Effect of Osteopathic Medical Management on Neurologic Development in Children

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For 3 years, children between 18 months and 12 years of age with and without recognized neurologic deficits were studied at the Osteopathic Center for Children. Their response to 6 to 12 osteopathic manipulative treatments directed to all areas of impaired inherent physiologic motion was estimated from changes in three sensory and three motor areas of performance. Houle's Profile of Development was used to compare neurologic with chronological age and rate of development, and scores were age-adjusted. Results in children after treatment were compared with those following a waiting period without treatment.

Neurologic performance significantly improved after treatment in children with diagnosed neurologic problems and to a lesser degree in children with medical or structural diagnoses. The advances in neurologic development continued over a several months' interval. The results support the use of osteopathic manipulative treatment as part of pediatric health care based on osteopathic medical philosophy and principles.

Osteopathy "is a science that deals with the natural forces of the body."[1] Osteopathic medical philosophy and principles have been used to guide pediatric health care at the Osteopathic Center for Children (OCC) of the College of Osteopathic Medicine of the Pacific (COMP) for more than 10 years. Such care has assisted children with a diversity of medical problems, and has enhanced their general well-being. The present controlled research study addresses one aspect of such care, the use of osteopathic manipulative treatment to restore the body's inherent physiologic mobility as a means of affecting neurologic development.

An increasing number of diagnostic labels are used to describe a diversity of long-standing problems of children, from attention deficit disorder[2] to speech inadequacies. There are few clear boundaries between them. Any one label may include major and minor components of other neurologic disorders; for example, a child with a learning disability may have a behavior problem, and disorders of perception may contribute to the learning difficulty.

A variety of etiologic factors may contribute to these labeled diagnoses; also, a specific etiologic influence may result in a diversity of clinical dysfunctions. A traumatic delivery, for example, may lead to mental retardation, perceptual dysfunction, or neuromotor disability, yet these clinical problems may also be related to toxic drug influences during pregnancy, genetic defects, or encephalitis in infancy and so on **(Figure 1)**. However, the accessible etiologic component that links the etiologic factor to the clinical problem is somatic dysfunction. This is defined as dysfunction of related parts of the body's framework. Somatic dysfunction is the consequence of the delivery experience in most instances, or trauma early in life in others. It may be found in the cranial or pelvic mechanism, or at any level in between; it may also be located in the musculoskeletal, membranous, and fascial mechanisms.

Observations at the OCC have emphasized the importance of the somatic system in the process of growth and development. Somatic dysfunction is found concomitantly with delayed neurologic development. Osteopathic medical principles applied in more than 20 years' practice (V.M.F.) of supplying health care to children have provided the basis for relating etiology, dysfunction or disease, and the need for manipulative treatment.

This study was designed to test the clinical view that intervention directed toward removing or reducing the influence of somatic dysfunction on cerebral dysfunction permits neurologic development and performance to progress to a child's optimum potential.

Methods

This research project and method for obtaining the parent's consent and child's assent were approved by

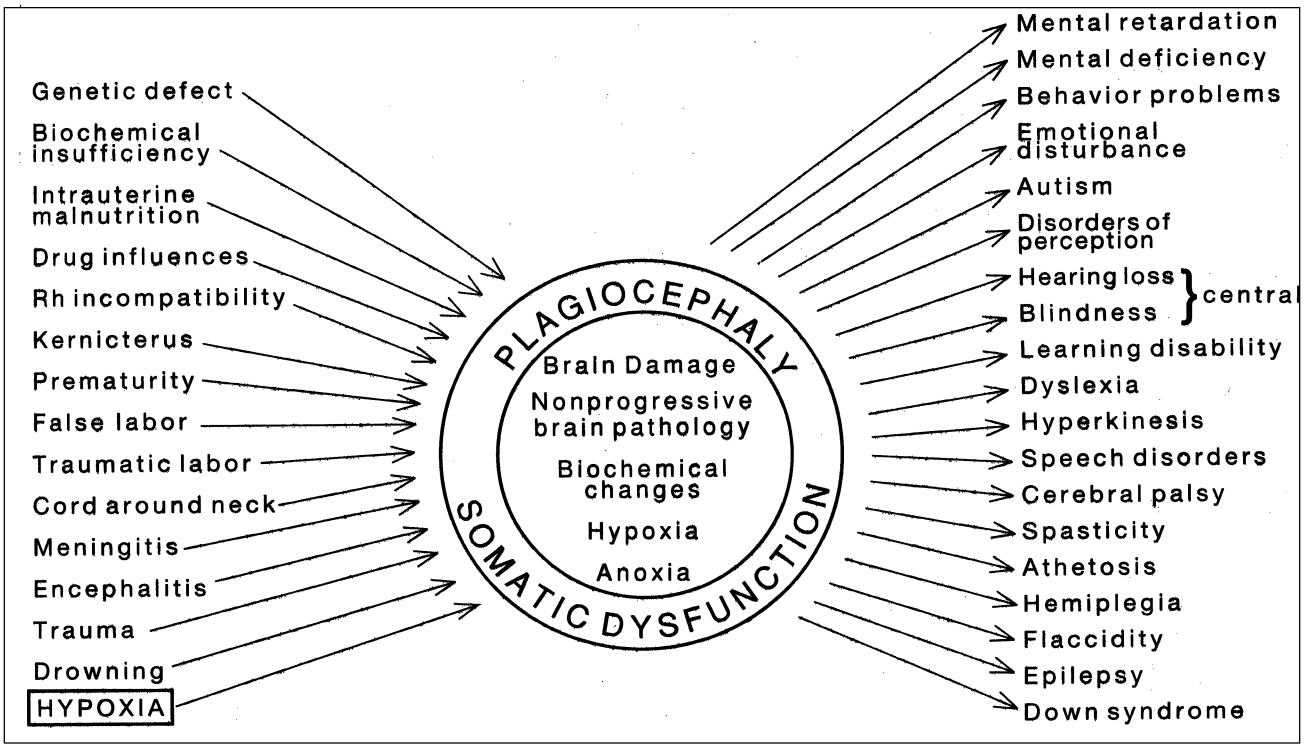

Figure 1. *Etiologic influences and clinical dysfunctions, in relation to the strain pattern amenable to manipulative treatment. A distinction should be made between visible organic histopathologic change and the more subtle neurochemical pathophysiologic change.*

