Motor Skills as Predictors of Intellectual ability of Pupils with Cerebral Palsy

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Abstract

This paper presents results on a study which used the Gross Motor Function Classification System-Expanded and Revised (GMFCS-E & R), Manual Ability Classification System (MACS) and adapted Pictorial Test of Intelligence, Second Edition (PTI-2) to assess the gross motor skills, fine motor skills and intellectual ability of pupils with cerebral palsy. Additionally, the potential relationship between motor skills and intellectual ability of pupils with cerebral palsy were explored. One hundred and thirty-three pupils with cerebral palsy (79 males; 54 females) completed the study. The results revealed that majority of pupils with cerebral palsy function at the higher levels of the GMFCS-E & R and MACS (levels I/II). Applying a linear regression model, both gross and fine motor skills statistically significantly predicted intellectual ability of pupils with cerebral palsy. While the relation between motor skills and intellectual ability of persons with cerebral palsy has typically been viewed from the perspective of gross motor skills, it may be useful to emphasize fine motor activities as well.

Keywords: Gross motor, fine motor skills, intellectual ability, pupils with cerebral palsy

Introduction

Deficiencies in motor skills are distinctive features of individuals with cerebral palsy. Cerebral palsy is defined as "a group of disorders of the development of movement and posture, resulting in activity limitations that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain" (Rosenbaum, Paneth, Leviton, Goldstein, Bax, Damiano, … Jacobsson, 2007, p. 8).

Children typically develop a repertoire of motor skills from the first year of life to adulthood. Motor skills are categorized as basic motor skills (fundamental motor skills) and recreational motor skills (Haywood & Getchell, 2014). According to Haywood and Getchell (2014), basic motor skills are the first to develop and consist of locomotor skills and object control skills. Locomotor skills are skills required to move through space and include walking, running, hopping, sliding, jumping and leaping. Object control skills on the other hand are skills related to manipulating objects.

Basic motor skills form the basis of future motor skills and performance of physical activities (Clark & Metcalfe, 2002). Basic motor skills are further categorized as gross and fine motor skills. While gross motor skills are related to whole body movements such as sitting, walking and climbing stairs, fine motor skills involve movements that require the manipulation of the fingers, hand and wrist and include activities such as picking up objects, holding and using writing materials and dressing (Sacks & Buckley, 2003). Despite the described dichotomy in basic motor skills, many motor activities require the concurrent use of both gross and fine motor skills (Krebs, 2000); thus, gross and find motor skill activities are not mutually exclusive.

In school settings, motor skills are essential precursors for school readiness and academic performance (Sandler, Watson, Footo, Levine, Coleman, & Hooper, 1992; Sortor & Kulp, 2003). Fine motor skills enhance the quality and speed of classroom-related task performance. Recent research has proven that fine motor skills are vital for the development of math and reading skills as well as productive learning behaviours (Grissmer, Grimm, Aiyer, Murrah & Steele, 2010; Pagani, Fitzpatrick, Archambaul & Janosz, 2010). Again, the development of gross motor skills enhances pupils' ability to navigate the school environment, maintain appropriate sitting postures and provide the physical endurance required to cope with a full school-day work. Essentially, gross motor skills are required to hone fine motor skills (Brook, Wagenfeld & Thomsopson, 2017). For example, a pupil's ability to support his/her upper body on a seat has been found to invariably affect his/her ability to write (Kid Sense, 2017).

Motor skills are developmental in nature and tend to improve with age in typically developing children with the bulk of the skills developed by age five years (Ulrich, 2000). However, a child with cerebral palsy may have delayed gross motor skills (Woollacott & Burtner, 1996) and fine motor skills beyond age five (Van Rooijen, Verhoeven, Smits, Ketelaar, Becher & Steenbergen, 2012). Specifically, children with cerebral palsy consistently score lower on the measurement of the building blocks of motor skills such as strength, balance, agility, flexibility, co-ordination, proprioception, and reaction time compared to the normative population (Barela, Focks, Hilgeholt, Barela, Carvalho & Savelsbergh, 2011; Berg-Emons, van Baak, de Barbanson, Speth & Saris, 1996; Saavedra, Joshi, Woollacott & van Donkelaar, 2009).

In recent times, there has been a marked shift towards classifying cerebral palsy according to functional independence in the form of gross and fine motor skills rather than the underlying motor impairment (Arnould, Bleyenheuft & Thonnard, 2014; Chagas, Defilipo, Lemos, Mancini, Fronio & Carvalho, 2008; Van Rooijen, Verhoeven & Steenbergen, 2015). Traditionally, the ability to walk has been touted as the most important gross motor skill for children with cerebral palsy as it is central to most activities of daily living (Jahnsen, Villien, Egeland, Stanghelle & Holm, 2004). Consequently, many assessment tools of gross motor skills of individuals with cerebral palsy are based on the ability of the affected persons to walk. Gross Motor Function Classification System (GMFCS) is one such tool used globally to assess gross motor skills of persons with cerebral palsy. The Manual Ability Classification System (MACS) is complementary to the GMFCS-E & R, and is designed to assess the fine motor skills of persons with cerebral palsy in daily activities.

Eseigbe, Anyiam, Wammanda, Obajuluw and Rotibi (2014) studied the gross motor skills of 235 children with cerebral palsy who were under 12 years of age. Over half of the participants could not walk independently or with an assistive device (GMFCS-E & R levels IV & V. Similarly, Okeke and Ojinnaka (2010) reported that, majority of children with cerebral palsy in a study that involved assessing their

nutritional status were in the lower levels of the GMFCS. Chagas et al. (2008) posited that gross motor skills were generally compromised in children with cerebral palsy; children with lesser limb distribution generally had better gross motor skills compared to their peers with greater limb distribution based on the GMFCS. This finding is corroborated by Himmelmann et al. (2006) who discovered that nearly 70% of a total of 353 children with cerebral palsy had limited gross motor skills for their respective ages.

