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Correlation between Gross Motor Activities and Hand Writing Skills in Elementary School Children

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ABSTRACT

The purpose of the study was to determine the relation between developmental gross motor activities and hand writing skills in elementary school aged children. One hundred normal Egyptian children of both sexes were selected out of 600 from three private national elementary language schools, their ages ranged from 48-72 months old. Fifty four children were in grade senior kinder (group A) and 46 children were in grade one (group B). Each child in both groups was evaluated individually by using Peabody Developmental Motor Scale (PDMS-2) to determine the level of gross motor activities and the McMaster Handwriting Assessment Protocol (MHAP) to detect level of hand writing skills including speed of near point copying, speed of dictation, hand dominance and type of pencil grasp. The results of the study revealed significant positive correlation between gross motor quotient and speed of near point copying in both groups: Group A (n = 54, r = 0.664, p = 0.000), group B (n = 46, r = 0.769, p = 0.000) and significant positive correlation between gross motor quotient and speed of dictation in both groups: Group A (n = 54, r = 0.621, p = 0.000), group B (n = 46, r = 0.667, p = 0.000). Results also revealed non-significant positive correlation between gross motor quotient and hand dominance in both groups:group A (n = 54, r = 0.440, p = 0.842), group B (n = 46, r = 0.505, p = 0.617) and non-significant positive correlation between gross motor quotient and type of grasp in both groups: Group A (n = 54, r = 0.782, p = 0.09), group B (n = 46, r = 0.759, p = 0.171). It can be concluded that in the selected age range, gross motor skills were strongly correlated to speed of hand writing either in near point copying or dictation and not correlated to hand dominance or type of pencil grasp.

Key words: Gross motor activities, handwriting, PDMS, MHAP, school aged children

INTRODUCTION

Hand writing is an essential tool that requires development of student's skills at their earlier grades. It is a complex process which involves close coordination between musculoskeletal and nervous systems. It is one of the most unique features of humans' cultural development (Karlsdottir and Stefansson, 2002). Writing continues to be an essential life skill in daily life as a form of communication, archiving, expression of creativity and knowledge. Therefore it is an essential skill, one should possess in today's context and it forms an integral part of a student's life whether primary, secondary or tertiary (Nilukshika *et al*., 2012).

Failure to attain handwriting competency during the earlier school age often has negative effects on both academic success and self-esteem (Tomchek and Schneck, 2006). Hand writing is a complex occupational task. There are many underlying component skills that may interfere with its performance. Fine motor control, bilateral and visual-motor integration, motor planning, in hand manipulation, proprioception, visual perception, sustained attention and sensory awareness of the fingers are some of the component skills identified (Feder and Majnemer, 2007).

Poor handwriting may be related to intrinsic factors, extrinsic factors or both. Intrinsic factors refer to the child's actual handwriting perceptual motor capabilities including hand manipulation, bilateral integration, motor planning, visual motor integration, visual perception, kinesthesia, sensory awareness and sustained attention (Tomchek and Schneck, 2006). Extrinsic factors are related to environmental components as lighting, noise, black board distance when copying or biomechanical components as sitting position, chair/desk height, writing instrument used, type of paper used and its placement on the desk (Feder and Majnemer, 2007).

Nilukshika *et al*. (2012) stated that the foundational prerequisites for efficient, legible handwriting are visual perceptual motor components (the integration of gross motor, fine motor and oculomotor skills). Gross motor skills refer primarily to the postural control needed for hand writing; a good base of support in sitting, with hips at 90°C and feet stabilized on the floor, good pelvic and spinal alignment, cervical control for downward visual gaze and shoulder integrity for arm and hand control (Erhardt and Meade, 2005). Fine motor skills refer to finger dissociation and grading of muscle activity coordinated with fixation at wrist, elbow and shoulder in order to ensure a mature stable functional pencil grasp (Schwellnus *et al*., 2012). Oculomotor skills involve basic motor control of the extraocular muscles; visual perception (the ability to organize and interpret what is seen) and visual motor maturation (ability to integrate the visual image of letters or shapes with the appropriate motor response (Erhardt and Meade, 2005).

