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ELECTROMYOGRAPHIC EVALUATION OF STRUCTURAL INTEGRATION TECHNIQUES

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Structural Integrationis an intervention technique designed to enhance one's well-being through postural improvement. Eleven male subjects were studied before and after ten sessions of Structural Integration using telemetric electromyographic recordings. The findings point to improved organization and greater balance in the neuromuscular system following the intervention.

Of the numerous new intervention techniques designed to enhance general well-being of average people through postural improvement, Structural Integration developed by Ida Rolf is one that has received rapid and popular acclaim. The theory and techniques of Structural Integration (SI) are derived from the elemental fact that human bodies are organized in space, subject to the pull of gravity. If gravitational force is effectively managed through the lines of gravity, mechanical stress is minimized allowing freedom of movement and economical use of energy. All deviations from ideal structural alignment create unnecessary stress on the organism.

Sound as this concept is, it is not unique to SI but is at least professed by most physical therapeutic and exercise techniques. What appears unique to this method, however, is its holistic concept which emphasizes the mechanisms associated with structural imbalance and their far-reaching effects upon adaptability, efficiency, and behavior, and the unusual techniques employed for intervention and change.

Structural Integration strictly adheres to the conceptual base of the total, dynamic oneness of body-mind and behavioral expression. Body structure is viewed as a visible incarnation of personality. Attitudes and feelings are inextricably manifest in postural and movement patterns. Emotional and physical stresses or injury translate into musculoskeletal compensations to form disorganized, ineffectual patterns which persist, having a destructive effect on the biological equipment, and concomitant strain on adaptability and emotional orientation.

Most comparable systems envision the mechanisms of posturally imbalanced bodies as undesirable strength, weakness, and tightness in local muscle groups and joints, relying on exercises and joint manipulation for change. Structural Integration, often referred to as the Rolf Technique, or "rolfing" looks to a more fundamental, causal condition in the nature of connective tissue, the universal body tissue which organizes all cells and accounts for body conformation. Specific emphasis is placed on the myofascial system which ensheaths and overlays muscles and provides support for joints (Rolf, 1973). When connective tissue loses resiliency and takes a set, the individual muscle autonomy and the synergistic interplay of muscle groups is seriously impeded. The strain of acute local restrictions is spread to more distant areas through the network of fascial planes. Understanding the plasticity of connective tissue, however, allows its restructuring into a more interactive, resilient system conducive to efficient movement and energy conservation. Body reintegration by SI

> . . . requires stretching and restoring elasticity to shortened and thickened connective tissue, detaching fibrils that have formed between muscles hampering lines of pull, repositing tendons and ligaments that are bunched and shortened so that joints can move freely and muscles reciprocate and collaborate in the total acts of moving (Rolf, 1973).

Practitioners using the Rolf Technique do not manipulate or force joint movement, but rather concentrate on the soft tissue, applying the neces-

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sary force with fingers, elbows, clenched fists, and open hands. To completely reverse the destructive effects of gravity, the myofascial system must be reorganized as a whole, which requires a series of ten sessions, each with a specific focus.

Clinical and experimental evaluations of the effects of SI have pointed to improved posture and movement efficiency for all persons, even the already skilled dancers and athletes, to feelings of greater relaxation, emotional release, and improved adaptability, as well as general well-being.

The procedures of Structural Integration aim to create and maintain a more balanced energy system which conserves energy rather than expends it (Rolf, 1973). Whether neuromuscular refinements constitute the primary mechanism by which the body becomes aligned and more unstressfully responsive, or whether neuromuscular changes are end results along with structural and behavioral ones, it seems evident that an essential link between structure and movement behavior must exist in the energy configuration of the muscular system. Therefore, the following study of the energy patterns displayed by electromyographic (EMG) recordings of muscle contraction was undertaken.

It was hypothesized that SI of the myofascial system would effect the nature and patterns of muscular action in the following ways:

a) Alter global neuromuscular patterns during rest and activity.

b) Change the frequency spectra of motor unit depolarization.

c) Facilitate more effective movement.

METHOD

Fifteen male subjects between the ages of 25 to 45 volunteered to participate in this study. None had any gross physical or emotional disabilities. Telemetric electromyographic recordings were taken immediately before and after ten sessions of Structural Integration-two sessions each week for five weeks. Subjects were rolfed in alternating sessions by two practitioners, Ida Rolf and Peter Melchoir. Each subject received five sessions from each practitioner.