the COMP Institutional Review Board. All children aged 18 months to 12 years brought to the OCC between August 1986 and June 1989 were eligible for inclusion in the research. The children at OCC come from a wide geographic area and represent diverse psychosocioeconomic backgrounds.

At the initial visit, the primary care-giver, usually the mother, was interviewed alone, told of the research project, and asked to study and sign the consent document. A detailed history, including pregnancy, labor, neonatal state, infancy and childhood growth and development, traumatic events, illnesses, and nutritional habits, and a family history were taken. The child was weighed, measured, and then evaluated without members of the family present. A standing study of the anatomic landmarks was performed if the condition of the child permitted. Active motion and mobility including crawling, creeping, walking, and skipping were observed.

Examination in the supine position included evaluation of leg lengths and range of motion, pelvic alignment, inherent mobility of the sacrum, vertebral structural and functional symmetry, respiratory excursion of the thoracic cage and its inherent fascial motility, and the structure and inherent motion of the cranial mechanism. Extraocular muscle function and convergence were tested, and any anomalous function was noted. Dental occlusion, the form of the oral cavity, and temporomandibular joint function were examined. Special testing, such as tympanometry and audiometry, were included if indicated.

An exit conference with both parents, if possible, and without the child allowed them to receive a diagnostic impression as well as an introduction to the osteopathic medical concept in general and its specific indications for the child. Any additional diagnostic studies indicated were requested at this time. Instructions concerning the testing schedule and treatment program were given but the actual appointment schedule was arranged by the appointment secretary.

Children were assigned to one of two diagnostic groups: medical or neurologic. The medical group included children with medical or structural problems but no recognized neurologic deficits. The neurologic group included children with previously diagnosed neurologic inadequacies in such areas as academic performance, behavior, neuromotor function, developmental delay, and/or learning.

Osteopathic manipulative treatments were scheduled by the appointment secretary to begin soon after the initial interview for the start-first group or after 8 to 12

Table 1
Profile of Development: Sensory Input*

Scale/age range	Visual	Auditory	Tactile
• Excellent: 36 months • Average: 72 months • Satisfactory: 96 months	Able to read first-grade material; evidences laterality	Further understands language and abstract concepts; evidences laterality	Tactiley identifies heads and tails of coins; evidences laterality
• Excellent: 22 months • Average: 48 months • Satisfactory: 67 months	Able to identify visual symbols within experience	Begins to understand language and abstract concepts	Tactiley differentiates miniature objects
• Excellent: 13 months • Average: 24 months • Satisfactory: 45 months	Able to discriminate dissimilar and similar pictures	Understands 25 words	Tactiley differentiates medium-size objects
• Excellent: 8 months • Average: 12 months • Satisfactory: 26 months	Able to converge eyes; has simple depth perception	Consistently able to understand 2 words	Able to tactiley discriminate the third dimension
• Excellent: 4 months • Average: 8 months • Satisfactory: 13 months	Tracks vertically; perceives detail	Aware of meaningful change in tonality	Perceives and responds to gnostic sensation
• Excellent: 1 month • Average: 2.5 months • Satisfactory: 4.5 months	Tracks horizontally; perceives outlines	Consistently able to react to threatening sounds	Reacts normally to painful stimulus
Birth	Pupils respond to light	Reflexly responds to sudden loud noise	Exhibits Babinski reflex

*Adapted from "Profile of Development." American Academy for Human Development, Piqua, Ohio, 1989.

weeks' delay for the waiting-list group. This assignment to start-first or waiting-list group was based on the physician's (V.M.F.) appointment schedule. Osteopathic palpatory examination and treatment data obtained at research treatment visits were coded and entered into the computer data base.

Assessments of neurologic development were made by a co-researcher (P.S.) before the series of osteopathic manipulative treatments, once for the start-first group and twice for the waiting-list group. These data were entered into the computer data base, but data and analysis were not available to the physician administering manipulative treatment (V.M.F.) until the child had completed the treatment schedule.

Estimation of neurologic development

Houle's[3] Profile of Development (POD), based on earlier studies by LeWinn,[4] was used to estimate the neurologic developmental status of the children. The profile includes three measures of sensory performance (visual, auditory, and tactile competence) **(Table 1)** and three of motor performance (manual competence, mobility, and spoken language) **(Table 2)**.

The POD measures **(Tables 1 and 2)** identify slow, average, and exceptional rate of development within each sensory and motor performance level. The performance levels predict development rate and allow self-comparison of a child's development during growth. The age for each highest sensory and motor performance is averaged to obtain an estimate of neurologic developmental age.

We divided the child's averaged neurologic developmental age by the chronological age at the time of testing. This ratio minimizes the influence of aging on changes occurring in a series of POD assessments. The ratio would have been artificially reduced when a child's test data occurred after age 6 years. In the few cases in which this occurred, the POD normative score and the ratios were adjusted by adding months to the POD age range **(Tables 1 and 2)** corresponding to the difference between 72 months and the actual chronological age.

