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Motor Proficiency in Children with Neurofibromatosis Type 1

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Abstract

Purpose—Neurofibromatosis type 1 (NF1) is a genetic disorder with associated musculoskeletal abnormalities, tumors, and developmental delays. The purpose of this study was to investigate and characterize the motor proficiency of children with NF1.

Methods—Children with NF1 were assessed using the Bruininks-Oseretsky Test (BOT 2) instrument. The NF1 group scores were compared to age and sex-matched test norms.

Results—Twenty-six children participated in the study. The NF1 group had statistically significant lower scores ($p < .05$) for the total motor composite ($z = -1.62$) and 7 of the 8 subtests. Nineteen percent (N=5) scored in the average category, 54% (N=14) scored in the below-average category, and 27% (N=7) scored in the well-below-average category.

Conclusions—Children with NF1 have significantly lower motor proficiency than the BOT 2 normative scores. The results indicate the BOT 2 is useful in identifying and characterizing delays in motor proficiency for children with NF1.

Keywords

age factors; child; motor performance; motor skills; Neurofibromatosis type 1; sex factors

Introduction

Neurofibromatosis type 1 (NF1) is one of the most common genetic disorders presenting in childhood with an incidence of 1/3000. Examples of the clinical manifestations of NF1 include café-au-lait macules, tumors of peripheral nerves, optic pathway tumors, long bone dysplasia, developmental delays, and learning disabilities. NF1 is associated with skeletal abnormalities such as short stature, scoliosis, and long bone fracture with non-union. Children with NF1 have abnormalities of bone and muscle as evidenced by decreased bone mineral density, decreased bone strength, and low muscle mass, all of which may predispose them to fractures and scoliosis.[1,2] Adults with NF1 demonstrate decreased muscular force in hand grip strength.[3]

Children with NF1 have been reported to have specific learning disabilities, attention deficit hyperactivity disorder, delays in language, executive functioning, visual perceptual skills, and memory contributing to problems with academic achievement.[4] They also have poorer performance in neuromotor functions compared to their unaffected siblings,[5-7] and are at a

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6-fold increased risk for receiving remedial teaching for learning, behavior, speech or motor problems.[8] Chapman et al.[6] examined 10 children with NF1 using a structured evaluation of behavioral observations and found a consistent profile of motor disinhibition and awkward motor output.

The cognitive problems and the musculoskeletal impairments in children with NF1 may contribute to difficulty learning and executing motor skills. Whereas previous research investigations have described the cognitive, behavioral, and musculoskeletal impairments in children with NF1, there is a lack of research analyzing the motor proficiency of children with NF1 using reliable outcome measures designed to specifically evaluate the motor skills of children. The Bruininks Osertsky Test of Motor Proficiency second edition (BOT 2) has been found to be a reliable measure of motor proficiency and is 1 of the most frequently used assessments for evaluating and discriminating motor proficiency in children. [9] The BOT 2 was found to be a reliable outcome measure for evaluating motor proficiency in children with intellectual disorders.[10] The current study reports the motor proficiency outcomes in children with NF1 and documents the ability of the BOT 2 to characterize motor proficiency in NF1.

Methods

Previously published effect sizes[10] and population variances reported in the BOT 2 manual[11] were used to calculate power and resulted in an estimate of N=26. (G*power 3, Heinrich-Heine University, Dusseldorf Germany). Children with NF1 were recruited from the University of Utah NF1 Clinic and through advertising with a local NF1 support group organized by the Children's Tumor Foundation. Subjects were examined by 1 investigator (DS) to confirm the clinical diagnosis of NF1. Only individuals who fulfilled the NIH clinical diagnostic criteria for NF1 were included.[12,13] Exclusion criteria were the presence of a visual impairment, an orthopedic procedure within the last 6 months, and tibial dysplasia. These conditions were excluded to reduce the influence of visual impairments on eye-hand coordination and the influence of surgery or musculoskeletal impairments on motor skill performance. Children less than 4 years of age were not included due to limitations of the BOT 2 instrument in young children. Institutional Review Board approval for the study was obtained from the University of Utah. All children who agreed to participate and met the inclusion criteria were enrolled in the study and completed the evaluation.