Two subjects failed to complete the post-testing procedures and data from two other subjects were eliminated because of drug usage. Final analyses were carried out on data from I I subjects.

EMG PROCEDURES

Data were intercepted by miniature bipolar silver/silver chloride surface electrodes; transmitted and discriminated by a four channel telemetry EMG system produced by Biosentry (Irig channels 11, 12, 13, 14) and recorded on a Nagra III tape recorder with simultaneous telemetered verbal stating and movement description.

Data recordings were continuously monitored by audio signal, by two oscilloscopes and a Beckman Dynograph ink writer. Recorded raw data were further graphed in analog form by a light-beam recorder and digitally converted by TRW Systems Analysis Corporation, San Pedro, California. From these digital data, statistical computations were processed on both amplitude and frequency information. Integrated analog displays were produced from the frequency data only.

Electrode placements, developed in the Movement Behavior EMG Laboratory,† were carefully measured from bony landmarks. Skin was prepared by light abrasion with 600 ought sandpaper. Electrodes were filled with saline jelly and affixed by double adhesive disks. Accepted skin resistance was five thousand ohms or less.

Electrodes were placed on the following muscles: Placement 1, scaleni (neck), anterior deltoid (arm), erector spinae (spine), and gluteus medius and minimus (hip); Placement 2, posterior and anterior deltoid (shoulder), erector spinae (spine), and rectus abdominus (abdomen).‡ A common ground was attached to the lateral epicondyle of the humerus.

Movements sampled by Placement 1 included walking, jogging, sitting, head rotating, stepping up on stool, lifting stool, lateral neck flexing, carrying stool, side sliding, and throwing. Those sampled by Placement 2 were walking, jogging, stepping up on stool, lifting stool, carrying stool, side sliding, and throwing. Directions for each movement task were carefully described. Time was standardized preceding and during all static held positions and the direction and number of repetitions were regulated during moving tasks.

DATA ANALYSES

Analog Comparisons

Pre and post SI raw data myograms were compared

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‡ Electrode placements are available from the authors.

on the 19 activities monitored by Placement 1 and 2. Several parameters were used for comparison :

a) Duration of major muscle contraction was a measure of the seconds of muscular electrical activity for each task (Figure 1).

b) Ascending and descending gradient slope of the contraction was an evaluation of the symmetry of the electrical activity as it increased and decreased in amplitude, (Figure 2).

c) Temporal onset of agonist and antagonist contraction (Figure 3) was a comparison of the simultaneous or sequential onset of the action of the agonist, the muscle producing the movement with the antagonist, the muscle controlling or resisting the movement.

d) Specificity of muscle action referred to the location of the electrical activity during each task whether isolated to the muscles performing the movement or to those remote from the locus of primary action (Figure 4).

e) Envelope pattern is the specific analog EMG of each muscle contraction evaluated as to the clarity or the random intervening electrical activity (Figure 5).

f) Level of baseline bioelectric activity referred to the resting level before and after each task and during the resting stage in between repetitive tasks (Figure 6).

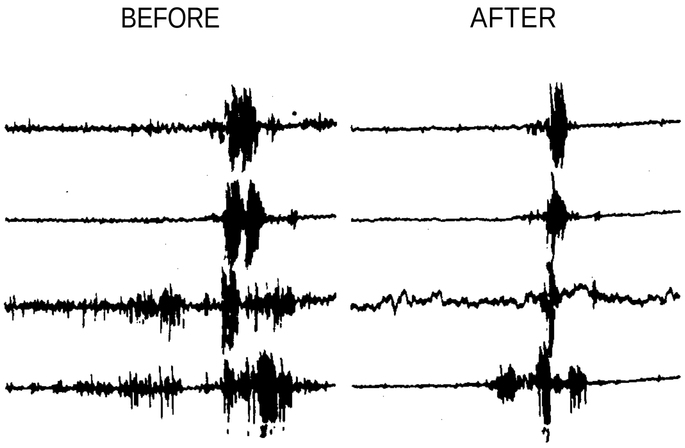

FIGURE 1 EMG duration (throw).