Grasp patterns generally develop from least mature (i.e., radial palmar grasp) to most mature (i.e., lateral or dynamic tripod grasp) and changes in grasp can continue until the child is approximately 10.5 years of age (Parush *et al*., 1998; Pollock *et al*., 2009). Several authors described most common pencil grasps as: (1) The Dynamic Tripod (DT) grasp involves the thumb, index and middle fingers functioning as a tripod to allow small, well-coordinated movements of the fingers originating from the inter-phalangeal joints and muscles of the hand and forearm, (2) The Lateral Tripod (LT) grasp the thumb is adducted against the lateral aspect of the index finger and often crosses over the top of the writing utensil (Schneck and Henderson, 1990), (3) Static Tripod (ST) grasp the pencil is stabilized against the side of the middle finger and held by the pads of the index finger and thumb. The hand is moved as a unit by the wrist and forearm in writing and (4) Four Fingers grasp (FF) very similar to the DT grasp but involves the thumb and three fingers (Schwellnus *et al*., 2012).

MATERIALS AND METHODS

This study was conducted at duration between November 2013 and April 2014. One hundred children of both sexes were recruited out of about 600 children from 3 different private national elementary language schools. The study was performed in Zagazig, Sharkia Governorate, Egypt. The children ranged in age from 48-72 months participated in this study. They could achieve minimal active pencil grasp, could understand and follow orders given to them during evaluation and were able to sit upright independently. They were selected according to a pre filled questionnaire by their parents who gave information about whether their children suffered from any learning disorders, behavioral or psychological disorders, developmental delays or sensory impairments, any chronic disease that may restrict activity level, deformities in upper limbs or lower limbs. It also collected data about children practicing a regular sport activity, using orthosis or assistive devices in hand or arm, or having previous orthopedic surgery in the upper limb. Selected children (met the inclusive criteria) were assigned to two groups according to grade level: group A for children in grade senior kinder (n = 54) and group B for children in grade 1 (n = 46). Each child in the two groups was assessed individually by two assessment tools including Peabody Developmental Motor Scale (PDMS-2) and McMaster Handwriting Assessment Protocol (MHAP). The study was approved by an Ethical Committee of Faculty of Physical Therapy, Cairo University. Permission to apply the study in the children's school's was taken from the school's departments. Parents were informed about details of the research before participation of their children.

Assessments conducted in the children's schools included

Peabody Developmental Motor Scale (PDMS-2): Peabody Developmental Motor Scale was used to determine the level of the child gross motor activities according to Folio and Fewell (2000). The PDMS-2 consists of six subtests (Reflexes, Stationary, Locomotion, Object Manipulation, Grasping, Visual motor integration) that measure interrelated motor abilities that develop early in life. In this study, 3 subtests were conducted for each child including: Stationary, Locomotion and Object Manipulation to calculate a Gross Motor Quotient (GMQ) for each child in both groups. Gross Motor Quotient was calculated from summation of standard scores of the three subtests used then converting it to a quotient according to table listed in the scale battery.

According to Folio and Fewell (2000), Table 1 demonstrates a guide to interpreting PDMS-2 quotient scores. High scores on the GMQ are made by children with well-developed gross motor abilities. These children would have above average movement and balance skills and are likely to be described as agile, well-coordinated and graceful in their movements. However, low scores are made by those children who have weak movement and balance skills who are likely to be described as clumsy, uncoordinated and in efficient.

McMaster Handwriting Assessment Protocol (MHAP): Children were asked to fill in the forms introduced to them (in the form of formal scribbling and letter writing) according to their grades to estimate the child's ease or difficulty in performing each activity. The activities were done without other technical or human help and whatever the strategy used. Child's writing was analyzed according to the checklist provided within the scale battery including speed of near point copying and speed of dictation. The assessment was conducted in the child's primary learning environment (classroom) as follows: (1) The child's record was reviewed, (2) The child's primary teacher and parents were liaised regarding concerns, (3) Classroom observation was conducted including notebook/workbook review to be familiar with child, (4) Grade specific writing tasks were completed with the child and finally (5) During the completion of writing tasks, the type of the child's pencil grasp and hand dominance were observed.