Participants were assessed at the Shriners Hospitals for Children Salt Lake City Movement Analysis Lab by an experienced physical therapist (BJ). Their height and weight were measured and the percent BMI calculated.[14] Their motor proficiency was examined using the BOT 2.[11] This test instrument is an individually administered measure of fine and gross motor skills of children 4 through 21 years of age. The test consists of 8 subtests which measure fine motor precision, fine motor integration, manual dexterity, upper limb coordination, bilateral coordination, balance, running speed/agility, and strength. The subtest scores are combined into 4 motor area composite scores. Each motor-area composite consists of 2 subtests that assess related aspects of motor function. The 4 motor area composites are: 1) Fine Manual Control (control of the distal musculature of the hands in performing fine motor skills), 2) Manual Coordination (control and coordination of the arms and hands), 3) Body Coordination (control and coordination of posture and balance), and 4) Strength and Agility (aspects of fitness and performance of gross motor skills). A "Total Motor Composite" score is generated from the above 4 motor area composite scores representing an overall score for motor proficiency. Composite scores are categorized into 5 groups: well-above average (z-score of 2 or greater), above average (z-score of 1 to 2), average (z-score of 1 to −1), below average (z-score of −1 to −2), and well-below average (z-score of −2 or less).

The normative sample of the BOT 2 included 1,520 youth stratified by age and gender and included children with developmental disabilities. Inter-rater reliability, test-retest reliability and internal consistency were moderate to strong (>.80).[11] Content validity, internal structure, and relationships with other measures of motor performance were strong (r=.80).

Data Analysis

Data was analyzed using SPSS v. 17.0 (Chicago, IL). The distributions of z scores for each composite score were evaluated using Q-Q plots and were found to be normally distributed. Differences between z scores for the males and females and the 3 age groups were evaluated with an independent t-test and 1 way ANOVA. The mean z scores were calculated for each composite using the tables in the BOT 2 manual, then a z-table was used to identify a critical value (p<.05). The relationship of composite scores to the total motor composite score was evaluated using simple linear regression. The age and sex specific mean scores for each subtest were used for comparison since previous literature found differences between males and females in some age categories.[15] One sample t-tests were used to compare the NF1 group subtest mean scores to BOT 2 subtest mean scores.

Results

Twenty six children (ages 4-15 years) with NF1 were assessed using the BOT 2 (Table 1). There were 13 males and 13 females. The mean age was 8.25 (standard deviation 3.25). Fifty-four percent of the children were in the 4 to 7 year old age range. There were no statistically significant differences between males or females (p=.26) or between the scores of the children in the 3 age ranges (p=.17). Children in the NF1 group had a mean percent body mass index of 38% (SD 30).

The age and sex specific scores were used to determine raw scores for each subtest using the BOT 2 manual. The raw scores were converted to composite scores and z scores using the test manual. The NF1 group of children had statistically significant lower scores ($z = -1.62$, p<.05) than the normative test sample for the Total Motor Composite (Table 2). No individual had a “Total Motor Composite” score in the above average or well-above average range. Nineteen percent (N=5) of the NF1 group scored in the average category, 54% (N=14) scored in the below average category, and 27% (N=7) scored in the well below average category. The mean z scores for males (−1.77) was lower than the mean z scores for females (−1.33) although this difference was not statistically significant. The strength and agility mean composite z score was the lowest (−1.62) followed by body coordination mean composite z score (−1.48) (Table 3). Regression analysis of the relationship between the motor area composite scores and total motor composite score revealed that 67% of the variance was accounted for by the strength and agility composite score. Sixty one percent of the variance was accounted for by the fine manual composite score (Table 4).

The results of the 1 sample t test resulted in significantly lower scores for fine motor precision, fine manual integration, upper limb coordination, bilateral coordination, balance, run speed/agility, and strength. Manual dexterity scores were not significantly different (Table 5). Cohen’s d was calculated to determine effect size using the mean standard deviation scores reported in the BOT 2 manual. There was a small effect size for manual dexterity (d =0.23), a moderate effect size for fine motor integration (d=0.69), and a large effect size for fine motor precision (d =1.24), upper limb coordination (d = 1.33), bilateral coordination (d = 1.21), balance (d = 1.69), run speed/agility (d = 1.28), and strength (d = 1.16).[16].

Discussion

The NF1 group demonstrated statistically significant lower motor proficiency compared to the BOT 2 normative data. The BOT 2 was useful in characterizing the NF1 group's motor proficiency. The strength and agility composite score explained a large portion of the variance in the total motor composite score. Running speed and strength subtests are combined to calculate the strength and agility motor area composite score. Both of these subtest scores were significantly lower than age and sex matched normative subtest scores. Wrotniak et al.[12] found that a positive relationship exists between motor proficiency and physical activity level in children, and the observed motor proficiency impairments associated with NF1 may make it difficult for children with NF1 to engage in recreation and leisure activities. Since children with NF1 are reported to have decreased bone mineral density[1] and increased fracture rates,[2] possibly decreased physical activity and the lack of load bearing activities contributes to osteopenia and fractures. Given that jumping activities during adolescent growth increase bone mass [17,18] improving motor proficiency to increase jumping may result in improved bone mass accrual. Motor training programs have improved motor skills[19] and motor function[20] in children with developmental coordination disorder, and similar motor training programs may be an effective intervention to improve motor proficiency in children with NF1. We are not aware of any studies evaluating the efficacy of therapeutic exercise in children with NF1, although physical therapy interventions may be appropriate to improve motor proficiency. Targeting strength, agility, bilateral coordination, and balance within a training program seems reasonable based on the deficits reported herein.

