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RESEARCH REPORT

Investigating the Associations between Core Strength, Postural Control and Fine Motor Performance in Children

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ABSTRACT

Study Design: Quantitative design including statistical analysis. **Objectives:** The objective of this study was to determine if there is an association between core strength, postural control, fine motor precision and integration, specifically in typical children in the first and third grades, ages 6-10. The secondary purpose of this study was to determine if there was an association between BMI and fine and gross motor ability in this same population.

Background: The relationship between core strength, postural control and fine motor skills in children is not well understood. The assumption that trunk stability and control are necessary for the maturation of manual dexterity has influenced the development of therapeutic treatment methods. This is based on the idea that postural control and balance are the ability of the body to maintain its position in space for the purpose of stability. **Methods and**

Measures: 113 children were tested using the strength, balance, precision, and integration subtests of the Bruininks-Oseretsky Test of Motor Proficiency, second edition (BOT-2). Age, height, weight, percent body fat, and activity information were obtained. **Results:** An association was found between the subscales of strength and integration, integration and precision, and precision and balance. Significant associations were also found between BMI and the gross motor subtests. **Conclusion:** This study was among the first to examine the association between core strength, postural control, and fine motor skills. Further research is needed to determine if fine and gross motor skill attainment is correlated when a specific intervention is administered.

Background

The relationship between core strength, postural control and fine motor skills in developing children is not well understood. Motor development in children typically occurs according to a sequence pattern and timing.¹⁷ The assumption that trunk stability and control are necessary for the maturation of manual dexterity has influenced the development of therapeutic treatment methods.^{1,2} This is based on the idea that postural control and balance are the

ability of the body to maintain its position in space for the purpose of stability.⁶

Few studies have looked at the association between core strength, postural control, and fine motor abilities such as precision and integration, especially in children. It has been suggested that distal ability may be influenced by postural control of the head and neck.¹⁶ A study examining infants, suggested that the absence of early postural control could affect prehension or the ability to grasp.¹⁰ Yet another study investigated

the relationship between proximal and distal motor control in infants, ages 2-6 months, and only a weak correlation was found.⁴ However, due to the lack of statistical support of this association, therapists should be cautious about assuming that working on proximal control will improve distal deficits in children. Only one study examined the relationship between postural control and fine motor dexterity in school aged children in kindergarten.¹⁵ The authors administered the balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency, first edition (BOT) as a measure of postural control and the nine-hole peg test to assess fine motor dexterity. They found low to moderate correlations between performances on these tests and suggested using a larger subject pool and older children, for whom the BOT is more appropriate.

Studies have also suggested that there may be an association between body mass index (BMI) and gross and fine motor abilities in children. One study examined the contribution of postural control and fine motor skills in children and found that those classified as obese had significantly lower scores during the tandem standing on the balance beam compared to the other BMI-groups (categories set according to Cole et al⁵) and the overweight BMI group had significantly lower scores than the normal BMI group.⁷ During the fine motor skill task, the obese BMI group scored significantly lower than the overweight and normal BMI groups. Another study examined the relationship between BMI, leisure habits, and gross motor abilities in first grade children.¹¹ The study found that children with a higher BMI (overweight and obese percentiles referenced from a German percentile graph) had significant, but weak correlations with lower gross motor scores on the Körperkoordinationstest für Kinder (KTK) Test, which included balancing backwards, one-legged obstacle jumping, jumping from side to side as well as sideway movements.

There are few standardized measures that assess core strength, postural control, and fine motor skills in children. Two standardized tools that are currently used to assess gross and fine motor function in school-aged children are the Peabody Scales of Motor Development, second edition (PDMS-2) and the Bruininks-Oseretsky Test of Motor Proficiency, second edition (BOT-2).^{3,9} The PDMS-2 is used to assess fine and gross motor skills in children 0-72 months and contains 6 subtests. The BOT-2 assesses fine and gross motor skills in children ages 4-21 years and is comprised of 8 subtests including: fine motor precision, fine motor integration, manual dexterity, bilateral coordination, balance, running speed and agility, upper-limb coordination, and strength. For the purposes of this study, the researchers chose the subtests of balance and strength to represent the best objective measures of postural control and core strength and the subtests of precision and integration to represent fine motor control.