Statistical Analysis

Amplitude To reduce the quantity of data and possible duplication, Pearson intercorrelations were run on the digital amplitude data of all 12 activities of Placement 1. Six activities-lying, jogging, rotating **head, lifting stool, side sliding**

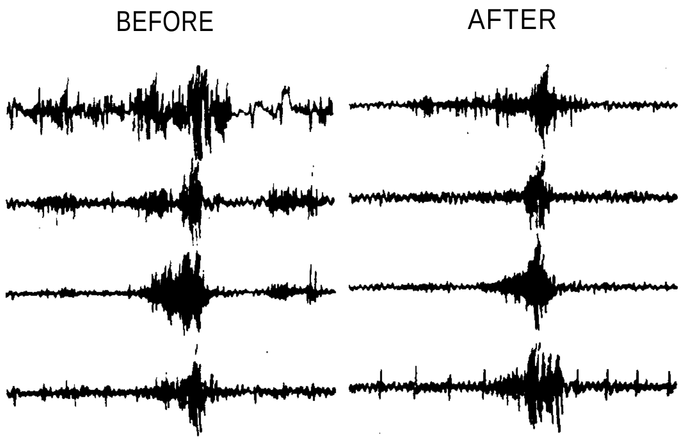

FIGURE 2 EMG gradient slope (throw).

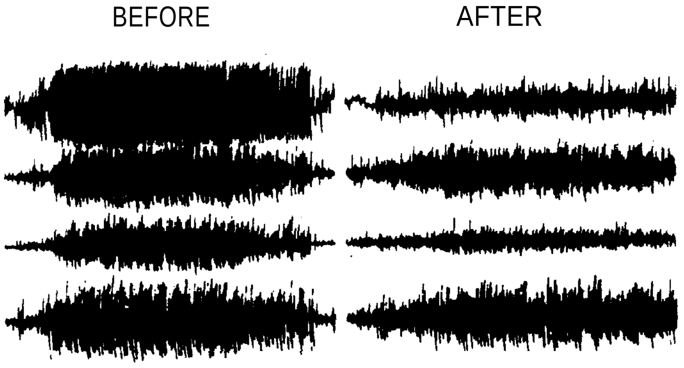

FIGURE 3 Temporal onset agonists-antagonists (lift stool).

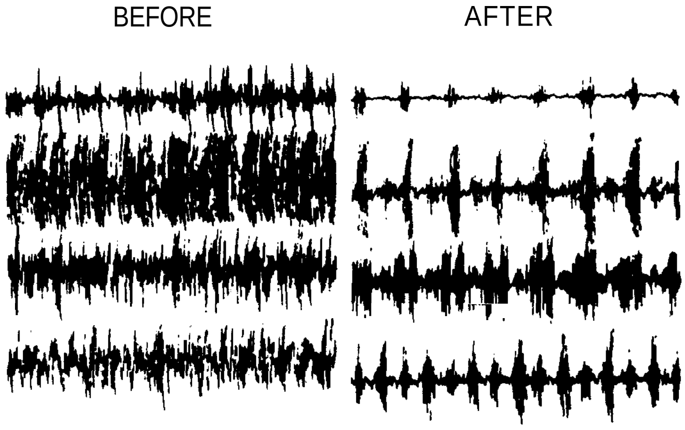

FIGURE 4 EMG muscle specificity (jog).

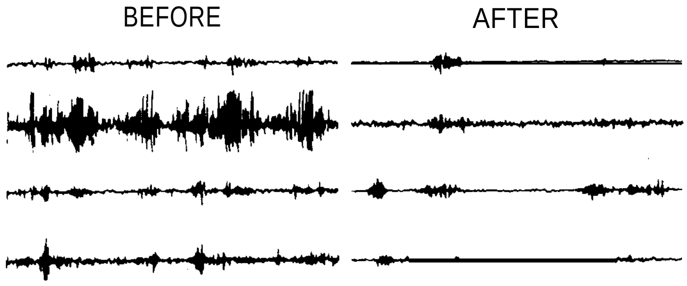

FIGURE 5 Random action potentials (stool step).