An age-adjusted score of 1 represents an average neurologic development score for a child of that age. Age-adjusted scores above 1 represent above-average neu-

Table 2
Profile of Development: Motor Input*

Scale/age range	Mobility	Language	Manual
• Excellent: 36 months • Average: 72 months • Satisfactory: 96 months	Able to do skilled activities; evidences laterality	Uses first-grade vocabulary with good sentence structure	Writes on first-grade level
• Excellent: 22 months • Average: 48 months • Satisfactory: 67 months	Walks and runs in nonaberrated cross pattern	Speaks 5- to 8-word sentences with good articulation	Performs bimanual tasks efficiently
• Excellent: 13 months • Average: 24 months • Satisfactory: 45 months	Walks with arms held below waist	Speaks 25 words and uses several 2-word couplets	Capable of cortical opposition bilaterally and simultaneously
• Excellent: 8 months • Average: 12 months • Satisfactory: 26 months	Walks unassisted without pattern for 10 steps; arms elevated	Spontaneously uses 2 words	Capable of cortical opposition, either hand
• Excellent: 4 months • Average: 8 months • Satisfactory: 13 months	Creeps in nonaberrated cross pattern	Makes meaningful, and goal-directed sounds with good tonality	Has volitional prehensile grasp
• Excellent: 1 month • Average: 2.5 months • Satisfactory: 4.5 months	Crawls in nonaberrated cross pattern	Consistently has vital cry in response to threatening sounds or events	Able to release object grasped
Birth	Randomly moves arms and legs	Birth cry present	Reflexly able to grasp object

*Adapted from "Profile of Development." American Academy for Human Development, Piqua, Ohio, 1989.

rologic development, and age-adjusted scores below 1, a below-average score.

Osteopathic palpatory diagnosis and manipulative treatment

The osteopathic palpatory diagnosis and manipulative treatments were provided by a single physician (V.M.F.). The objective of the treatment program was the restoration of unrestricted, symmetric, physiologic inherent mobility in all parts of the body. Manifest clinical change in symptoms was of secondary consideration. The individual treatment was tailored to the needs of the particular child and might be administered to any part of the body from the head to the feet. Each treatment was a completed experience whereby changes occurring in one area would be compatible with responses elsewhere, and bilateral symmetry of function would be established in the area of treatment. The feel of the tissues is the ultimate guide to the procedure performed and the point of conclusion.

Techniques used included measures to influence bone and articulations, membranes and fascia, muscle activity, lymphatic drainage and cerebrospinal fluid motility, arterial and venous circulation, and visceral function, all of which serve to enhance the body's own inherent therapeutic potency. (Detailed records of each treatment are on file.)

Six to 12 treatments were usually given at 1-week intervals. The child was taught to lie on the table without restraints unless there were uncontrollable involuntary motions for which protection was needed lest the child roll on to the floor. Interesting toys held attention, and live classical piano music accompanied all treatments.

Research design

Table 3 shows the research design and number of participants at each POD testing. All children who had an initial diagnostic examination and were tested with the POD at least once are included in this Table. The initial testing of the waiting-list group is called the *baseline* and the second test the *pretest* because it was followed by treatment. The start-first group began treatment soon after the initial examination, so their first testing was called a *pretest.* Tests immediately following completion of treatments were called *post-tests*, and

Table 3
Research Design and Number of Participants in Each Testing*

Groups	Neurologic problems				Medical problems			
	Baseline	Pretest	Post-test	Follow-up	Baseline	Pretest	Post-test	Follow-up
Research Groups								
• Waiting-list								
Boys	12	11	8	5	3	3	2	1
Girls	10	9	8	7	4	3	1	0
Total	22	20	16	12	7	6	3	1
• Start-first†								
Boys		23	21	8		15	14	6
Girls		11	11	3		20	18	13
Total		34	31 - 32‡	11		35	32	19
Comparison groups§								
• Incomplete								
Boys	12				14			
Girls	6				13			
Total	18				27			
• Drop-out								
Boys	17				9			
Girls	11				6			
Total	28				15			
Grand total (first test)	186							

*Data are for all participants who took the tests.
†The first test for the start-first group was the pretest; for the waiting-list group, the first test was the baseline test.
‡One child had incomplete data on some subscales.
§The incomplete and dropout comparison groups were not part of the original research design. They consist of children who took only one test. They either then had treatment and left the program without a second test (incomplete group) or left the program without participating in treatment (dropout group).

tests made weeks after treatment, *follow-up* tests.

The numbers of participants changed so much from one testing to another **(Table 3)** that statistical comparisons were based on different samples as the study proceeded. As a partial control for bias, those children who did not complete a second testing on the POD were placed in comparison groups as noted in **Table 3.** Children in the comparison groups are not classified by their potential research group assignment (waiting-list, start-first) since these assignments were not made until after the second testing. Control for bias due to failure to complete testings after the second test was partially accomplished by using a repeated measures design in which participants served as their own controls. No attempt was made to compare for possible differential dropping out after the second testing in terms of absolute levels of performance, but this possibility can be inferred from the tables.

The initial design did not contemplate classifying the children according to diagnostic categories of medical and neurologic problems. This classification, however, is shown in **Table 3,** because it later proved to be important.

The POD scores for individuals were not available to the treating physician (V. M. F.) before the initial evaluation and assignment to treatment schedules. Changes in these scores were not known by the physician until after all treatments were completed.

The assignments of participants to the waiting-list and start-first groups and types of presenting problems were not available to the co-investigator for research design data analysis (R.E.C.) until after treatments were completed and the POD data had been entered into the data base. The co-investigator for POD testing and scoring (P.S.) was also blind to the group and type-of-problem assignments until all testing was completed. Both co-investigators were blind to demographic background and medical history of participants until completion of treatments.

