hips simulating the demands of upright standing alignment, in this way it fulfills the prerequisites of standing [26]. This position is particularly useful for establishing lower trunk and pelvic control and further promoting upright balance control. During kneeling, the facilitation of hip muscle tone (e.g., gluteus medius) is focused in order to stabilize postural alignment in the frontal plane during stance there is a decrease in center of pressure because in the kneeling position the center of mass is situated closer to the ground, which is inherently easier to stabilize. During kneeling, there is an absence of proprioceptive input from the foot sole and structures related to the ankle. Therefore, the postural control system in kneeling has to rely on the available somatosensory inputs coming from structures associated with the knee joint (e.g., thigh muscles) plus the visual and vestibular inputs. The result of the present study has been proven by these studies that during kneel standing the upper trunk muscles, anteriorly abdominals and posteriorly erector spinae work to maintain the trunk control. Similarly the alignment and stability which are the basic elements for also developed as a preparation for standing.

### Relationship between Standing Ability and Unilateral Bridging

During the unilateral bridging exercise, the ipsilateral Internal Oblique (IO) and contralateral external oblique (EO) showed significantly higher EMG activity [18]. In another similar study done by Kavcic N., *et al.* (2004) reported that during unilateral bridging exercise the IO and EO seem to demonstrate consistently a large impact on induced increasing and decreasing stability. Both the oblique muscles work together and have an important role in controlling the neutral spine position for proper body alignment during this exercise. When the contralateral leg is raised, a rotational moment about the spine occurs. The ipsilateral IO cause an ipsilateral rotational moment about the spine and the ipsilateral EO also create a moment in the opposite direction to counter the spine moment. To stop the spine from twisting, appropriate muscle activity generates stability. No single muscle seem to be superior to another and all the back muscles act together in the same way to create a stable position of the spine during this exercise [27].

In 2007 Ekstrom RA., *et al.* studied the muscles activated during unilateral bridging and revealed that gluteus maximus, longissimus thoracis, multifidus demonstrated similar activity [19].

Arokoski JP, *et al.* (1999) found that back extensor muscles were highly activated during this exercise. The activity of lumbar multifidus muscle was coupled with longissimus thoracis. Rectus abdominus was active bilaterally during same side lower extremity extension [24]. In general, during this exercise load on paraspinal muscle was more when compared to abdominal muscles. As loads are applied to the spine there is an integration of the many different torso muscles in order to balance the stability and moment demands [28]. Andersen LL., *et al.* (2010) found the gluteus maximus and quadriceps muscle activity during lifting of the ipsilateral lower extremity [29]. All dorsal extensor muscles were activated on a low level and lumbar erector spinae was activated to the highest level [30]. Gluteal muscle group acts to stabilize the pelvis during unilateral bridging. Particularly, the gluteus maximus acts to externally rotate the hip and extend the trunk, whereas the gluteus medius abducts the hip, stabilizes the pelvis, and assists in external hip rotation for body alignment. The external oblique muscle group is activated in an effort to support the pelvis before limb movement. Typically, when rotating to the right, the contralateral or left external oblique is activated. The decrease in oblique activation was expected because none of the exercises performed were rotational in nature. Similar muscles which are activated during standing are activated in unilateral bridging as explained by the above mentioned sources in the present study it is related to standing by 0.41. It is proven by the above studies that during unilateral bridging trunk muscles and hip muscles especially extensors and abductors work to maintain the alignment as these muscles are also needed to maintain the standing posture.

### Relationship between Standing Ability and Upper Trunk Extension and Lower Trunk Extension

During both upper and lower trunk extension exercises whole dorsal extensor chain was activated. In both tasks, the neuromuscular activity was higher for the spine-extensor muscles than for the hip-extensor muscles, indicating that these tasks were mainly “back-training” exercises [30]. The result of this study supports the result of the present study that trunk extensors are activated during standing and also during trunk extension exercises. EMG activities of the erector spinae in the upper trunk extension exercise and lumbar erector spinae extension activity is increased during lower trunk extension. The hip extensors, gluteus maximus, semitendinosus and semi membranous muscles were activated during the extension phase [25].

Arokoski JP, *et al.* (1999) found that erector spinae and multifidus have greater activity during upper and lower trunk extension [24]. Menacho MO., *et al.* (2010) found that lower trunk extension generated significantly more activity in the lumbar extensor muscles. There was a significant increase in back extensor activity when observed during prone back extension exercises. The result of the present study is supported by these studies that during these extension exercises the extensor muscles are activated to align the body. The upper and lower trunk extension are related to standing ability in the present study by 0.37 and 0.36 respectively as in these exercises extensor muscle activity is more as in standing posture [31].

### Relationship between Standing Ability and Leg Press

During leg press exercise along with quadriceps muscle, hip and ankle extensors, are brought into action to align the hip, knee and ankle in proper alignment. Escamilla RF, *et al.* (2001) found that during leg press quadriceps, hamstring and gastrocnemius muscles generated peak force when the knee was extended [32]. Fabio VS., *et al.* (2005) in his studied that the activity of the vastus lateralis muscle was significantly higher than that of the vastus medialis oblique muscle with the tibia in medial rotation [33].

Andersen LL., *et al.* (2010) quadriceps femoris muscle EMG activity was higher in leg press exercise compared with isolated knee extension [29]. Leg press exercise is more functional and complex multi joint movements, which explain the higher neuromuscular activation. Thus, it was suggests that a combination of simple and complex exercises probably should be used during rehabilitation to optimally stimulate maximal muscle strength and hypertrophy and to improve postural balance and inter muscular coordination. Gluteus maximus muscle EMG activity was found to be higher in leg press exercises. Muscles activated during leg press are related to standing ability by 0.41. In standing as well as in leg press activity of the lower limb muscles are highly required to maintain the alignment of lower limb.