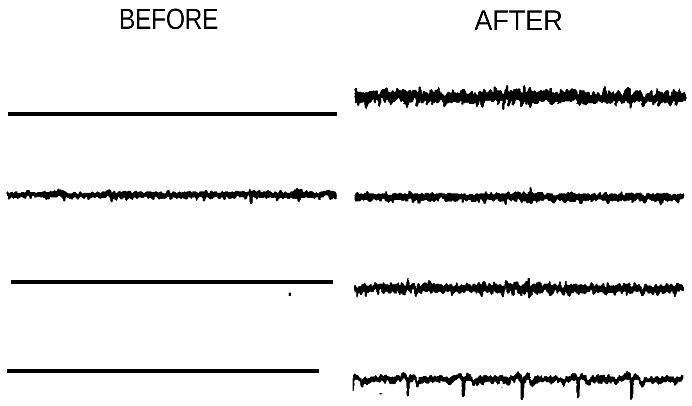

FIGURE 6 EMG baseline activity (lying).

and throwing-produced sufficiently low **inter**correlations to indicate different information. Pearson correlations and Fisher t values were obtained on pre and post SI amplitude data from these activities on each of four muscles (Table I).

Frequency analysis Analog data from all four channels pre and post SI were frequency digitized from 0 to 250 Hz for 11 subjects. Two subjects were eliminated when data disclosed high frequency antifacts of unknown origin. Final frequency computations contained nine subjects. Reliability of the frequency measures by evens-odds Pearson Correlation, corrected by Spearman-Brown Prophesy Formula for half tests, were r = lying **.963,** jog **.972,** rotate head **.952,** lift stool **.940,** side slide **.969,** and throw **.976,** each with a p = **.01** or better.

All six selected activities with four channels were further processed by Power Density Spectra Frequency Analysis. Using a five H_z window

TABLE I
EMG amplitude comparisons **pre-post** structural integration

Activity	‘Channel	*M* Pre	*M* Post	*SD* Pre	*SD* Post	N	r	*t*
Lying	1.	.0097	.0164	.0079	.0262	11	.505	1.11
	2.	.0218	.0298	.0166	.0251	11	.304	1.66
	3.	.0469	.0820	.0919	.1089	11	.563	1.85^b
	4.	.0197	.0285	.0158	.0626	11	.324	1.92^b
Jog	1.	.0302	.0331	.0490	.0430	11	.316	1.38
	2.	.0392	.0504	.0412	.0515	11	.069	2.02^b
	3.	.1139	.1453	.1383	.1605	11	.521	2.14^b
	4.	.072I	.0721	.1272	.1139	11	.532	.036
Rotate head	1.	.0743	.0506	.1205	.0828	11	.642^b	I.85^b
	2.	.0232	.0292	.0195	.0214	11	.277	2.35
	3.	.0581	.0905	.0932	.1142	11	.449	2.09^b
	4.	.0208	.0264	.0395	.0442	II	.022	1.37
Lift stool	1.	.0276	.0330	.0300	.0402	//	.175	.476
	2.	.1762	.1669	.2325	.1842	11	.457	.105
	3.	.1284	.1887	.1367	.1947	II	.214	2.47^b
	4.	.0450	.0466	.0854	.0536	11	.269	.399
Side slide	1.	.0343	.0410	.0530	.0530	//	.518	.798
	2.	.0443	.0564	.0461	.0565	//	.555	2.59
	3.	.1244	.1587	.1470	.1716	//	.766^c	2.28^b
	4.	.1101	.0993	.0169	.1311	//	.554	.733
Throw	1.	.0694	.0806	.1202	.1257	11	.694^b	.417
	2.	.2084	.2358	.2896	.3080	11	.784^c	.314
	3.	.1839	.2216	.2350	.2521	11	.656^b	.815
	4.	.0830	.0892	.1364	.1300	11	.807^c	.042

Significant values:
^{a} < .10
^{b} < .05
^{c} < .01

TABLE II
(0–40) frequency band **comparisons pre-post** structural integration by four channels