All data entered into the data base were analyzed by

Table 4
Age-Adjusted Total Profile of Development (POD) Scores and those for Mobility and Manual Dexterity from Initial Testing, by Group, Type of Problem, and Sex

Group and scale*	Neurologic problems				Medical problems				Total Group	
	Boys		Girls		Boys		Girls			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Waiting list (baseline)										
Mobility	0.673	0.178	0.770	0.351	0.738	0.007	1.126	0.838	0.763	0.353
Manual	0.735	0.172	0.745	0.272	0.714	0.297	0.937	0.991	0.758	0.346
Total	0.809	0.092	0.808	0.289	0.842	0.197	0.969	0.543	0.826	0.241
	(n = 12)		(n = 10)		(n = 3)		(n = 3†)		(n = 28)	
Start-first (pretest)										
Mobility	0.501	0.340	0.488	0.296	1.045	0.646	0.879	0.365	0.730	0.480
Manual	0.728	0.282	0.535	0.242	0.980	0.378	1.002	0.309	0.833	0.349
Total	0.717	0.308	0.614	0.213	1.061	0.445	1.071	0.258	0.881	0.368
	(n = 22†)		(n = 11)		(n = 15)		(n = 20)		(n = 68)	
Dropout (baseline)	0.414	0.368	0.512	0.230	1.007	0.524	0.710	0.193	0.626	0.443
Mobility	0.523	0.297	0.702	0.327	1.272	0.377	0.927	0.126	0.807	0.437
Manual	0.622	0.251	0.635	0.207	1.216	0.371	0.873	0.111	0.810	0.379
Total										
	(n = 13)		(n = 8)		(n = 9)		(n = 3)		(n = 33)	
Incomplete (baseline)										
Mobility	0.525	0.336	0.632	0.495	0.788	0.379	0.994	0.480	0.756	0.440
Manual	0.619	0.292	0.692	0.500	0.944	0.240	1.069	0.472	0.859	0.401
Total	0.633	0.312	0.771	0.471	0.955	0.287	1.048	0.276	0.875	0.354
	(n = 10)		(n = 6)		(n = 13)		(n = 11)		(n = 40)	

**Mobility*: section of POD score measuring only mobility; *Manual:* section of POD score measuring only manual dexterity; *Total*: POD score including mobility, manual dexterity, speech, visual ability, auditory competence, and perceptive tactility.
†Small discrepancies between n value here and in Table 3 were produced because some children were not measurable on mobility and manual scales and only complete data for these scales were analyzed.

using SPSS PC-Plus programs.[5] A multivariate analysis of variance (MANOVA) was carried out to determine the contributions of different variables and their combinations (interactions) to the variance and the statistical significance of the contributions. Significance levels of .06 to .10 were considered worthy of further investigation, whereas levels of .05 or less were judged to be fully acceptable evidence for the research hypothesis being tested (for rejecting a null hypothesis of no significant outcome).

Results

Only the most essential results are presented here. The basic data and complete analysis may be obtained by writing the senior author (V.M.F.).

The total number of children of appropriate ages and with medical, structural, or neurologic problems who presented themselves to OCC between August 1986 and June 1989 was 209. For a variety of reasons 23 of these children did not return for the initial testing with the POD. Of the 186 remaining children (105 boys and 81

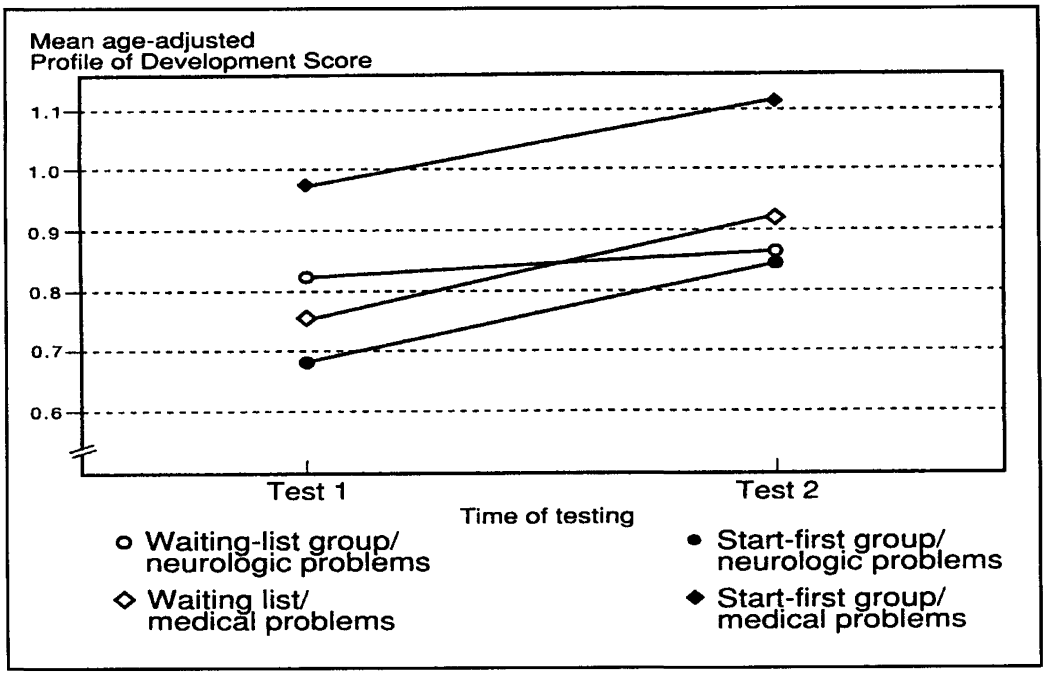

Figure 2. *Comparison of changes in average total Profile of Develop-ment scores between first and second testings for children classified by research group, waiting-list (wait) or start-first (start), and by type of problem, neurologic (neuro) or medical (med). Test 1 for the wait subgroups is baseline and test 2 is pretest with no treatment between testings. Test 1 for the start subgroups is pretest, and test 2, post-test with treatment between the two testings.*
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girls), all met the criterion for entering the study by completing at least one POD testing. As can be seen in **Table 3**, 43 children failed to complete the treatment schedule (dropout group) and 45 failed to take a post-test after completing treatments (incomplete group). A follow-up test was completed by only 43 of the original 186. In the waiting-list group only 13 completed the follow-up testing.