However, similar studies from other parts of the world based on the GMFCS point to higher scores by children with cerebral palsy. In the Netherlands, a study by Smits et al. (2013) revealed that nearly half of all children and young adults with cerebral palsy had no limitation with respect to gross motor skills. Reid, Carlin and Reddihough (2011) in a study that involved using GMFCS to assess the severity of cerebral palsy, reported that, up to 61% of persons with the condition had mild motor impairments (GMFCS levels I/II). Similarly, Carnahan, Arner and Hägglund (2007) reported that over 61% of persons with cerebral palsy could walk independently in a study that compared gross and fine motor skills in different subtypes of cerebral palsy. Tella, Gbiri, Osho and Ogunrinu (2011) also evaluated the quality of life of children with cerebral palsy in Nigeria reported nearly 70% of the children could walk independently.

Unlike gross motor skills, fine motor skills of children with cerebral palsy have not been extensively studied. A study by Carnahan, Arner and Hägglund (2007) compared gross and fine motor skills of 359 children with cerebral palsy and found that 64% were independent in age relevant fine motor activities. Similarly, Arner, Eliasson, Nicklasson, Sommerstein and Hagglund (2008) in their study, reported that 64% of 367 children with cerebral palsy were independent in age relevant fine motor skills. In that same study 14% of children with cerebral palsy had no fine motor skills and were entirely dependent on others for fine motor activities.

In their embodiment theory, Thelen and Smith (2000) hypothesized that body manipulation of the individual was crucial in interacting with the external environment and the subsequent development of cognitive skills. Similarly, Oudgenoeg-Paz, Volman and Leseman (2012) asserted that cognitive abilities emanated from the interactions between an infant and the external environment as well as how the infant embodies the experiences of the interactions. The few studies that have examined the relationship between motor skills and intellectual functioning among persons with cerebral palsy have mainly focused on gross motor skills. Furthermore, these studies have been limited to correlation analyses. For instance, Al-Nemr and Abdelazeim (2017) examined the relationship between gross motor skills and attention and executive function, in a study of 6-12-year olds with diplegic cerebral palsy. Al-Nemr and Abdelazeim found positive associations between gross motor skills and the two facets of intellectual functioning. Similarly, Song (2013) reported that gross motor function was positively correlated with cognitive functioning in 68 children with different types of cerebral palsy. Furthermore, Enkelarr, Ketelaa, and Gorter (2008) found a positive correlation between motor functioning and intellectual ability in a study of 78 toddlers with cerebral palsy. Again, Vohr et al. (2005) examined the relationship between the number of motor impaired limbs and intellectual ability of children with cerebral palsy. The researchers reported a linear relationship between the number of motor impaired limbs and intellectual ability except for children with hemiplegic cerebral palsy. Similarly, Russman et al. (2004) recorded a general relationship, though not absolute, between the number of affected limbs in cerebral palsy and related intellectual ability.

Relative to fine motor skills, Van Rooijen, Verhoeven and Steenbergen (2015) established fine motor skills were predictive of early numeracy performance of children with cerebral palsy in a longitudinal study. In this study, the researchers assessed the gross and fine motor skills of pupils with cerebral palsy in four Special Schools in Ghana and then applied bivariate linear regression in examining the potential relationship between gross motor skills and intellectual ability, as well as the potential

relationship between fine motor skills and intellectual ability in the same sample of pupils with cerebral palsy.

Method

A proportionate stratified sample of one hundred and thirty-three (133) pupils (79 males; 54 females) aged 5-12 years with cerebral palsy from four special schools in Ghana were involved in the study. The mean age of pupils was 10.5 years (sd=1.8) with the modal age being 12 years. The majority of pupils with cerebral palsy were in upper primary, they did not utilize assistive device for walking, and had hemiplegic cerebral palsy. A pilot study was conducted to adapt and norm the Pictorial Test of Intelligence-2 (PTI-2) on a Ghanaian sample. The PTI-2 was deemed suitable for this study as it requires little to no verbal or motor skill effort from examinees, making it suitable for pupils with cerebral palsy. However, since PTI-2 was developed based on a United States sample and normed on same, there was the need to adapt some of the items in Test as well as norm it on a Ghanaian sample. In adapting the PTI-2, the researchers first replaced text instructions in the picture book that demanded answers not familiar in the Ghanaian culture. For the Verbal Abstraction (VA) subtest, three accompanying text instructions were altered to make participants choose answers familiar in the Ghanaian context. Specifically, participants were asked to identify "factory", "clay man" and "glove" as depicted in the picture options. Item analysis in the form of item difficulty index and item discrimination index were applied in selecting these items to ensure consistency with the original items as the items on the PTI-2 are generally progressively more difficult. However, the Form Discrimination (FD) and Quantitative Concept (QC) sections of the PTI-2 were deemed suitable for the Ghanaian context. The researchers also expanded the items on the PTI-2 to include suitable items for upper primary pupils in Ghana (9-12 years). This was essential because PTI-2 was designed for pupils with upper age limit of 8 years 11 months. Ten age-appropriate items were added to the three different subtests of the PTI-2 to make it suitable for the age groups 9 to 12 years. Each item added to the adapted PTI-2 had an item difficulty index of 0.6 or

below in a sample of pupils aged 9 to 12 years. Point-biserial correlation was applied to test item discrimination index. Subsequently, only items with positive and relatively higher point-biserial correlation were included. For the VA subtest, the new items that were added were: canoe, night, athlete, pet, flyover, bus, hawk, airplane, traffic light, and zebra crossing. Similarly, culturally-appropriate patterns and shapes were added to the FD while more age-appropriate mathematical operations including subtraction and division were added to the QC.

The researchers used six months (May-October, 2019) to norm the adapted PTI-2 on a sample of typically developing Ghanaian pupils. The pupils were selected from 10 public primary schools in Kwahu East District and Tamale Metropolis respectively. In terms of location, Tamale Metropolis was selected from the Northern sector of the country, while Kwahu East District represented the Southern sector of the country. Zoning of the country into northern and southern zones is an acceptable practice in research and administration (Hayford, 2007; UNICEF, 2018). The normative population consisted of 920 (515 males; 405 females) typically developing pupils ranging from 5-12 years and was sub-grouped into 5, 6, 7, 8, 9, 10, 11 and 12-year olds, forming 8 sub-groups. It was necessary to norm the PTI-2 using typically developing pupils in order to have standard scores that reflect the general population of 5-12-year olds in Ghana. Simple random sampling was then applied to each age sub-group to select 30 pupils, thus a total of 240 pupils (135 males; 105 females) completed the norming process. The sub-group sample size of 30 was deemed suitable for each age group as the Central Limit Theorem (CLT) predicts this would yield a normal distribution.