Activity	N	*M*		*SD*		*r*	*t*
4 channels	9	Pre	**Post**	**Pre**	Post		
Lying		.1013	.0825	.0175	.0399	.015	1.650
Throwing		.1013	.0922	.0130	.0640	.520	.522
Channel I	9						
Lying		.1302	.1072	.0167	.0432	.478	1.680
Throwing		.1643	.1479	.0288	.0580	.138	.780
Channel 11	9						
Lying		.0753	.1072	.0444	.0856	.168	3.770[c]
Throwing		.1133	.0862	.0202	.0221	.469	5.930[d]
Channel III	9						
Lying		.1373	.1303	.0442	.0364	.570	4.714
Throwing		.1188	.0935	.0480	.0353	.866	5.45[d]
Channel IV	9						
Lying		.0619	.0501	.0071	.0409	.000	4.38[c]
Throwing		.0638	.0761	.0499	.0419	.024	4.47[c]

Significant values:
[a] <.10
[b] <.05
[c] <.01
[d] <.001

integrated analogue displays were developed. From these integrated analogues a low band O-40 H_z and a high band 60-180 H_z were selected for statistical comparison of lying and throwing pre and post Sl by Pearson Correlations and Fisher *t* values' (Tables I I and 111). Lying and throwing were chosen because these represent motor tasks requiring the least and the most neuromuscular excitation.

Since neither isolated muscles (channels) nor a composite of all muscles reflect the patterns essential for efficient action, further comparisons were made based upon the functional differences of muscles ; those classified as tonic or stabilizing muscles and those kinetic or moving muscles. Kinesiologists accept that in integrated movements muscles have unique contributions to the quality of movement produced based upon their location, the nature of the motor units, and the architectural structure. Tokizane and Shimazu (1964) described stabilizing muscles as containing a preponderance of tonic motor units low in frequency depolarization, with short fibers and lying deep around joints particularly in the trunk and spine, providing excellent isometric (holding) capacities. They further described moving muscles to contain more kinetic motor units with higher frequency depolarization, of longer fibers and prevalent in the limbs, providing faster motion effective in phasic or isotonic movements (Tokizane, 1964).

Of the muscles sampled in this study, the spine and neck muscles met the criteria of stabilizing muscles and the arm and hip muscles were appropriate moving muscles. Pearson Correlations and Fisher *t* values were computed on pre and post SI stabilizing muscles (channels 1 and 3) and moving muscles (channels 2 and 4) during lying and throwing (Table IV).

Cluster group comparisons Three cluster groups of these same subjects were obtained from EEG Averaged Evoked Responses, Saccadi Eye Movements Procedure, and biochemical measurements using a "nearest neighbor" ISO-DATA Analysis (Silverman, Rappaport, Hopkins, Ellman,

TABLE III
(80-160) frequency band comparisons pre-post structural integration by four channels

Activity	N	M		SD			
4 Channels	9	Pre	Post	Pre	Post		
Lying		.0268	.0347	.0907	.1011	.784[c]	.348
Throwing		.0306	.0292	.0960	.0960	.871[c]	.000
Channel I	9						
Lying		.0197	.0312	.0110	.1430	.216	.209
Throwing		.0124	.OJll	.1110	.1210	.446	.037
Channel II	9						
Lying		.0183	.0249	.0699	.0049	.071	.256
Throwing		.0272	.0336	.0250	.0550	.525	.722
Channel III	9						
Lying		.0195	.0225	.0266	.0066	.405	.371
Throwing		.0296	.0265	.0186	.0120	.673	.637
Channel IV	9						
Lying		.0495	.0605	.0316	.0192	.322	.917
Throwing		.0322	.0329	.0148	.0050	.001	.002

Significant values (two-tailed test)
[b] <.05
[c] <.01

TABLE IV
(O-40) frequency band comparisons **pre-post** structural integration **by** stabilizing and moving muscles

Lying	N	M		SD		r	t
	9	Pre	Post	Pre	Post		
Stabilizing (neck-spine)		.177	.104	.040	.OJO	.580	10.00[d]
Moving (arm-hip)		.068	.022	.046	.010	.756	4.15[c]
Throwing	N	M		SD		r	t
	9	**Pre**	Post	Pre	Post		
Stabilizing (neck-spine)		.126	.177	.020	.070	.945	2.80[b]
Moving (arm-hip)		.088	.017	.081	.010	.588	1.46

Significant **values:**
[a] <.10
[b] <.05
[c] <.01
[d] <.001

Hubbard, Bellaza, Baldwin, Griffin and Kling, 1973). Using these three cluster groups intergroup comparisons by Fisher *t* values of the low band frequency O-40 H_z data disclosed that these clusters differed significantly on 14 of 24 EMG measures (muscles) before SI and in 11 of 24 measures after SI while lying and throwing (Table V). Further comparisons are reported in the findings and in (Table VI).