Table 1: A guide to interpreting PDMS-2 quotient scores

Quotient scores	Description
131-165	Very superior
121-130	Superior
111-120	Above average
90-110	Average
80-89	Below average
70-79	Poor
35-69	Very poor

PDMS-2: Peabody development motor scale

Assessment tasks included

Near point copying: The writing sample was placed approximately 3 inches away from the student's paper. The student was asked to copy the appropriate (grade level) word/passage on his/her typical writing paper. The time to complete the task was recorded using a stop watch for calculation of writing speed.

Dictation: The student was asked to write the dictated sentence (grade level). The time to complete the task was recorded using a stop watch for calculation of writing.

Statistical analysis: It was conducted using SPSS for windows, version 18 (SPSS, Inc., Chicago, IL). Pearson product moment correlation coefficient (r) was used to determine the correlations among the GMQ, speed of near point copying and speed of dictation in both groups. Spearman's rank correlation coefficient (r_s) was used to determine correlations between the GMQ, hand dominance and type of grasp. The initial alpha level for the correlation analysis was set at 0.05.

RESULTS

Descriptive data of both groups (A and B)

Age: Table 2 demonstrates that Mean±SD values of age for children in both groups (A and B) were 54.7±6 and 64.1±2.96 months, respectively.

Sex distribution: Table 3 demonstrates the frequency distribution of the sex in both groups (A and B). Inspection of the table reveals that the distribution of boys and girls in group A was 53 and 47%, respectively, while in group B, it was 60 and 40%, respectively.

Distribution of GMQ values: Table 4 demonstrates the frequency distribution of the GMQ scores in both groups (A and B). Inspection of the table reveals that the distribution of students achieving very superior level in both groups (A and B) was 2%, while students achieving superior level in both groups (A and B) were 6 and 22%, respectively. Students within above average level represented 33% of group A and 65% of group B while students within average level represented 59% of group A and 11% of group B.

Distribution of Hand dominance: Table 5 demonstrates the frequency distribution of hand dominance in both groups (A and B). Inspection of the table reveals that the distribution of RT handed students and LT handed students in group A was 80 and 20%, respectively, while in group B, it was 61 and 39%, respectively.

Distribution of type of grasp: Table 6 demonstrates the frequency distribution of type of grasp in both groups (A and B). Inspection of the table reveals that the distribution of dynamic tripod

Table 2: Age in months for both A and B groups

	Group A			Group B		
Item	X±SD	Min	Max	X±SD	Min	Max
Age (months)	54.7±6	48	59	64.1±2.96	60	72

X: Mean, SD: Standard deviation, Min: Minimum, Max: Maximum

Table 3: Frequency distribution of sex in both A and B groups

	Group A		Group B	
Sex	No.	%	No.	%
Boys	29	53	28	60
Girls	25	47	18	40
Total	54	100	46	100

No: Number, %: Percentage

Table 4: Frequency distribution of GMQ scores in both A and B groups

	Group A		Group B	
GMQ level	No.	%	No.	%
Very superior	1	2	1	2
Superior	3	6	10	22
Above average	18	33	30	65
Average	32	59	5	11
Total	54	100	46	100

No: Number, GMQ: Gross motor quotient, %: Percentage

Table 5: Frequency distribution of hand dominance in both A and B groups

	Group A		Group B	
Hand dominance	No.	%	No.	%
RT	43	80	28	61
LT	11	20	18	39
Total	54	100	46	100

RT: Right handed, LT: Left handed, %: Percentage, No: Number

Table 6: Frequency distribution of type of grasp in both A and B groups

	Group A		Group B	
Type of grasp	No.	%	No.	%
DT	38	69	30	65
LT	10	19	10	22
ST	3	6	5	10
FF	2	4	1	3
Other	1	2	0	0
Total	54	100	46	100

No: Number, %: Percentage, DT: Dynamic tripod, LT: Lateral tripod ST: Static tripod FF: Four fingers

grasp in both groups (A and B) was 69 and 52%, respectively, while distribution of lateral tripod grasp was 19 and 28%, respectively. The distribution of static tripod grasp in both groups (A and B) represented only 6 and 7%, respectively, while four fingers grasp represented 4 and 13%, respectively. Other patterns of pencil grasp appeared in just one student representing only 2% of group A while group B was absent of other immature patterns of pencil grasp.