Prior to administering the adapted PTI-2 to the normative sample the researchers solicited the consent of parents to allow their children to participate in the study. Researchers explained the purpose and procedure of the study to parents and asked them to sign an informed consent form on behalf of their children. Additionally, the researchers established rapport with participants (children) by explaining the purpose of the study to them and also encouraged them to participate. The test was

administered on an individual basis. Three examples of the adapted PTI-2 were introduced to the children to familiarize them with the test before they were then taken through the VA, FD, and QC subtests. Each subtest was terminated when pupil got 3 of the 5 successive items wrong. Few participants were unable to complete the test even though the researchers gave them the needed encouragement.

The sum of the raw scores for each subtest was converted to percentile ranks based on the number of participants that scored at or below a particular raw score. The percentile ranks were then converted to standard scores based on a distribution with a mean of 10 and standard deviation of 3. The standard scores of the three different subtests were then summed to obtain the overall standard score for each participant, termed the composite standard score of intelligence (CSSI). The composite standard scores were then converted to composite quotient based on a distribution with a mean of 100 and a standard deviation of 15. Per this study, the CSSI is applied in the analysis as it is more consistent with the raw scores and standard scores; the composite quotient represents a ratio capable of unduly influencing the regression analysis. It was necessary to convert raw scores to standard scores to allow for comparison of scores between different age groups. Without the conversion to standard scores, older participants would have an obvious advantage over younger ones relative to scores obtained on the adapted PTI-2.

Assessing the Motor Skills and Intellectual Ability of Pupils with Cerebral Palsy in Ghana

Assessment of motor skills and intellectual ability of pupils with cerebral palsy took place in their respective schools in Ghana. Assessment of gross motor skills began with careful observation of the gait of pupils as they made their way to the assessment desk. Furthermore, their ability to support their bodies on the chair and move from sitting to standing were observed. Finally, the ability of pupils with cerebral palsy to move up and down a mobile staircase was tested. Pupils were accordingly scored on the GMFCS-E & R. Pupils were given simple and clear instructions on how to handle

specific age-appropriate objects such as toys, crayons, pencils and plastic bottles placed on the desk. Additionally, the researchers demonstrated the handling of the objects to ensure pupils were absolutely clear on what was expected of them. Pupils generally applied their dominant hands in executing the fine motor skills but some task demanded the use of both hands. Pupils were then scored on the MACS. The adapted PTI-2 was applied right after the motor skill assessment as pupils sat facing the researchers. Pupils were taken through the examples of the different subtests before they proceeded to answer the different tasks.

Results

Demographic Characteristics of Pupils with Cerebral Palsy (Participants)

The basic demographic characteristics of pupils with cerebral palsy who participated in the study are presented in Table 1.

Table 1: Demographic Characteristics of pupils with cerebral palsy

Demographic	Male n (%)	Female n (%)	Total n (%)
Age (years)			
5	4 (5.1)	0	4 (3.0)
6	0	0	0
7	4 (5.1)	0	4 (3.0)
8	3 (3.8)	9 (16.7)	12 (9.0)
9	15 (19.0)	5 (9.3)	20 (15.0)
10	9 (11.4)	3 (5.6)	12 (9.0)
11	8 (10.1)	9 (16.7)	17 (12.8)
12	36 (45.6)	28 (51.9)	64 (48.1)
Class			
Upper primary	67 (84.8)	31 (57.4)	98 (73.7)
Lower primary	12 (15.2)	23 (42.6)	35 (26.3)
Use of Assistive (walking) device			
Yes	3 (3.8)	2 (3.7)	5 (3.8)
No	74 (93.7)	52 (96.3)	128 (96.2)
Limb distribution	9 (11.4)	7 (13.0)	16 (12)
Monoplegia	23 (29.1)	15 (27.8)	38 (28.1)

Diplegia	44 (55.7)	31 (57.4)	75 (56.4)
Hemiplegia	3 (3.8)	1 (1.9)	4 (3.0)
Tetraplegia			

One hundred and thirty-three pupils with cerebral palsy completed all the tasks in the study (79 males; 54 females). The mean age of pupils with cerebral palsy who participated in the study was 10.5 years (sd=1.8) with the modal age being 12 years for both male and female participants. Majority of the participants (73.7%) were in upper primary but a high proportion (26.3%) were in lower primary. Again, majority of the pupils (96.2%) did not utilize an assistive walking device. The results further show that hemiplegic cerebral palsy was the most dominant form (56.4%) of the condition among the participants.

Gross and Fine Motor Skills of Pupils with Cerebral Palsy

Table 2 presents scores of pupils with cerebral palsy on tasks in gross and fine motor skills. The scores presented in the table are direct representation of the different levels on the GMFCS-E & R and the MACS (levels I-V).

Table 2: GMFCS and MACS Levels of Pupils with Cerebral Palsy

Motor Skill	Male n (%)	Female n (%)	Total n (%)
GMFCS-E & R			
Level I	45 (57.0)	33 (61)	78 (58.6)
Level II	18 (22.8)	9 (16.7)	27 (20.3)
Level III	5 (6.3)	11 (20.4)	16 (12.0)
Level IV	11 (13.9)	1 (1.9)	12 (9.0)
Level V	0	0	0
MACS			
Level I	45 (57.0)	34 (63.0)	79 (59.4)
Level II	4 (5.1)	0	4 (3.0)

Level III	19 (24.1)	15 (27.8)	34 (25.6)
Level IV	11 (13.9)	5 (9.3)	16 (12.0)
Level V	0	0	0

Note. GMFCS-E & R= Gross Motor Function Classification System-Expanded and Revised MACS= Manual Ability Classification System (Fine motor skills)