FINDINGS

Because this study was designed to explore the configuration of energy in motor behavior before and after Structural Integration rather than specific hypotheses, results are presented in the form of findings of the neuromuscular response patterns, and their implications. However, since the findings came from statistical and analog analysis of the data, displays, and tables are presented to support each finding.

1) Post SI subjects performed the same motor tasks with shorter duration of muscle contraction (Figure 1) and with a tendency toward greater amplitude during contraction. Table I shows an increased amplitude in spine and arm during five of six motor tasks N = 9, with *t* values significant at $<.05$.

Although EMG amplitude data have been consistently reported to indicate the amount of energy expended in an act, when interpreted alone, the amplitude parameter is of questionable value. Amplitude data are actually the product of both the power and the frequency of muscle depolarization. Thus an action composed of a high power of low frequency can produce similar amplitude measures to a small quantity of high frequency action. The power is a measure of the amount of motor units activated, whereas the frequency is an indication of the speed of firing of the motor units. High frequency motor units differ in structure and in the upstream source of neural innervation from low frequency motor units as they likewise produce a different quality of movement.

Without resorting to complex frequency analyses, an increase in amplitude is important when it coexists with a shorter duration time. Such occurred after SI during moderately active tasks of jogging, rotating head, lifting and side sliding. In these instances the resistances from inertia, gravity and friction were overcome rapidly, which conserved energy, improved efficiency and made possible more dynamic action. Also the greater

TABLE V
Intergroup cluster comparison of 0–40 H_z frequency band

Activity	Pre SI *t*			Post SI *t*		
Lying	Groups I-II	Groups I-III	Groups II-III	Groups I-II	Groups I-III	Groups II–III
Channel 1.	.469	.600	.979	.006	.097	.952
2.	2.71^b	2.92^b	9.22^d	1.80	1.48	1.42
3.	13.40^d	4.79^c	38.33^d	7.14^d	18.21^d	7.47^d
4.	2.49’	.197	48.45’	.960	.206	2.14’
Throwing	Groups I-II	Groups I-111	Groups II-111	Groups I–II	Groups I-111	Groups II-III
Channel 1.	1.48	.043	2.88^b	.588	4.59^c	6.31’
2.	4.55’	3.83^b	2.67^b	33.30^d	5.74’	3.25^b
3.	22.26’	2.75^b	.000	.563	2.79^b	3.32^b
4.	1.28	I.03	.516	.714	.556	.652

P values (2 tailed test):
. $<.10$
^{b} $<.05$
^{c} $<.01$
^{d} $<.001$

TABLE VI
Mean frequencies of cluster groups lying and throwing pre-post structural integration

	Lying					
	(0–40) Frequencies		(80– 160) Frequencies		Energy — All Frequencies	
	M		*M*		*M*	
	Pre	Post	Pre	Post	Pre	Post
Cluster I	.117	.066	.024	.033	.070	.049
Cluster II	.109	.078	.027	.038	.068	.058
Cluster III	.077	.oao	.032	.032	.054	.056
	Throwing					
	(O-40) Frequencies		(80– 160) Frequencies		Energy — All Frequencies	
	M		*M*		*M*	
	Pre	Post	Pre	Post	Pre	Post
Cluster I	.133	.103	.026	.023	.079	.063
Cluster II	.085	.096	.033	.030	.059	.063
Cluster III	,104	.097	.032	.032	.068	.064

amplitude displayed in the spine provided stabilization for effective use of arms and legs in transmitting force to objects or to the body in locomotion.

2) The envelope pattern of the EMG post SI displayed a more regular ascending and descending gradient slope of the amplitude parameter (Figure 2).