Analysis of health and background variables

When levels of initial POD test scores were analyzed by MANOVA using health status and background (such as age, birth weight, duration of breast feeding, developmental milestones, and family history) as dependent variables and research versus comparison groups, types of problem (neurologic, medical) and sex as independent variables, no significant differences were found for either the separate independent variables or their interactions. The research groups were in fact well matched with the comparison groups in terms of health and background variables.

Initial Profile of Development Scores

Table 4 presents the mean POD scores for mobility and manual dexterity and total sensory and motor development from initial testing when the full research design including comparison groups (incomplete and dropout) **(Table 3)** is used. MANOVA showed no significant differences for group or sex variables or any interaction between variables. Only the effect for type of problem was significant (typically at the .001 level on the POD total scale and most subscales). The medical category had consistently higher POD means than the neurologic category. The initial average POD total score for those classified as having medical problems was equal to that expected for the normative sample (1.0), whereas the average for those in the neurologic category was sharply lower (.60).

The research groups were comparable to comparison groups at the first testing on POD scales, as they were on background variables. Profile of Development subscales testing for motor functioning were selected because this was initially assumed to be the area on which osteopathic treatment would have the greatest effect.

Table 5
Mean Profile of Development (POD) Scores from Tests 1 and 2, by Group, Type of Problem, Scale, and Time of Testing

Test and scale*	Waiting-list group				Start-first group				Total sample	
	Neurologic problems		Medical problems		Neurologic problems		Medical problems			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Test 1	**Baseline**				**Pretest**					
Mobility	0.724	0.280	0.705	0.156	0.489	0.329	0.973	0.514	0.733	0.437
Manual	0.737	0.228	0.578	0.303	0.665	0.290	0.986	0.341	0.793	0.330
Total	0.815	0.197	0.777	0.212	0.678	0.289	1.071	0.360	0.858	0.338
Test 2	**Pretest**				**Post-test**					
Mobility	0.801	0.341	0.716	0.164	0.693	0.395	1.115	0.523	0.872	0.464
Manual	0.826	0.205	0.788	0.264	0.877	0.424	1.087	0.375	0.937	0.371
Total	0.872	0.202	0.943	0.160	0.872	0.379	1.151	0.356	0.977	0.350
	(n = 20)		(n = 6)		(n = 31 - 32†)		(n = 32)		(n = 88)	

* *Mobility*: section of POD score measuring only mobility; *Manual*: section of POD score measuring only manual dexterity; *Total*: POD score including mobility, manual dexterity, speech, visual ability, auditory competence, and perceptive tactility.
†One child had incomplete data on some scales.

Table 6
***F*-Ratios (MANOVA) for Profile of Development (POD) Scores: Test 1 Versus Test 2**

Comparison	Total*			Mobility			Manual		
	F†	*P*‡	df§	*F*	*P*	df	*F*	*P*	df
Group (*G*)	1.15	.29	1/84	0.54	.47	1/85	2.24	.14	1/84
Type of problem (*TP*)	4.33	.04		3.28	.07		0.96	.33	
G x TP¶	3.55	.06		5.20	.03		4.54	.04	
Test (*T*) (1,2)	29.61	.00		12.91	.00		18.86	.00	
G x T	0.30	.59		4.27	.04		0.01	.92	
TP x T	0.00	.96		1.15	.31		0.01	.94	
G x TP x T	5.97	.02		0.00	.97		2.74	.10	

**Total:* POD score including mobility, manual dexterity, speech, visual ability, auditory competence, and perceptive tactility. *Mobility*: section of POD score measuring only mobility. *Manual*: section of POD score measuring only manual dexterity.
† *F* ratio compares mean differences to error
‡Probability of the mean difference recurring by chance only. $P \leq .05$ is considered significant; $P \approx .00$ means a *P* value < .005.
§The number of degrees of freedom, based on the number of mean differences (numerator) and scores in the error term (denominator) of the *F* ratio.
¶Two or more symbols with a times sign between them represent the joint effect of two or more variables (an interaction).

Effects of treatment and motivation

Table 5 shows the POD means for the research sample that completed two POD testings. The sample on the second testing was reduced slightly in size (**Table 3**). The variables of group, type of problems, and type of test were compared to study the relative effect of osteopathic manipulative treatment on neurologic development versus the combined motivational effects of being examined, interviewed, tested with the POD, and accepted into the treatment program. **Figure 2** shows changes in average total POD scores between the baseline test and pretest (without treatment) for the waiting-list group, and between the pretest and post-test (after completion of treatment) for the start-first group. These changes are shown separately for the neurologic and medical categories. **Table 5** shows the values on which **Figure 2** is based.