In terms of gross motor skills, over half (58.6%) of the pupils in the study were on level I of GMFCS-E & R. Level I meant this category of pupils with cerebral palsy were able to perform most gross motor skills including the ability to walk independently, move into and out of a chair without support, as well as climb up and down stairs without the support of a rail. One fifth (20.3%) of the pupils with cerebral palsy in the study were on level II of the GMFCS-E & R, with males recording a slightly higher percentage than their female counterparts. These pupils were able to walk independently in most settings but required assistance in the form of armrest to push out of chair; they also made use of rails when moving up and down stairs. Twelve percent of the pupils were on level III of the scale with females having a relatively higher percentage on this score than their male counterparts. Level III meant, these children required a hand held mobility device to aid walking and assistance to climb up and down-stairs. Furthermore, they were able to sit on the chair but required some level of trunk support to maximize the use of their hands. Less than 10% of the pupils with cerebral palsy in the study were at level IV of the GMFCS-E & R. These pupils required physical assistance to walk, adaptive seating for trunk and pelvic control and some level of physical assistance to transfer from chair to standing.

In the area of fine motor skills, 59.4% of pupils with cerebral palsy in the study were at level I of the MACS. Pupils in this category exhibited the highest fine motor skills and handled the different objects with ease. Additionally, these pupils handled objects with speed and accuracy. Only 5% of male participants were at level II of the MACS with no female in this category. Pupils at level II of MACS were able to handle most of the objects during the fine motor skills assessment but with reduced speed and

accuracy. A quarter of pupils with cerebral palsy in the study were on level III of the MACS. Pupils with cerebral palsy in this category had difficulties in handling the objects used in the fine motor skills assessment. The fine motor skills exhibited were generally slow and ponderous. They performed fine motor tasks with limited success. Also, 12% of the pupils performed at level IV of the MACS. These pupils could handle few selected objects with limited success, and tended to apply a lot of effort in their attempt to accomplish the fine motor tasks. Also, some of these pupils required assistance for partial accomplishment of the different tasks.

Relationship between Motor Skills and Intellectual Ability of Pupils with Cerebral Palsy

Establishing the relationship between motor skills and intellectual ability involved juxtaposing motor skill levels against mean values derived from the assessment of intellectual ability. Relative to intellectual ability of pupils with cerebral palsy, CSSI which represents the sum of the three different subtests of the adapted PTI-2 was applied in the analysis as it is more consistent with the raw scores and standard scores; the composite quotient represents a ratio capable of unduly influencing the regression analysis. Additionally, inferential statistics in the form of bivariate linear regression was applied in revealing the exact relationship between the variables.

Table 3 presents motor skills of pupils with cerebral palsy against scores obtained from the three different subtests of the adapted PTI-2 and the corresponding CSSI.

Table 3: Motor Skill Levels against Scores on Intellectual Ability

Motor Skill   Intellectual Ability (mean ± sd)

GMFCS-E&R	VA	FD	QC	CSSI
Level I	15.0 ± 4.2	13.2 ± 3.1	11.2 ± 3.0	39.4 ± 8.8
Level II	7.1 ± 6.0	8.1 ± 4.6	6.4 ± 3.2	21.6 ± 13.6
Level III	7.3 ± 3.9	8.4 ± 3.9	9.6 ± 4.2	25.3 ± 12.0
Level IV	1.8 ± 1.0	3.2 ± 0.8	2.6 ± 0.9	7.58 ± 2.1
Level V	-	-	-	-
MACS				
Level I	14.9 ± 4.2	13.1 ± 3.1	11.3 ± 3.0	39.2 ± 8.9
Level II	5 ± 0.8	6.3 ± 1.0	6.3 ± 1.0	16.3 ± 0.5
Level III	7.5 ± 5.7	8.4 ± 4.8	7.8 ± 4.2	23.7 ± 14.3
Level IV	2.9 ± 2.1	4.1 ± 1.9	3.9 ± 2.5	10.9 ± 6.3
Level V	-	-	-	-

Note. GMFCS-E&R = Gross Motor Function Classification System-Expanded and Revised MACS = Manual Ability Classification System, VA = Verbal Abstraction, FD = Form Discrimination, QC = Quantitative Concept, CSSI = Composite Standard Score of Intelligence

From Table 3, pupils with cerebral palsy in the higher levels of the GMFCS-E & R (levels I-III) scored higher on the different subtests of the adapted PTI-2 and on the CSSI. However, pupils in level III of the GMFCS-E & R scored higher mean values on the different subtests compared to those on level II. It was noted that the mean values related to levels II and III had relatively higher standard deviations; the individual scores were more dispersed around the mean value.

For fine motor skills, the trend of the MACS levels against those of the three individual subtests of the adapted PTI-2 was similar to that of the GMFCS-E & R. The pupils with cerebral palsy in the higher levels of the MACS (levels I-III) scored better on the individual subtests of the adapted PTI-2. However, it was noted that pupils on MACS level III scored slightly higher mean values on the individual subtests of the adapted PTI-2 compared to those on level II.

Figure 1 below is the fitted line plot of intellectual ability against gross motor skills of the pupils with cerebral palsy in the study. The graph depicts a linear