The body coordination score (combination of balance and bilateral coordination subtests) contributed 35% of the variance in the total motor composite score. Wuang & Su[10] reported low sensitivity (32.65%) and high specificity (84.31%) for the balance section of the BOT2. The BOT2 may be better at identifying children who do not have balance impairments than identifying those with balance impairments. It will be necessary to use a more sensitive measure for detecting balance impairments, such as center of pressure measures on a force plate. Balance may play a role in contributing to low motor proficiency in children with NF1 since the mean balance score differences and the effect sizes were large. However, additional testing is recommended to evaluate balance ability. Balance and coordination impairments may play a role in increased fracture rates in individuals with NF1 and future research is necessary to rule out the possibility of clumsiness and falls contributing to the increased fracture rate.

The NF1 group also had significantly lower scores on the BOT 2 in fine motor skills. The fine manual control composite score accounted for 61% of the variance of the total motor composite score. Fine motor precision, fine motor integration and upper limb coordination subtest scores were significantly lower than the BOT 2 normative data. Since fine motor skills such as writing, drawing, cutting, and keyboarding are important for academic work, fine motor limitations should also be explored to determine if they contribute to the academic difficulties seen in children with NF1. Hyman et al.[7] studied 81 children with NF1 and 49 of their siblings. Problems with academic achievement were present in 52% of children with NF1 as compared to 8% of their siblings. Specific learning disabilities were identified in 20% of the children and the remaining 32% had general learning problems. We found similar numbers of children with motor proficiency impairments. Fifty-four percent of the NF1 groups total motor composite scores fell in the below average category, and 27% fell in the well below average category. It is our clinical experience that parents of children with NF1 report concerns about their children's motor abilities. However, these motor deficiencies may be subtle and not recognized without a detailed assessment of their motor

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functions. We propose that all children with NF1 should be screened for motor delays and referred for occupational and physical therapy services if delays are identified.

The current study investigated a relatively small number of children from 1 regional center. In addition, the parents who enrolled their children in the study may have been more concerned about their children's coordination leading to a potential bias in our sample. Therefore, further investigation with additional individuals with NF1from multiple sites will be important. Another limitation is that even though children with NF1 show statistically significant lower motor proficiency, this change may not be clinically important. We found large effect sizes for 6 of the 8 subtests and these effect sizes reflect differences in motor proficiency of 1.16 to 1.69 standard deviations between the NF1 group and the BOT 2 mean scores. In particular, 27% of the NF1 group's total motor composite scores fell in the well below average category (greater than 2 standard deviations below the mean), qualifying them for special education services in most educational settings.

Conclusions

The BOT 2 was useful in identifying and characterizing fine and gross motor delays in children with NF1. The NF1 group had decreased total motor proficiency and showed the greatest difference in their balance and strength subtest scores, followed by running speed and agility, fine motor precision, upper limb coordination bilateral coordination, and fine motor integration. These results are likely to be clinically important since lower motor proficiency may limit children with NF1 from performing the running and jumping activities necessary for improving bone strength and mass. The results are also likely to be relevant to academic performance since fine motor skills are important for writing, keyboarding, and cutting activities at school. Given that 81% of the children with NF1had below average or well below average scores for total motor proficiency, physical therapy would likely be beneficial for a large subset of children with NF1. Deficiencies were seen in 7 of the 8 subtests (fine motor precision, fine motor integration, upper limb coordination, bilateral coordination, balance, run speed/agility, and strength) suggesting that an approach focusing on multiple aspects of motor proficiency will be needed when designing physical therapy interventions. Particular attention should be given to strength and agility as this motor composite category contributed largely to the overall motor proficiency deficit.

Further research is indicated to establish a relationship between poor motor proficiency, physical inactivity and the musculoskeletal impairments seen in children with NF1. Future clinical trials utilizing interventions to improve motor proficiency in children with NF1, both pharmacologic and non-pharmacologic, will require the use of validated endpoints. The BOT 2 instrument is a potential tool which could be used in future clinical trials for measuring motor proficiency in NF1.