Table 6 shows the results from a MANOVA for in-

Table 7
Mean Age-Adjusted Profile of Development (POD) Scores by Group and Type of Problem for Children Who Completed Tests 1, 2, and 3

Test and scale*	Waiting-list group				Start-first group				Total Group	
	Neurologic problems		Medical problems		Neurologic problems		Medical problems			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Test 1	**Baseline**				**Pretest**					
Mobility	0.712	0.306	0.673	0.187	0.456	0.226	0.868	0.389	0.714	0.348
Manual	0.739	0.237	0.657	0.393	0.735	0.226	0.970	0.301	0.823	0.288
Total	0.807	0.215	0.783	0.276	0.729	0.113	1.001	0.275	0.863	0.250
Test 2	**Pretest**				**Post-test**					
Mobility	0.794	0.379	0.650	0.176	0.706	0.272	1.031	0.452	0.857	0.399
Manual	0.825	0.183	0.713	0.239	0.994	0.375	1.034	0.348	0.937	0.315
Total	0.865	0.281	0.870	0.160	0.931	0.241	1.086	0.300	0.966	0.268
Test 3	**Post-test**				**Follow-up**					
Mobility	0.929	0.350	0.755	0.124	0.946	0.535	1.143	0.433	1.005	0.428
Manual	0.884	0.158	0.970	0.289	1.021	0.291	1.083	0.261	0.997	0.249
Total	0.969	0.236	1.020	0.223	1.036	0.304	1.159	0.286	1.061	0.276
	(n = 16)		(n = 3)		(n = 11)		(n = 19)		(n = 49)	

* *Mobility*: section of POD score measuring only mobility; *Manual*: section of POD score measuring only manual dexterity; *Total*: POD score including mobility, manual dexterity, speech, visual ability, auditory competence, and perceptive tactility.

Table 8
***F*-Ratios (MANOVA) for Profile of Development (POD) Scores: Tests 1, 2, and 3**

Comparison	Total*			Mobility			Manual		
	F†	*P*‡	df§	*F*	*P*	df	*F*	*P*	df
Group (*G*)	1.46	.23	1/45	0.74	.39	1/45	3.81	.06	1/45
Type of problem (*TP*)	1.26	.27		0.58	.45		0.18	.67	
G x TP¶	0.99	.33		2.93	.09		0.68	.41	
Test (*T*) (1,2)	27.06	.00	2/90	12.00	.00	2/90	15.01	.00	2/90
G x T	0.74	.48		2.44	.09		1.27	.29	
TP x T	0.39	.73		1.24	.29		1.36	.26	
G x TP x T	1.87	.16		0.11	.90		2.38	.10	
Test 1 & 2 only for medical & neurologic categories separately for *G x T* effect									
Neurologic	3.54	.07	1/25						
Medical	0.00	.98	1/20						

**Total:* POD score including mobility, manual dexterity, speech, visual ability, auditory competence, and perceptive tactility. *Mobility*: section of POD score measuring only mobility. *Manual*: section of POD score measuring only manual dexterity.

† *F* ratio compares mean differences to error.

‡Probability of the mean difference recurring by chance only. $P \leq .05$ is considered significant; $P \approx .00$ means a *P* value < .005.

§The number of degrees of freedom, based on the number of mean differences (numerator) and scores in the error term (denominator) of the *F* ratio.

¶Two or more symbols with a times sign between them represent the joint effect of two or more variables (an interaction).

dependent groups and repeated measures for both the total POD score and for the mobility and manual dexterity subscales. With all children combined into one total sample, the change in POD scores on the three scales between the first and second testing (the test effect) was highly significant ($P<.001$). When the scores for both testings are combined for the waiting-list and start-first groups and averaged, no significant differences are found: The groups are equivalent when all other variables are combined. Some smaller and less consistently significant effects were found on sensory POD scales, but the results are not presented here.

However, the mean scores of the type-of-problem categories (neurologic, medical) within groups differ almost significantly on all three POD scales when scores for tests 1 and 2 are combined (the groups x type-of-problem interaction). This was not true on the scores from the initial testing alone. Changes for the waiting list group took place in the absence of treatments, whereas those for the start-first group are seen shortly after completion of treatment. The waiting-list neurologic group averages dropped slightly between the base-line and pretest whereas averages of the start-first neurologic group rose sharply between tests (a separate analysis of change for this category alone showed significant increase in average score between tests, $P<.01$). In contrast, the increases between tests in the waiting-list medical group and start-first medical group averages were nearly the same and were equally significant ($P<.01$ in both cases).

Table 7 gives the mean POD scores for the groups of children who completed the first three POD testings. The number of children who completed three tests, 49, was a marked reduction from the 88 who completed two tests **(see Table 5)**.

Table 8 shows the results of MANOVA on the total, mobility, and manual dexterity POD scales **(see Table 7)**. Only the time of testing (T) showed significant increases (all three scales $P<.0001$).

The pattern of change in average POD performance for tests 1, 2, and between 2 and 3 is similar to that shown for the larger sample for tests 1 and 2. The medical problem groups show significant and comparable improvement regardless of what happens to them (waiting, treatment, follow-up). The neurologic groups show greater improvement after treatment (pretest to post-test) than between the base-line and pretest (waiting-list group) or post-test and follow-up (start-first group) when no treatment is given. This difference, however, shows only marginal significance on the mobility scale only ($P=.07$). The medical group showed virtually no changes on test scores attributable to their being in the waiting-list or start-first groups.[3]

Separate analyses (MANOVA) were done for the changes between POD tests 1 and 2 for those children who completed test 3. The results were closely comparable to those shown in **Tables 5 and 6.** Whatever the reasons for not continuing on in the research, they had little effect on the pattern of findings shown between tests 1 and 2 for the children who continued on to test 3.