The primary purpose of this study was to determine if there was an association between core strength, postural control, and fine motor precision and integration, specifically in typical children in the first and third grades, ages 6-10. The secondary purpose of this study was to determine if there was an association between BMI and fine and gross motor ability in typical children in the first and third grades, ages 6-10.

Methods

The Institutional Review Board (IRB) at the University of Dayton (UD) and the administrator and principal at each participating school approved this quantitative research report.

Subjects

Subjects were a convenience sample of children 6-10 years of age, from two different elementary schools in one

Midwestern town. Children with documented motor delays, and/or orthopedic, neurological, or metabolic disorders per report of the school's occupational therapists were excluded from the convenience sample prior to requesting written permission from parent(s) or guardian(s) for a child to participate. Informed consent forms were sent home with all children in the first and third grades, ages 6-10, for parent or guardian signatures. There were 113 students who returned signed forms and participated in the study. All rights of the subjects were protected.

Procedures

Three UD doctor of physical therapy students, one undergraduate pre-physical therapy/exercise science major, one pediatric physical therapist (pediatric clinical specialist), and two K-12 school occupational therapists collected all data. Four to five children were brought into the testing room from their regular classes. The children progressed in a random order through 5 stations to whichever one was available. Age, height, weight, body fat percent, and activity and free time questions were collected at 1 station. The other 4 stations consisted of 2 fine motor stations, a postural control station, and a strength station with one subject per station. Each subtest was graded and administered by a consistent person and discussion of grading criteria was performed to minimize subjectivity of the results.

Height and Weight Measurements

Height and weight measurements were collected per the recommendations of the National Health and Nutritional Examination Survey III (NHANES III).¹⁴ Body weight was measured in light clothing with shoes to the nearest pound on a beam balance scale. Body weight was originally measured in pounds and was converted to the SI unit of kilograms (1 kilogram = 2.2 pounds) for the final results. Height was

measured without shoes with the head position in the Frankfort plane (eye and ear level) to the nearest ¼ inch with a yardstick. The standard conversion of 1 inch = 1 centimeter was used to convert inches into the SI unit of centimeters for reporting final data. Subject's age and gender were also recorded.

Body Composition Measurements

BMI was calculated using the OMRON Fat Analyzer Model HBF-3ed (Model HB-300, Omron Healthcare, Vernon Hills, Illinois). The analyzer required the researcher to enter data for height, weight, age, and gender for each subject in to the bioelectric impedance tool, but only height and weight were used to calculate BMI. Once the data were entered, the subject lightly gripped the device with a hand placed on each of 2 handles and with arms in full extension for approximately 30 seconds. The OMRON was chosen because of ease of use and it has lower predictive errors than other such tools on the market.¹² According to research by Dixon et al. and Lukaskit, the reliability for bioelectrical impedance is 0.70-0.80 which is similar to a gold standard measure, air displacement densitometry, which has a reliability of 0.88-0.93.^{8,13} Based on their BMI, subjects were categorized into non-obese, overweight or obese based on the guidelines defined by Cole et al.⁵

Physical Activity Measures

A search was performed for physical activity questionnaires; however, none were able to be obtained that were appropriate for this study. Subjects answered 2 questions: 1) What is your favorite activity? 2) How do you spend your free time? The students' answers to the questions were divided into 3 different categories in order for the results to become measurable. For each question, a category of 1, 2, or 3 was recorded based on the participant's response. Category 1 represented all sedentary responses, category 2 represented a mixture of

sedentary activities and physical activities, and category 3 consisted of all physical activity responses.