relationship between the variables. Further, the fitted line plot does not reveal any significant outliers.
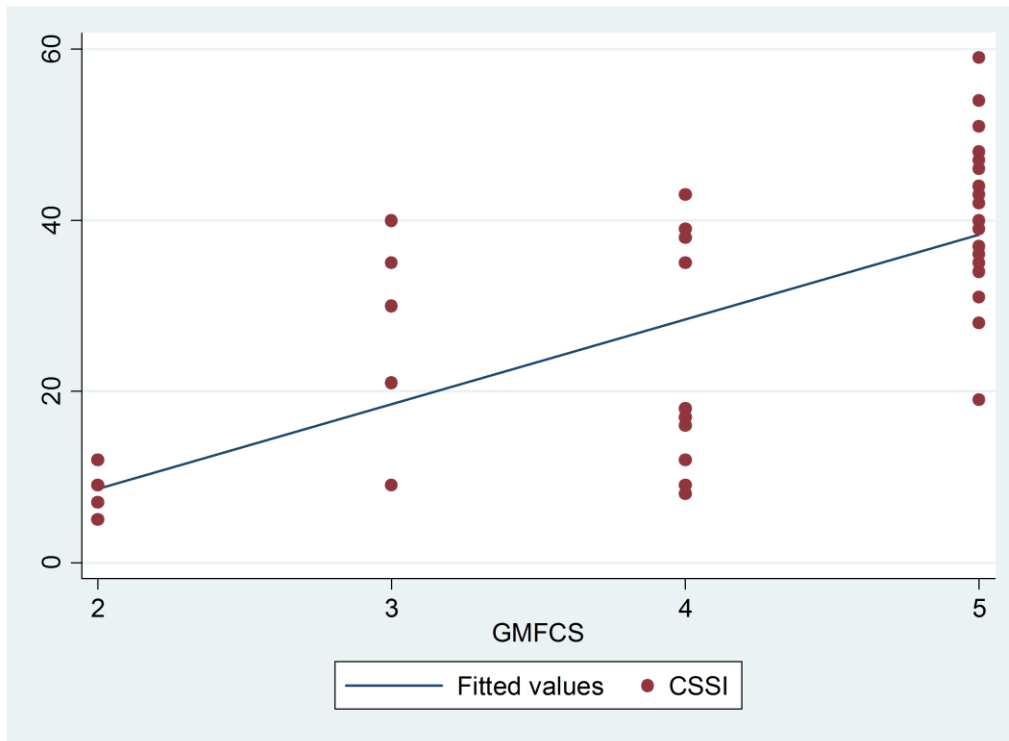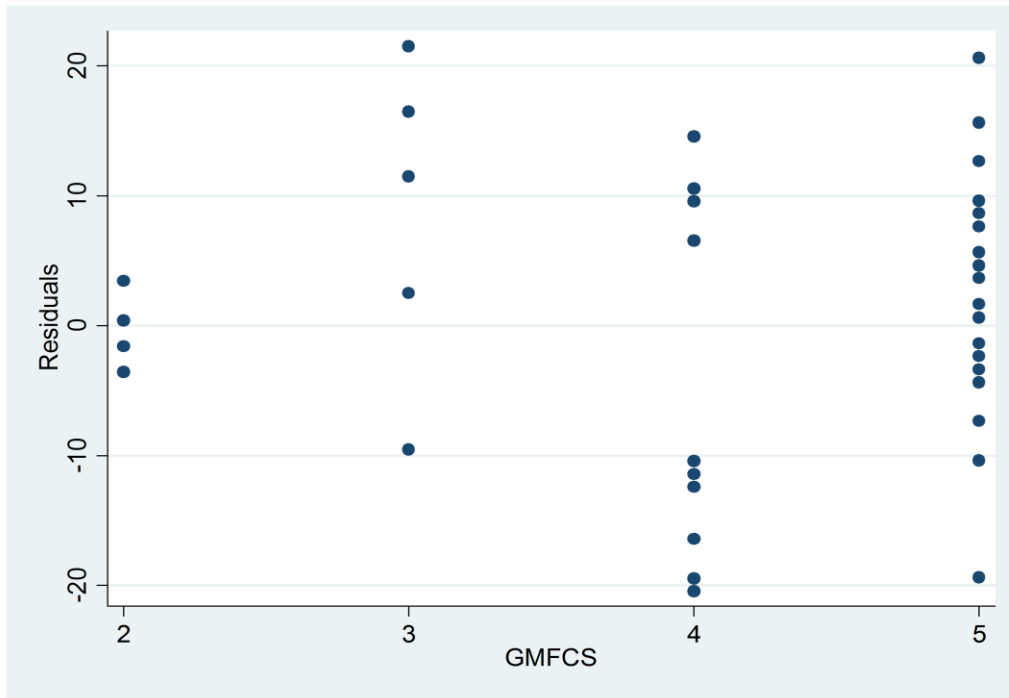

Note: GMFCS = Gross Motor Function Classification System (Expanded and Revised). GMFCS-E & R are reversed to allow for monotonicity with CSSI scores.

Figure 2. A residual-versus-predictor plot related to gross motor skills and intellectual ability

Figure 2 is the residual-versus-predictor plot related to gross motor skills and intellectual ability with no significant outliers. The bivariate linear regression established that gross motor skills statistically significantly predicted intellectual ability, $F (1, 131) =112.64$, $p = 0.00$ and gross motor skills accounted for 46% of the explained variability in intellectual ability. The regression equation was: predicted intellectual ability = -11.29 + 9.93 (gross motor skill level).

Further, test of independence of observation was executed using the Durbin-Watson Statistic, yielding an acceptable value of 1.72. Figure 2, the residual-versus-

predictor plot for homoscedasticity related to intellectual ability and gross motor skills, reveals the data satisfies homoscedasticity.

Note: GMFCS = Gross Motor Function Classification System (Expanded and Revised). GMFCS-E&R are reversed to allow for monotonicity with CSSI scores.

Figure 2. A residual-versus-predictor plot related to gross motor skills and intellectual ability

Figure 2 is the residual-versus-predictor plot related to gross motor skills and intellectual ability with no significant outliers.