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Table 1

Neurofibromatosis Type 1 (NF1) Group Characteristics (N=26)

Sample Characteristics N=26			
		N	**Valid Percent**
Age	4-7 year olds	14 (8 F, 7 M)	54%
	8-11 year olds	9 (3 F, 5 M)	35%
	12-15 year olds	3 (2 F, 1 M)	11%
Gender	Male	13	50%
	Female	13	50%

Table 2

Results of *z* score analysis of NF1 group for a one tailed test of significance, (α .05**)**

***z* score analysis for a one tailed test of significance, (α = .05)**		
Composite	**Mean z score**	**P value**
Fine manual control	−.93	.18
Manual coordination	−.95	.18
Body coordination	−1.37	.09
Strength and agility	−1.48	.07
Total Motor	−1.62	.05

Table 3

Individual and Mean BOT 2 Composite Scores for Neurofibromatosis Type 1

Participants (N=26)							
Subject	**Age**	**Gender**	**Total Motor Composite z score**	**Fine Manual Control z score**	**Manual Coord z score**	**Body Coord z score**	**Strength & Agility z score**
01	6.11	male	−0.6	0.5	1	−1	−1.9
02	11.8	female	−1	0	−0.3	−1.8	−0.4
03	14.4	female	0.7	0.5	1	0.8	0.8
04	7.11	male	−2.3	−1.5	−0.2	−1.1	−1.1
05	8.5	male	−2.5	−1.8	0.1	−2	−3
06	9.9	female	−1.2	0.5	−1.2	−0.7	−0.9
07	4.9	female	−2.4	−1.5	−3	−1.1	−2.4
08	8.2	male	−1.5	−0.1	0	−1.7	−1.5
09	7.5	male	−1.1	−1.3	−0.2	−1.3	−0.8
10	5.11	male	−1.5	−1.6	−1.1	−1.2	−1.1
11	9.9	male	−3	−2.5	−2.3	−2.5	−2.7
12	5.6	male	−2.3	−1.2	−2.3	−1.8	−2.3
13	6.8	male	−1.1	−0.6	−0.8	−1.5	−0.7
14	15.11	female	−2	−2.3	−2.4	−2.5	−2
15	5.9	female	−1.8	−1.4	−1.7	−1.5	−1.2
16	6.2	female	−1.9	−1.5	−1.8	−1.3	−2
17	6.2	female	−1.5	−1	−1.1	−1.5	−1.8
18	8.7	female	−0.9	−0.3	−1.3	−0.8	−0.3
19	6.11	female	−1.1	−0.7	0	−1.7	−1.1
20	6.11	female	−1.8	−1	−0.8	−2.2	−1.7
21	6.11	female	−1.2	−0.8	0.1	−1.5	−1.3
22	11.6	male	−3	−1	−1.5	−3	−3
23	7.7	female	−1.6	−0.7	−1.2	−0.5	−2.2
24	6.6	male	−0.4	0.2	0.1	−1.1	−0.1
25	14.1	male	−1.2	−0.6	−1.6	1	−1.3
26	9.2	male	−2.5	−2.5	−2.1	−2.2	−2.2

Participants (N=26)

Subject	Age	Gender	Total Motor Composite z score	Fine Manual Control z score	Manual Coord z score	Body Coord z score	Strength & Agility z score
Mean z score (SD)			−1.62 (0.85)	−0.93 (0.78)	−0.95 (1.03)	−1.37 (0.88)	−1.48 (0.93)
Mean % Rank			14%	20%	25%	14%	15%

Table 4

Results of regression analysis comparing total motor composite to motor area composite

Regression analysis of composite comparisons

Comparison to total motor composite	R	95% Confidence Interval for R	r^2
Fine manual control	.784	−1.294 to −.752	.61
Manual coordination	.634	−1.52 to −.901	.40
Body coordination	.590	−1.41 to −.524	.35
Strength and agility	.816	−1.2 to −.370	.67

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Table 5

Results of t-test analysis of NF1 group

Subtest	One Sample t-test (α = .05)					
	t	Mean Difference	p value	95% Confidence interval of the difference	BOT 2 mean subtest Standard deviation	Effect size Cohen's d
Fine Motor Precision	−4.35	6.65	<.001	−9.79 to 3.5	5.36	1.24
Fine Motor Integration	−2.147	4.19	.042	−8.2 to .17	6.03	0.69
Manual Dexterity	−0.702	1.04	.489	−4.10 to 2.02	4.45	0.23
Upper Limb Coordination	−3.85	8.37	.001	−12.85 to 3.89	6.3	1.33
Bilateral Coordination	−2.71	4.99	.012	−8.7 to −1.19	4.13	1.21
Balance	−7.19	7.78	<.001	−10 to −5.56	4.59	1.69
Run/Agility	−5.5	8	<.001	−11 to −5	6.27	1.28
Strength	−5.55	6.76	<.001	−9 to −4.25	5.84	1.16