Core Strength Measurements

Strength was measured using the strength subtest of the BOT-2.³ This subtest contains 5 items including standing long jump (measured in inches), knee push-ups and sit-ups (number completed in 30 seconds), wall sit and V-up (time held up to 60 seconds). Each item was given a numerical score with the larger number representing the better test performance and then totaled to give a final strength subtest score. The maximum score for this subtest is 42. The test-retest reliability for this subtest for ages 4-7 years and 8-12 years is .82 and .89 respectively, and the inter-rater reliability is .99.³

Postural Control Measurements

Postural control was measured using the balance subtest of the BOT-2.³ This subtest contains 9 items including standing with feet apart on a line-eyes open, walking forward on a line, standing on 1 leg on a line-eyes open, standing with feet apart on a line-eyes closed, walking forward heel-to-toe on a line, standing on 1 leg on a line-eyes closed, standing on 1 leg on a balance beam-eyes open, standing heel-to-toe on a balance beam, and standing on 1 leg on a balance beam-eyes closed. As outlined in the BOT-2, the balance items, such as standing on a line with feet apart-eyes open and eyes closed, standing on 1 leg on a line-eyes open and eyes closed, standing on 1 leg on a balance beam-eyes open and eyes closed, and standing heel-to-toe on a balance beam, are scored by the number of seconds the subject could hold the position. The maximum score a subject could obtain was 10 points. The walking items, such as walking forward on a line and walking forward heel-to-toe on a line are scored by the number of steps the subject took with the maximum score of 6 points. The score for all 9 items were tallied to obtain an overall

balance score, with a maximum score of 37 points. The test-retest reliability for this subtest for ages 4-7 years and 8-12 years is .65 and .45 respectively, and the inter-rater reliability is .99.³

Precision Measurements

Precision, a fine motor component, was measured using the precision subtest of the BOT-2.³ This subtest contains 7 items including filling in shapes-circle, filling in shapes-star, drawing lines through paths-crooked, drawing lines through paths-curved, connecting dots, folding paper, and cutting out a circle. Based on performance, a numerical score was given for each skill as defined by the guidelines in the BOT-2, and items were totaled for a final precision subtest score. This subtest has a maximum score of 41. The test-retest reliability for this subtest for ages 4-7 years and 8-12 years is .71 and .47 respectively, and the inter-rater reliability is .84.³

Integration Measurements

Integration, a component of fine motor skills, was measured using the integration subtest of the BOT-2.³ This subtest contains 8 items including copying a circle, copying a square, copying overlapping circles, copying a wavy line, copying a triangle, copying a diamond, copying a star, and copying overlapping pencils. Each skill was given a numerical score as defined by the BOT-2, and then totaled to give an overall integration subtest score. The maximum score for this subtest is 40. For ages 4-7 years and 8-12 years, the test-retest reliability is .77 and .66 respectively for this subtest, and the inter-rater reliability is .92.³

Statistical Methods

Descriptive statistics including means, standard deviations, and ranges were completed for all measured variables and participant demographics. For the primary objective, partial correlation tests were

Table 1: Descriptive Statistics

	<i>Age (years)</i>	<i>Height (cm)</i>	<i>Weight (kg)</i>	<i>BMI (kg/m²)</i>
Mean	7.89	131.98	32.71	18.44
Standard Deviation	±1.19	±9.39	±9.69	±3.74
Range (max-min)	4.00	46.99	57.96	23.00

Table 2: Correlation between subtests

	<i>Precision</i>	<i>Integration</i>	<i>Balance</i>	<i>Strength</i>
Precision	1.000			
Integration	0.220*	1.000		
Balance	0.187*	0.128	1.000	
Strength	0.062	0.270*	0.183	1.000

* = Indicates significant correlation ($p < 0.05$)

Table 3: Correlation between subtests and BMI

	<i>Precision</i>	<i>Integration</i>	<i>Balance</i>	<i>Strength</i>
BMI	-0.161	-0.078	-0.232*	-0.268*

* = Indicates significant correlation ($p < 0.05$)

conducted, controlling for subject age, in order to investigate potential associations between the strength, balance, precision and integration subtests. Partial correlations were also utilized to investigate all potential associations between fine and gross motor subtests with BMI. Microsoft Excel and SPSS 17.0 were utilized for data management and statistical analysis.

Results

113 subjects (59 females, 54 males) completed the study. Descriptive statistics are displayed in Table 1. Partial correlation tests (Table 2), while controlling for age, revealed statistically significant correlations ($p < 0.05$) between scores on subtests of strength and integration ($p = 0.004$, $r = 0.270$),

integration and precision ($p = 0.020$, $r = 0.220$), and precision and balance ($p = 0.049$, $r = 0.187$). Even though the subtests were significantly correlated, the corresponding r -values were low, indicating that the magnitude of the associations were low. Strength and precision, strength and balance, and integration and balance were not significantly correlated ($p \geq 0.05$).