Figure 3 presents the normal P-P plot depicting normal distribution of the residuals related to intellectual ability and gross motor skills.
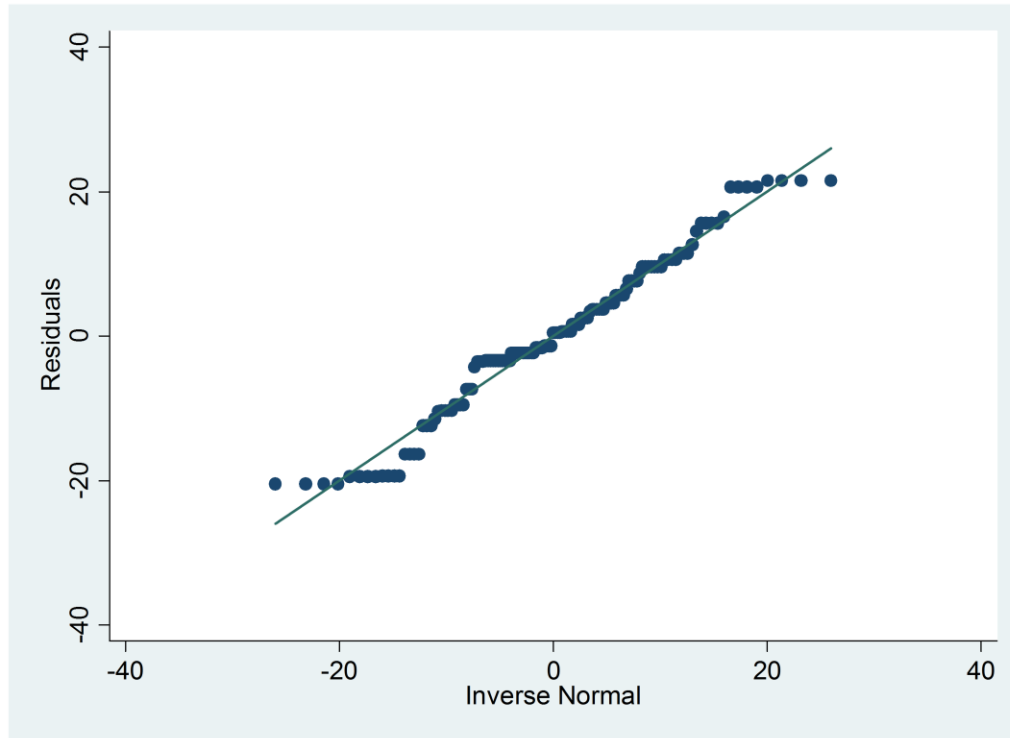
Figure 3. Normal P-P plot

Figure 3 is the Normal P-P plot depicting normal distribution of the residuals related to intellectual ability and gross motor skills.

Figure 4 below is the fitted line plot of intellectual ability against fine motor skills of pupils with cerebral palsy. The graph depicts a linear relationship between intellectual ability and fine motor skills. Furthermore, the fitted line plot does not reveal any significant outliers.
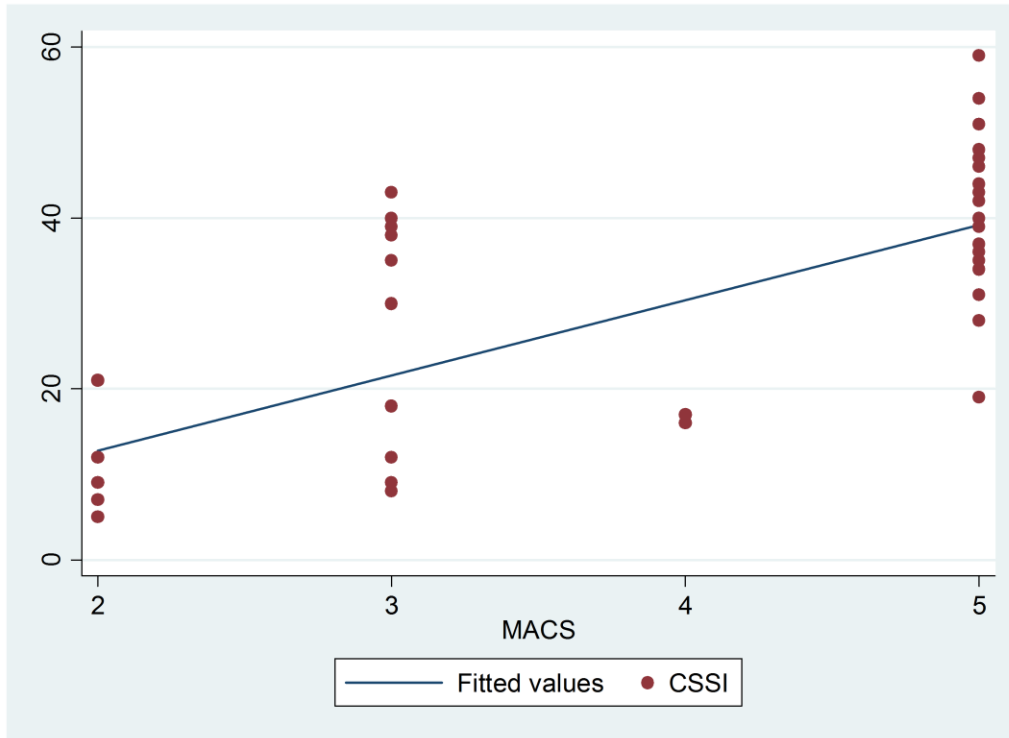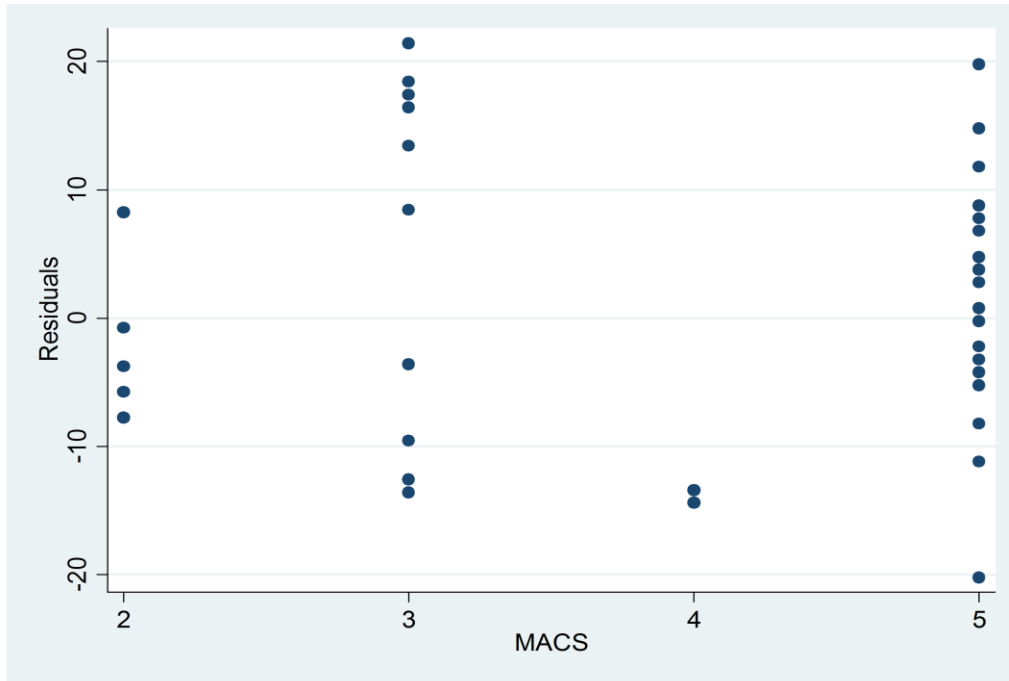
Note. MACS= Manual Ability Classification System, CSSI= Composite Standard Score of Intelligence. MACS levels are reversed to allow for monotonic relationship with CSSI scores.