### Relationship between Standing Ability and Strength of Lower Trunk Extensor, Hip Abductor, Hip Extensor, Quadriceps and Plantar Flexor, Muscle Length of Hamstring and Adductor Length

The results of the present study support the hypothesis that isometric muscle forces and muscle length are predictors of standing abilities of children with CP. The variance in the subject's standing abilities explained by muscle force and muscle length was 55% which is statistically significant. This finding indicates that the greater the isometric muscle force and greater the standing abilities of children with CP. Weakness was more pronounced distally in the groups with CP, and the hip flexors and ankle plantar flexors in spastic CP tended to be relatively stronger than their antagonists. Children with spastic CP demonstrate quantifiable lower extremity weakness and muscle imbalance across joints [34]. During the current study, weakness of muscles was found and reason behind for the weakness of muscles was explained by Mockford M., *et al.* (2010) that the children with CP are weak because of both neurologic and muscular changes [35]. Muscle weakness in cerebral palsy is due to reduced central drive, abnormal neural maturation, insufficient and disorganized motor recruitment, impaired voluntary control, impaired reciprocal inhibition, altered setting of muscle spindles and reinforcement of abnormal neural circuits. It was also suggested that muscle tissue is altered with selective atrophy of fast fibers and altered myosin expression, changes in fiber length and cross-sectional area, changes in the length-tension curve, reduced elasticity, and impoverished muscle tissue development. The primary reason for muscle weakness in CP is not antagonist restraint from spasticity or co contraction, but a primary inability of the agonist to produce sufficiently high force levels [36]. The importance of muscle strength for children with CP can be seen in the direct relation between strength and motor function. Strength of the knee extensors of children with CP has been correlated with gross motor ability like standing and walking. Children with stronger knee extensors are more likely to perform better on gross motor skills like can stand for more duration, can walk more quickly and have greater energy economy when walking. Children with diplegic type CP were weak and there were differences between muscle groups, with the quadriceps being stronger than other groups. There is a correlation between the muscle strength and function.

Similarly, Stackhouse SK., *et al.* (2005) found that the children with CP were weaker, had a lower maximal voluntary isometric contraction and a higher rate of antagonist co- activation than typically developing children. The finding suggested that the tendency towards crouched posture in spastic cerebral palsy increased the workload of the quadriceps muscle to maintain the posture [37]. Crouched posture changes the relative orientation of the body segments and thus alters dynamic coupling between joints which leads to major reductions in the hip and knee extension accelerations generated by several important stance-phase muscles [38]. Isometric and isokinetic muscle testing proved to be reliable in the CP population.

These methods can be used in most age groups, and when performed properly can yield reliable results. In a study by Lowes LP, *et al.* (2004) supports the result of the current study which reports that the weakness in ankle plantar flexion, hip and knee extension, and hip abduction muscles may adversely influence standing balance. It was also stated that strengthening the ankle muscles may improve a child's ability to perform the ankle strategy typically seen in quiet stance or with small displacements in balance. Similarly, some children may need to increase hip extension force to perform a hip strategy used with larger displacements in standing [39]. The results of the present study, suggest that poor muscle force production may be a detrimental factor in standing balance of children with CP. Hip and knee extension strengthening could potentially aid the child in assuming a more upright posture. The crouched standing posture affects the pattern of postural muscle coordination used to maintain balance.

Tightness of medial hamstrings or adductors are often considered to be one of the factors that contributes to the excessive internal rotation in CP. It has been proved that during upright standing medial hamstring, adductor longus and adductor magnus leads to a slight internal rotation [40]. Hamstrings over-activity causes the excess knee flexion associated with crouch posture. Patients walking in a crouched posture may increase activation of the hamstrings during single support since the capacity of this muscle group to accelerate the hip and knee toward extension is maintained in crouched postures. Over time, this hamstrings over-activity would likely lead to muscle remodeling and tightness. Spasticity in hip adductors leads the hip to adduct and cross when the child has been supported in a standing



position [41]. Spasticity also tends to adduct, internally rotate and flex the hips during walking. Muscle imbalance due to spasticity in hip adductor severely impairs the biomechanics of hip joint in children with CP. It may limit the work of the hip extensor, impairing stability while standing. In the present study it was found that increase in hip adductor tightness and hamstring tightness decreases the standing ability.

In the present study, predictors of standing balance are studied through biomechanical aspects. According to Gurnfinkel V, *et al.* (1991) that peripheral inputs from visual, somatosensory (proprioception, cutaneous and joint receptors) and vestibular systems are also necessary to detect the body's position and movement in space with respect to gravity and environment. Each sense provides the CNS with specific information about position and motion of the body thus each sense provides a different frame of reference for postural control [42]. Postural control requires a complex interaction of musculoskeletal and neural system. The strength of the lower limb muscles and the performance of six therapeutic exercise helps in alignment of the body and to maintain the standing posture. So it is proved that increase in lower limb muscle strength and increased ability to perform these exercises is directly related to the increased standing ability. This the reason, that the results of the present study showed a total variability of 66 and 55% between standing ability and the performance of the therapeutic exercise, muscle strength and muscle length which showed a respectively.

### Conclusion

The findings of the present study shows that a relationship exists between standing ability and exercise performance of kneel stand, quadruped arm/leg lift, unilateral bridging, upper trunk extension, lower trunk extension and leg press. The study also shows a relationship between strength of lower trunk extensor, hip abductor, hip extensor, knee extensor and plantar flexor of children with spastic diplegic cerebral palsy. This experiment suggests subjects who perform better in the above functions also have better standing abilities. More the strength of the above mentioned muscles the more the standing abilities. This can be used for exercise prescription.

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