Partial correlation tests, while controlling for age, were also performed between BMI and each subtest (Table 3). Significant results were calculated between BMI and the gross motor subtests: BMI and balance ($p = 0.01$, $r = -0.232$); BMI and strength ($p = 0.004$, $r = -0.268$). Non-significant correlations were found between BMI and both fine motor subtests of integration and precision.

Discussion

In addressing the primary objective, the subscales of strength and integration, integration and precision, and precision and balance were significantly correlated and demonstrated a small positive relationship. For the secondary objective, there were significant associations found between the BMI and gross motor subtests, however results between BMI and fine motor subtests were not statistically significant. The results demonstrated that a child who was more obese scored lower on the gross motor subtests than a child who was not. In the statistical analyses of the partial correlations for the study objectives, the variable of age was controlled. This was done to remove the effects of age and have a clearer understanding of the relationship between the variables of interest.

In looking at the primary purpose, this study found results similar to previous research by Rosenblum and Josman¹⁵ with low, but significant, associations between performances on a postural control and a fine motor test, even though the current population is at a more appropriate age for the BOT-2. However, the association was only for precision skills. The current study also found significant associations between the integration fine motor subtest and the strength gross motor subtest, which has not been previously researched.

In looking at the association between BMI and fine and gross motor skills, our results were similar to previous research. In the study by D'Hondt et al,⁷ children of ages similar to the current study population were shown to have significantly lower scores on balance beam skills and fine motor tasks if they were in the obese BMI group. Graf et al¹¹ also found that children in first grade who had a higher BMI scored lower on gross motor tests. In the current study, comparable results were found with gross

motor skills, however no significance was found between fine motor tasks and BMI.

Therapeutic treatment methods have been based on the assumption that trunk control and postural stability are needed for the maturation of fine motor skills and therapists are often taught in school that working on trunk control and posture are key interventions for pediatric patients. This study has begun to confirm this by finding significant correlations between some fine and gross motor skills. In practice, this may indicate that a physical therapist could work on core strength and muscular endurance activities, which may lead to improving specific fine motor skills, such as copying shapes. Another possibility is that a therapist could focus on postural control/balance skills and potentially improve cutting ability or the accuracy of filling in different shapes. A therapist, especially when testing gross motor skills, may want to take into consideration if a child is more obese and note this in their assessment as the findings of this study indicate that a more obese child would have lower gross motor scores.

Further investigation is needed to provide evidence that focusing on improving postural control and strength in therapy sessions improves fine motor skills. The next step in this research would be to further examine the association between fine and gross motor skills. The influence of this association could be done by implementing an intervention related to fine and gross motor skills with typical children or those with mild delays. By implementing an intervention with children performing certain gross motor tasks, such as standing on one foot eyes open and closed, walking heel to toe on a line, curl ups, v ups, etc, then testing to see if any fine motor skills have also improved, might provide therapists with invaluable evidence in improving more than one skill

simultaneously. In discovering a potential relationship between fine and gross motor skills, physical and occupational therapists could apply this evidence clinically in the development of treatment programs in order to maximize the overall development of the pediatric patient in a more efficient manner.

Study Limitations

There were limitations to this study. The use of convenience sampling was a limitation. In addition, there was a lack of research on measures of postural control and core strength in children. The BOT-2 subtests of balance and strength were chosen because the researchers felt these represented the best objective measures of postural control and core strength due to the extensive research and reliability information available for this tool. Another limitation included the location of testing; the tests were conducted in either the library at the school or a large stage area in the gym. Students may have had trouble focusing on the direct task due to the ability to watch their other classmates undergo testing. This may have been a greater limitation in focusing on precision and integration for the fine motor tasks, for these areas required more attention.

Conclusion

Overall, this study was among the first to examine the association between core strength, postural control, and fine motor precision and integration. The data collected in this study has provided baseline information about the correlation between fine and gross motor subtests on the BOT-2. Further research is needed to determine if fine and gross motor skill attainment is correlated when a specific intervention is administered.

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