Mean values of GMQ, speed of near point copying and speed of dictation: As presented in Table 7 the Mean±SD values of GMQ at group A and B was 110.18±6.95 and 117.26±7.9, respectively. Also, the Mean±SD values of speed of near point copying at group A and group B was 13.79±1.74 and 23.89±4.66, respectively. In addition, the Mean±SD values of speed of dictation at group A and group B was 13.01±1.76 and 23.13±4.08, respectively.

Mean ranks of hand dominance and grasp: Table 8 demonstrates mean ranks of dominance and grasp in both groups (A and B). The mean rank of dominance in both groups was 48.74 and 52.57, respectively. In addition, the mean rank of grasp in both groups was 46.23 and 55.51, respectively.

Table 7: Descriptive statistics of gross motor quotient, speed of near point copying and speed dictation in both groups

	Mean±SD	
Dependent variables	Group A	Group B
GMQ	110.18±6.95	117.26±7.9
Speed of near point copying	13.79±1.74	23.89±4.66
Speed of dictation	13.01±1.76	23.13±4.08

Significant level is set at alpha level <0.05, GMQ: Gross motor quotient, X: Mean SD: Standard deviation

Table 8: Descriptive statistics of dominance and grasp in both groups

	Mean rank	
Dependent variables	Group A	Group B
Dominance	48.74	52.57
Grasp	46.23	55.51

Table 9: Correlation between gross motor quotient and measured hand writing skills (speed of near point copying, speed of dictation, hand dominance and type of grasp) for group A (n = 54)

GMQ	Speed of near point copying	Speed of dictation	Hand dominance	Grasp
r-value	0.664	0.621	0.440	0.782
p-value	0.000*	0.000*	0.842	0.09
Significance	S	S	NS	NS

*Significant at alpha level 0.05, GMQ: Gross motor quotient, r: Correlation coefficient, P: Probability value, S: Significant, NS: Non significant

Table 10: Correlation between GMQ and measured hand writing skills (speed of near point copying, speed of dictation, hand dominance and type of grasp) for group B (n = 46)

GMQ	Speed of near point copying	Speed of dictation	Hand dominance	Grasp
r-value	0.769	0.677	0.505	0.759
p-value	0.000*	0.000*	0.617	0.171
Significance	S	S	NS	NS

*Significant at alpha level 0.05, GMQ: Gross motor quotient, r: Correlation coefficient, P: Probability value, S: Significant, NS: Non-significant

Correlation between GMQ and measured hand writing skills variables (speed of near point copying, speed of dictation, hand dominance and type of grasp) in group A (n = 54):

As represented in Table 9, the results of the present study revealed that:

- There was significant strong positive correlation between GMQ and speed of near point copying (r = 0.664, p = 0.000*)
- There was significant strong positive correlation between GMQ and speed of dictation (r = 0.621, p = 0.000*)
- There was non-significant correlation between GMQ and hand dominance (r_s = 0.440, p = 0.842)
- There was non-significant correlation between GMQ and type of grasp (r_s = 0.782, p = 0.09)

Correlation between GMQ and measured hand writing skills variables (speed of near point copying, speed of dictation, hand dominance and type of grasp) in group B (n = 46):

As represented in Table 10, the results of the present study revealed that:

- There was significant strong positive correlation between GMQ and speed of near point copying (r = 0.769, p = 0.000*)
- There was significant strong positive correlation between GMQ and speed of dictation (r = 0.677, p = 0.000*)

- There was non-significant correlation between GMQ and hand dominance ($r = 0.505$, $p = 0.617$)
- There was non-significant correlation between GMQ and type of grasp ($r = 0.759$, $p = 0.171$)

DISCUSSION

The present study was conducted to investigate the correlation between developmental gross motor activities and hand writing skills for Egyptian elementary school children. Each child in both groups (group A and B) was evaluated individually by PDMS-2 to determine the level of gross motor activities and MHAP to detect level of hand writing skills.