Figure 4. Fitted Line Plot of Intellectual Ability versus Fine Motor Skills of Pupils with Cerebral Palsy

Figure 4 is the fitted line plot of intellectual ability against fine motor skills of pupils with cerebral palsy. The graph depicts a linear relationship between intellectual ability and fine motor skills. Furthermore, the fitted line plot does not reveal any significant outliers. The bivariate linear regression established that fine motor skills statistically significantly predicted intellectual ability, $F_{(1, 131)} = 125.21$, $p = 0.00$ and fine motor skills accounted for 48% of the explained variability in intellectual ability of pupils with cerebral palsy. The regression equation was: predicted intellectual ability = -4.87 + 8.82 (fine motor skill level).

Further, analysis of test of independence of observation using the Durbin-Watson Statistic yielded an acceptable value of 1.66. Figure 5, residual-versus-predictor

plot for homoscedasticity related to intellectual ability and fine motor skills, reveals the data satisfies homoscedasticity.

Note. MACS= Manual Ability Classification System. MACS levels are reversed to allow monotonicity with CSSI scores.

Figure 5. A residual-versus-predictor plot

Figure 5 is the residual-versus-predictor plot depicting the distribution of fine motor skills against residuals with no significant outliers.

Figure 6 is the normal P-P plot depicts normal distribution of the residuals related to intellectual ability and fine motor skills.
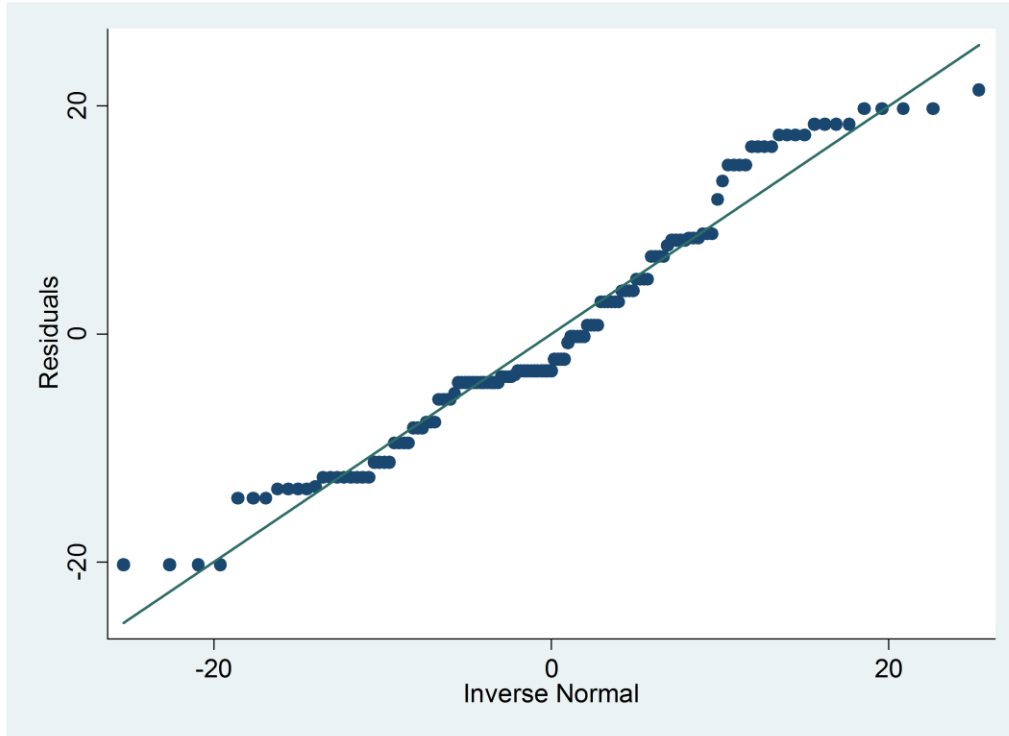
Figure 6. Normal P-P plot

Figure 6 is the normal P-P plot depicting normal distribution of the residuals related to intellectual ability and fine motor skills.

Discussion

The findings of this study offer a comprehensive motor skill profile of pupils with cerebral palsy (gross and fine motor skills) and explore the potential relationship between motor skills and intellectual ability of the same cohort. For pupils with cerebral palsy in the four special schools in Ghana, a condition characterized by motor disabilities (Rosenbaum et al., 2007), we hypothesize that both gross and fine motor skills significantly predict their respective intellectual abilities.