Persistence of effects after treatment

Table 9 shows the mean POD scores for the 13 children in the waiting-list group who completed all four possible testings. Scores for the total group steadily increased from the first to third test. This trend was highly significant ($P<.001$). The sample was too small to test between patterns for the type-of-problem categories. The performance scale increases for this sample during the follow-up period, as was found for the start-first group between their post-test and follow-up testings **(Table 7)**. Because the pattern between tests 1 and 3 for the waiting-list group was similar whether or not the group continued to test 4, the final outcome was unlikely to be due to reduced sample size.

Review of literature

Variations in neurologic performance have been related to neurophysiologic measures of central nervous system functions. Pinkerton and associates[6] compared 18 "good readers" with 14 "poor readers" in an ordinary classroom of 8- and 9-year-old children. Brainstem auditory evoked potentials in the right ear were significantly different from those in the left in the good readers, but such asymmetry was not found in children with learning difficulty. Small and coworkers[7] demonstrated similar electroen-cephalographic findings in children with attention deficit. Beckett,[8] Sklar[9] Satterfield,[10] Murdoch,[11] Van Mechelse,[12] Rebert,[13] and Gasser[14] and their respective coauthors have identified increased low-frequency electroencephalographic power in children with various learning problems.

These reports reflect an interaction between some aspect of behavior and the presence of asymmetric or altered nervous system conduction or transmission of afferent nerve impulses (or both). To what extent those differences in central nervous system measurements would be present in asymmetry of somatic function, or dysfunction, and to what extent they might be improved by osteopathic manipulative treatment that changes the neurologic developmental profile remains to be determined.

Table 9
Mean Age-Adjusted Profile of Development (POD) Scores for Tests 1 through 4 for Waiting-List Group

Test and scale*	Neurologic problems		Medical problems		Total Group	
	Mean	SD	Mean	SD	Mean	SD
Test 1 (baseline)						
Mobility	0.735	0.348	0.765	0.000	0.738	0.334
Manual	0.736	0.246	0.961	0.000	0.753	0.244
Total	0.812	0.244	1.005	0.000	0.826	0.240
Test 2 (pretest)						
Mobility	0.813	0.435	0.729	0.000	0.807	0.417
Manual	0.835	0.192	0.916	0.000	0.842	0.185
Total	0.880	0.246	1.041	0.000	0.892	0.240
Test 3 (post-test)						
Mobility	0.937	0.402	0.885	0.000	0.933	0.385
Manual	0.901	0.166	1.126	0.000	0.919	0.170
Total	0.980	0.263	1.247	0.000	1.000	0.262
Test 4 (follow-up)						
Mobility	1.086	0.525	0.859	0.000	1.068	0.507
Manual	0.951	0.217	1.327	0.000	0.983	0.232
Total	1.042	0.291	1.420	0.000	1.072	0.297
	(n = 12)		(n = 1)		(n = 13)	

**Mobility*: section of POD score measuring only mobility; *Manual*: section of POD score measuring only manual dexterity; *Total*: POD score including mobility, manual dexterity, speech, visual ability, auditory competence, and perceptive tactility.

The osteopathic medical approach to health and disease is founded on the concept that structure and function are interdependent. The important concept stated by Korr,[15] that the musculoskeletal system is "the primary machinery of life," is implicit in this approach. The autonomic nervous system fine tunes this supportive apparatus of the body to meet the ever-changing demands of that primary machinery. The parasympathetic division protects the internal environment, that is, it is trophotropic because of its nutritional function. The sympathetic division, by contrast, is ergotropic, influencing the performance of the whole body in response to the environment.

The studies on microcirculation of nerves by Sjöstrand and coworkers[16] demonstrate that slight trauma, that is, moderate nerve compression, might induce microvascular injury limited to the superficial nerve layers as indicated by microbleedings and edema formation in the epineurium. This is a reversible situation if the duration of compression is limited. We believe that impairment of physiologic inherent motility of any part of the musculoskeletal system will adversely affect nerve pathways passing through the region. This adverse effect in turn will induce capillary congestion in the immediate area and in viscera at the nerve's ending and reduce venous and lymphatic drainage. Furthermore, as Hix[17] indicates, the transport of an axoplasm along an axon to a terminal end organ is essential for complete growth and the maintenance of normal function. He concludes: "The inability of a visceral nerve to exert its early trophic influence on the organ it innervates may have meaningful consequences on the ability of the denied organ to metamorphose to its full anatomic and physiologic maturity." This statement of Hix suggests the importance of treating the musculoskeletal problems of children.

Plagiocephaly is a term used here to describe membranous articular strains that distort the cranial mechanism and impair symmetric inherent physiologic motility. In a study of 1250 newborn babies,[18] such strains were found in nearly 90% of neonates. Children with learning problems exhibit a wide range of somatic strain patterns related to trauma.[19] New technology, such as computed tomography of the brain and magnetic resonance imaging, provides additional evidence of brain injury.

Somatic dysfunction is not confined to the cranial mechanism. It may be found throughout the musculosk-

eletal, membranous, and fascial systems, in the coordination of diaphragmatic function, and in scars. The critical finding is impairment, distortion, or obstruction of the inherent motility. Such dysfunction is accessible to manipulative treatment, which will modify the dysfunction and restore the motility. Osteopathic physicians using osteopathic palpatory diagnosis and manipulative treatment have demonstrated beneficial effects in children with a wide diversity of academic, behavioral, developmental, neuromuscular, and perceptual problems.

No specific area of somatic dysfunction is presumed to be related to a particular clinical manifestation. Neither does treatment of one specific anatomic region resolve a child's problem. Treatment must address all areas of impaired inherent physiologic motion with the objective of restoring free and symmetric inherent motility.