Selection of PDMS-2 for the assessment of gross motor activities for children in this study as it is a valid and reliable for assessment of developmental activities in children from birth to 72 months old (Folio and Fewell, 2000). The tasks constructing PDMS-2 included various performance components related to hand writing (neuromuscular and neurodevelopmental status, perception, motor performance, visual motor integration, bilateral integration and sensory processing). There is much overlap between these areas of motor performance. Common performance components (muscle tone, strength, balance, coordination, visual motor integration, bilateral integration) serve as the foundation for skilled motor output. There is also significant reliance between these motor skill areas as stability provides a solid foundation from which skilled upper extremity usage is achieved. Items of PDMS-2 identify all the aspects of performance components within the context of play-based assessment (Tomchek and Schneck, 2006).

The importance of PDMS-2 as a valid and reliable means of measuring gross motor skills was demonstrated by Wiepert and Mercer (2002) who stated that PDMS-2 gross motor subtests are used to assess five skill areas including dynamic and static balance skills, proximal and distal muscle strength, dynamic and static postural control, locomotor skills and receipt and propulsion skills. This was supported by Tieman *et al*. (2005), who stated that the PDMS-2 is a valid measure for determining a child's eligibility of services in early intervention and preschool programs. Tomchek and Schneck (2006) added that PDMS-2 can be used in early assessment of gross motor skills within a play based context with underlying performance components related to handwriting skills. Coallier and Rouleau (2014) stated that the relationship between Visual Motor Integration (VMI) and hand writing performance is more important in early grades, particularly because young students tend to rely more on visual feedback and motor information to guide their movements to form and copy letters which may further affect their gross motor performance.

The McMaster Handwriting Assessment Protocol (MHAP) was used to detect level of hand writing skills. The measured hand writing skills (speed of near point copying, speed of dictation, hand dominance, type of pencil grasp) were selected as they represent the most objective skills that can be measured with the least chance of variation according to Pollock *et al*. (2009). It focuses on the perceptual-motor processes of 'Handwriting readiness' by which the child develops the capacity to profit from the instruction given in the teaching of handwriting (Marr *et al*., 2001; Schneck and Amundson, 2010). It provides a comprehensive measure for handwriting readiness including proper seating posture (Pollock *et al*., 2009; Schneck and Amundson, 2010), a mature pencil grasp (Schwellnus *et al*., 2012, 2013) and performing age-appropriate writing patterns (Marr *et al*., 2001). Van Hartingsveldt *et al*. (2014) recommended it to provide some direction in the identification of the specific areas of difficulty and assist with the clinical decision making process following assessment.

The age of the children participated in this study ranged from 48-72 months old. Folio and Fewell (2000) stated that the increase in strength of hand grip has shown to be greater between 4 and 5 years of age and the overall patterns are well developed by 5 years of age. Feder and Majnemer (2007) stated that within this age, the development of pencil grasp in children typically follows a predictable progression. They added that children in the first years of elementary school possess a wide range of skills and maturational differences which result in variations in writing readiness depending on the development of each child.

Results of the current study revealed significant strong positive correlation between GMQ and measured hand writing skills including speed of near point copying and speed of dictation in both groups. However, there was no correlation between GMQ and hand dominance or type of grasp in both groups. These results may be attributed to the fact that individual skills do not follow straight forward developmental trajectories as they do not develop in isolation but rather rely on development of under pinning skills as stated by Flatters *et al*. (2014). They suggested that in 4 year old children the motor output becomes less varied and more coordinated and children develop more coordinated and adjusted movements in parallel with the obvious cognitive functions and sensor motor control during normal development.