The study revealed majority of pupils with cerebral palsy from the four special schools in Ghana were on level I and II of the GMFCS-E&R. This finding suggests that those pupils were capable of independent execution of most school related gross motor

skill activities including walking, sitting, moving out of chair, and climbing up and down the stairs. This finding is consistent with the finding of Reid, Carlin and Reddihough (2011) who reported that over half of persons with cerebral palsy in a study that evaluated the severity of cerebral palsy based on GMFCS had mild motor impairments (GMFCS levels I/II). Similarly, Carnahan, Arner and Hägglund (2007) reported over 61% of persons with cerebral palsy could walk independently in a study that compared gross and fine motor skills in different subtypes of cerebral palsy. Furthermore, Tella, Gbiri, Osho and Ogunrinu (2011) who evaluated the quality of life of children with cerebral palsy in their study reported that nearly 70% of those children could walk independently. However, other studies have reported conflicting findings. Eseigbe, Anyiam, Wammanda, Obajuluw and Rotibi (2014) in assessing the gross motor skills of 235 children with cerebral palsy, who were under 12 years of age, revealed that over half of the participants could not walk independently, or with an assistive device (GMFCS-E&R levels IV/V). Similarly, Okeke and Ojinnaka (2010) reported majority of children with cerebral palsy in their study that involved assessing nutritional status were in the lower levels of the GMFCS. Chagas et al. (2008) reported that gross motor skills were generally compromised in the majority of children with cerebral palsy. Chagas et al.'s finding was corroborated by Himmelmann et al. (2006) who discovered that nearly 70% of a total of 353 children with cerebral palsy had limited gross motor skills for their respective ages. It is important to note that 21% of pupils with cerebral palsy in this current study were in the lower end of the GMFCS-E&R (levels III and IV). These pupils require assistive devices in executing most school-based gross motor activities. However, as indicated by the demographic characteristics of participants, the vast majority of pupils with cerebral palsy did not utilize any form of assistive walking device. Thus, the effect of any gross motor skill deficit was made more debilitating.

Similar to the gross motor skills, majority of the pupils in the study were classified as MACS levels I and II. These pupils were able to handle most age appropriate items; observed limitations in fine motor skills did not limit independence

in manual activities. They could handle school-related fine motor activities with ease. The finding is consistent with that of Carnahan, Arner and Hägglund (2007), as well as Arner, Eliasson, Nicklasson, Sommerstein and Hagglund (2008) both of whom reported over 60% children with cerebral palsy were independent in age relevant fine motor skills. On the other hand, over 37% of pupils with cerebral palsy in the current study were classified as being in the lower margins of the MACS (Levels III and IV). These pupils had difficulties with executing fine motor skills and struggled with school-based fine motor activities, and would benefit from school-based fine motor interventions.

Both gross motor and fine motor skills statistically significantly predicted intellectual ability of pupils with cerebral palsy from the four special schools in Ghana based on the linear regression model. The fact that gross motor and fine motor skills accounted for 46% and 48% respectively of the explained variability in intellectual ability of the pupils is quite significant. The finding suggests that similar to gross motor skills, fine motor skills may have as much influence on the intellectual development of pupils with cerebral palsy. Traditionally, the relationship between motor skills and intellectual functioning of persons with cerebral palsy has largely been viewed from the perspective of gross motor skills. However, fine motor skills represent critical skill set required for the full participation of pupils with cerebral palsy in school settings. Furthermore, most motor activities require the concurrent use of both set of skills as argued by Krebs (2000). Several authors (Pagani, Fitzpatrick, Archambaul & Janosz, 2010; Grissmer, Grimm, Aiyer, Murrah & Steele, 2010) have confirmed that fine motor skills enhance the quality and speed of classroom related task performance and are vital for the development of math and reading skills as well as productive learning behavior. Brook, Wagenfeld and Thomsopson (2017) on the other hand have pointed out that the development of gross motor skills in pupils enhances the ability to navigate the school environment, maintain appropriate sitting postures as well as provide the physical endurance required to cope with full day's work at school.

The finding that fine motor skills statistically significantly predicted intellectual ability of pupils with cerebral palsy is consistent with Van Rooijen, Verhoeven, and Steenbergen (2015) who established that fine motor skills were predictive of early numeracy in children with cerebral palsy. With respect to gross motor skills, Al-Nemr and Abdelazeim (2017) revealed positive associations between gross motor skills and attention as well as executive functioning. Song (2013) reported positive correlation between gross motor and cognitive functioning in different types of cerebral palsy. Enkelarr, Ketelaa, and Gorter (2008) established a positive correlation between motor functioning and intellectual ability among toddlers with cerebral palsy. Furthermore, the statistically significant linear relationship between gross motor skills and intellectual ability is consistent with the findings of Vohr et al. (2005) who reported a linear relationship between severity of motor impairment and intellectual ability of children with cerebral palsy in a study that based motor assessment of children with cerebral palsy on the number of affected limbs.

It is important to note that this study has been underpinned by embodiment theory which affirms cognitive development arises from an individual's interactions with the physical environment (Thelen & Smith, 2000). Other authors speculate that cognitive development is not entirely due to interactions between the individual and the physical environment; that cognitive skills acquired through physical interaction only serve to add to "core knowledge" inherent in the individual (Baillargeon, 2008; Hespos & Spelke, 2004; Spelke & Kinzler, 2007). Secondly, while this study establishes a potential link between motor skills (fine and gross motor skills) and intellectual ability of pupils with cerebral palsy, it does not describe how motor skills evolve with intellectual ability over time. Furthermore, it is possible the relationship is influenced by factors not accounted for in this study: environmental, socio-economic, cultural, and parental factors. It would be ideal for future research to longitudinally track how gross and fine motor skills evolve with intellectual ability in persons with cerebral palsy.

We conclude that body manipulation in the form of gross and fine motor skills on the part of pupils with cerebral palsy positively influence their intellectual development. Pupils with cerebral palsy with better gross and fine motor skills generally have greater and better interactions with the external environment, culminating in improved intellectual abilities. Conversely, pupils with cerebral palsy who have gross and fine motor skill deficits tend to have limited interaction with the external environment which negatively impacts their intellectual development.

In light of the findings and conclusion, we recommend that assessment of gross and fine motor skills, as well as intellectual ability of children with cerebral palsy should be an integral part of their pre-school assessment so as to plan effective motor skills interventions for this cohort of pupils. The pre-school assessment is particularly important as early intervention would not only potentially improve their respective gross and fine motor skills, but also, their intellectual abilities. Again, school authorities, should as much as possible, provide the necessary assistive technology and adaptive equipment that enhance the gross and fine motor skills of pupils with cerebral palsy in the special schools in the country. Finally, teachers of pupils with cerebral palsy should strive to implement interventions that not only improve gross motor skills, but fine motor skills as well.

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