Discussion

A number of factors influence results in research studies. We had to consider the possible influences of learning to take the tests and environmental factors at OCC or at home. The interest and expectations of the researchers, staff, and parents may create a favorable effect on a child. The changes in POD scores between the first and second tests in the waiting-list groups provide an estimate of such influences. We assume that because these are greatest at the beginning of our research study, their impact is much less after the child's second test.

Other controls for bias were used here. These included adjusting the original POD scores for age to remove possible changes in scoring that were due to maturation, comparing POD scoring in the various independent variable categories to equate for possible sampling bias resulting from children leaving the program initially and during the course resulting from children leaving the program initially and during the course of the research, and examining the relationships between medical history, background variables, and POD scoring. The fact that the average initial POD scores within the research groups (waiting-list and start-first) and within the comparison groups (incomplete and dropout) were not significantly different indicates that the makeup of the research groups was matched; also, that those who failed to take more than one POD test did not significantly bias the POD status of the remaining sample that continued on to take two or more POD tests. In short, differences between the first and later test scores were not biased significantly by selective elimination of children from the original sample due to different initial POD scores.

A significant change in the medical problem group's performance as estimated by the POD was observed both before treatment was initiated and after the period of osteopathic manipulative treatment. It is our observation that there are many children who perform at grade level, conduct themselves in an acceptable fashion, and, therefore, do not attract attention to minor deficiencies in neurologic development. Once inherent physiologic motion is restored by manipulative treatment, these children have improved capability to achieve a higher level of performance. Are these the underachievers of society?

These children provide an interesting comparison with children with manifest neurologic inadequacies. Children with diagnosed neurologic problems showed no significant response to the general motivational aspects of the program. Instead, their performance on the POD improved specifically in response to the osteopathic treatment **(Tables 6 and 8)**. It appears that the rate of neurologic development in children with medical problems increases with or without treatment but that children with neurologic problems need specific intervention to improve their rate of neurologic development.

Our research provides an answer to one question frequently asked of osteopathic physicians, "How long does the effect of manipulative treatment last?" Although only a few parents were sufficiently enthusiastic about research to bring their children back for a follow-up POD assessment, **Table 9** records significant ($P<.001$, total sample), continuing, positive changes several months after treatment was concluded. Because osteopathic manipulative treatment liberates and stimulates the inherent therapeutic potency in the patient, such continuing progress after treatment is to be expected.

Osteopathic medical management

Korr[20] emphasizes that osteopathic health care should be evaluated as customarily presented. The health care procedures usually used at OCC in providing children's health care were modified only to the extent necessary for conducting research. It is possible that non-treatment aspects of health care based on osteopathic medical philosophy and principles may have affected our results. Such non-treatment aspects are described to help the reader to estimate their impact. The focus on osteopathic manipulative treatment and neurologic developmental measurement, in our opinion, provides a reasonable basis for attributing the observed changes in performance to osteopathic manipulative treatment.

Osteopathic medical philosophy emphasizes care for the whole individual. This care includes attention to the somatic components of illness, interaction of body systems to illness and interventions, and interaction of the individual with the psychosocial environment. Music therapy, that is, live classical piano music selected to match the state of the child, and homeopathic medical treatment that stimulates the body's inherent defense are individualized for each child's health care management at OCC. Homeopathic medications are reserved for patients in whom response to osteopathic manipulative treatment has reached a plateau. Cooperation of young children is gained by guided play with purposeful toys. These interventions are changed during the course of care.

The plan at OCC to manage the challenging problems in childhood development is based on the following osteopathic medical principles:

- There is an interrelationship between structure and function. Structural integrity permitting freedom of inherent physiologic motion is the optimum condition in the musculoskeletal system that allows efficient function of all other body systems affected by somatovisceral and viscerosomatic reflexes.[21]
- There is a dynamic unity of the body. The fascia, one contributing influence on body unity, provides continuity of structure from the soles of the feet to the top of the head. Every musculoskeletal change results in widespread adjustments mediated throughout the fascial system.
- It is the body's inherent therapeutic capacity that heals a laceration, unites a fracture, overcomes acute infection, or stimulates neurologic development, integration, and function. This capacity is enhanced following osteopathic manipulative treatment.

Comment

A number of factors affected the outcome of this research. At the time of the initial visit to the Center, factors in the history, the course of the disability, the dysfunction, or the disease, and memories of previous experiences in diagnosis or treatment contribute to a child's potential for initial participation in the program. Gaining the cooperation and confidence of a child and inspiring that child to participate in treatment have a major impact on the outcome of care. Delay in initiation of osteopathic manipulative treatment may have contributed negatively to this outcome or to failure to complete a treatment program or to return for the final assessment. Because many patients come from distant parts, these geographic factors often contributed to dropping out.

Credibility of the research will be affected by the lack of a paradigm accepted by osteopathic clinical researchers for designing descriptive research studies. Our study has provided methods that reduce the physician's, evaluator's, and analyst's bias. Treatment of all subjects was based on a stated set of criteria for research and health care decisions. A quantitative measure was used for assessing sensory and motor performance. Data were collected, coded, and archived for future review. These procedures are steps toward establishing the acceptance of a paradigm and increasing the credibility of similar research.

Within the limitations posed by these considerations, the improvement in sensory and, to a greater extent, motor performance, assessed by a standard established to evaluate neurologic development, supports our assumption that the change in neurologic development is associated with somatic changes that accompany osteopathic manipulative treatment.

Conclusion

This controlled study provides quantitative descriptive data to support the use of osteopathic manipulative treatment as part of pediatric health care based on osteopathic philosophy and principles. The management used for children in this research study provides significantly improved sensory and motor performance in children with neurologic problems.

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