The importance of proximal stability was discussed by Erhardt and Meade (2005) who stated that proximal stability and coordination of proximal muscles provide stability at each proximal joint which is important to make it easy to sustain the fine motor tasks of eye and hand control needed for school. De Graaf-Peters *et al*. (2007) stated that poor postural stability affects the precision of arm movement's control. This explanation is supported by Lobo and Galloway (2008) who emphasized the importance of head and trunk stability as perquisite for the child to develop reaching and grasping behaviors. Furthermore, Claxton *et al*. (2013) proved that infants show improved postural stability if they are engaged in manual behavior. Such patterns of behavior suggest that the need for better manual skill acts as a driver to the postural system (Haddad *et al*., 2013).

Scharli *et al*. (2013) explained the relation between postural stability and visual motor skill development as in fixating between targets or visually tracking moving target often involves head movements which have consequences for postural stability. Berrigan *et al*. (2006) added that moving the arm causes shifts in the Centre Of Mass (COM) that require postural compensation. The ability to make Anticipatory Postural Adjustments (APAs) to cancel out forces generated by hand and/or head movements have been shown to develop from infancy onwards to support the development of manual behaviors such as reaching-to-grasp (Girolami *et al*., 2010).

Distribution of hand dominance in the present study revealed 80% of students in group A were RT handers and 20% were LT handers. While in group B 61% were RT handers and 39% were LT handers. There was no significant correlation between gross motor skills and handedness. Established handedness generally is considered to be an important indicator of hemispheric specialization and callosal myelination necessary for development of motoric skills, language and cognitive processes (Annett, 1998; Bishop, 1990a, b; Kraus, 2006). Physiologic evidence proved that both the contralateral and ipsilateral hemispheres control proximal arm muscles via multisynaptic pathways, where distal control of the hand and fingers is executed by the contralateral hemisphere via the corticospinal tract (Brinkman and Kuypers, 1973; Glickstein *et al*., 1998; Haaxma and Kuypers, 1974; Peters, 1995). Several authors observed that fine manipulations performed by distal musculature appear to be more lateralized than gross motor tasks involving mainly proximal musculature (Bryden *et al*., 1996; Peters and Pang, 1992; Kraus, 2006).

In the present study, five pencil grasp patterns were identified: dynamic tripod, lateral tripod, static tripod, four fingers and cross thumb grasp. Observation of the students' ways of holding the pencil showed that the dynamic tripod grasp is the most frequently used in both groups A and B (69 and 65%, respectively), followed by the lateral tripod grasp (19 and 22%, respectively), then the static tripod grasp (6% in group A and 10% in group B) and the least frequently used grasp types, are the four finger grasp (4 and 3% in both groups A and B) and cross thumb grasp (2% in group A only). On the other hand, distribution of GMQ levels of performance revealed that 59% of students in group A were within the average level and 22% in the above average level, 6% in the superior level and only 2% in the very superior level. While in group B, 65% were within above average level, 22% in superior level, 11 % within average level and only 2% within the very superior level.

Correlation between gross motor skills and type of grasp revealed non-significant relation. These results come in agreement with Schwellnus *et al*. (2012) who stated no relation between grasp patterns and gross motor skills. Mechanically, all pencil grasp patterns need a high level of precision and control (Elliott and Connolly, 1984; Amundson, 2005). The variations of grasps do not contribute to handwriting difficulties. In typically developing students there was no difference in the speed or legibility of handwriting using the dynamic tripod versus other grasps (Dennis and Swinth, 2001; Sassoon *et al*., 1986; Ziviani and Elkins, 1986). Research in this area suggested that the type of grip being used need not necessarily impede handwriting speed and legibility (Dennis and Swinth, 2001; Koziatek and Powell, 2003).

Akyol (2007) placed importance on the adequate development of the shoulder, arm, wrist and finger muscles and stressed that children with incomplete muscular development have difficulty in motor development. He added that all students (affectively, physically and cognitively) develop and grow at a certain level before they come to school. However, students with adequate development and growth process will be more ready for school activities.

CONCLUSION

From the obtained results of this study supported by the relevant literature, it can be concluded that in the selected age range (48-72 months) and grade levels (SK, G1), gross motor skills were strongly correlated to speed of handwriting either in near point copying or dictation. However, there was no significant correlation between gross motor skills and hand dominance or type of pencil grasp.

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