This finding probably results from a relative downward shift in the neural innervation source from upper motor neuron to lower motor neuron control. Numerous authors have reported that motor neurons in the brain, the alpha system, and those from the spinal cord, the gamma system, both contribute to muscle contraction (Boyd, 1964; Brazier, 1968 ; Evartes, 1973). As described earlier, individual muscles have characteristic differences in the frequency of depolarization. Likewise, skeletal muscles are innervated from both alpha and gamma sources. When the high frequency alpha system dominates, motor units fire so rapidly that the frequencies summate or are synchronous, producing a sudden onset of contraction showing an irregular gradient slope of the EMG. If the spinal level gamma system has greater control of the motor- act with its low frequency innervation, asynchronous motor unit firing occurs more often, causing a smooth gradient slope. Probably the smooth gradient slope after Sl indicates a downward shift in the neural control from cortical alpha to more spinal gamma control. Tokizane (1964) found that such a pattern occurred when motor tasks were more reflexive or had become more skillful. The functional result of this finding after SI indicates a smoother energy release particularly beneficial in sustained or repetitive contractions of many daily living activities.

3) Post SI there was more sequential contraction and less co-contraction of agonists and antagonists during all seven movements monitored by Placement 2. Figure 3 discloses simultaneous contraction of arm agonists and antagonists with an elevated antagonist amplitude pre SI. Post SI the antagonists contracted later and with less amplitude. After Rolf processing, the control of movement was accomplished by the agonist muscles, either by expedient recruitment of additional motor units or by change in the frequency of motor unit firing. Before processing movement was controlled and retarded by the antagonists.

Precise, small movements require more co-contraction of agonistic and antagonistic muscles, while the gross reflexive type movements sampled in this study are controlled most effectively by the sequential contraction displayed after SI.

It is interesting to note that Hunt (1974), using the same EMG procedures found a consistent pattern of co-contraction of agonists and antagonists in subjects during stress situations which elevated their anxiety state level, as measured by the State-Trait Index. Under non-stress conditions subjects displayed sequential contraction when performing the same gross motor acts. One is lead by these similarities to speculate about the possible effects of SI upon a state of anxiety.

4) Pre SI myograms displayed widespread neuromuscular exitation in other areas of the body not functionally related to the major action. After SI, muscular exitations were specific to the locus of primary action with little or no overflow to areas not functionally connected to the moving limb (Figure 4).

Hyperactive neural excitation is known to overflow to adjacent and remote neural pathways. The specificity of muscle action with decreased overall motor activity, post SI, constitutes improved neuromuscular organization, a less hyperactive state which should facilitate efficient movement. This finding tends to verify the statement by Rolf (1973) that ". . . energy input is no longer random but becomes specific to the task requirements."

5) The global EMG envelope patterns during continuous isometric or static contractions in sitting and standing before SI could not be differentiated from the rhythmic isotonic or moving contractions of walking, sliding, throwing and jogging. Random action potentials in between bouts of isotonic contractions accounted for the global similarity. After SI there was a clear-cut difference between isometric and isotonic contractions with little motor unit firing between the bouts of isotonic contractions (Figure 5). Random action potentials in between rhythmic activities indicate a hyperactive neuromuscular system, probably the result of heightened muscle spindle response, a stretch reflex activated by tight connective tissue. The functional results from decreased unnecessary neuromuscular action would be improved performance with less total energy expended.

The similarities between these findings and those with high and low anxiety trait subjects is striking (Hunt, 1974). With high anxiety subjects, the envelope patterns were indistinct, containing many random spikings, indicative of a constant state of neuromuscular tension. On the other hand, low anxiety trait subjects had a clearly differentiated envelope with periodic contraction and relaxation -a sharply defined difference between the amplitude of the resting baseline and activity.

6) The baseline bioelectric activity noted, in the pre SI myograms was at a moderate amplitude level and the same during resting and in between all motor tasks. Post SI the baseline was elevated during rest and isometric contractions such as standing and sitting and lowered in between rhythmic contractions of walking, lifting, jogging, and throwing (Figure 6).

Since the base level is a resting measure of bioelectric activity, the lowered baseline in between isotonic contractions may be interpreted as neural inhibition of the alpha system, whereas the elevated baseline during rest and isometric contractions appears to stem from frequency changes in motor unit depolarization, discovered in Power Density Spectra Analysis. Following SI the high frequency band of 60–180 H_z tended to increase during lying and decrease during throwing (Table III).

Because such findings have not been reported in EMG studies before, any explanation is speculative. However, the perceptual changes reported (Silverman, et al., 1973) from data collected from the same subjects following SI warrants consideration. Using EEG Averaged Evoked Response Stimulus Intensity Procedures they found that all subjects evidenced increases in the amplitude of their evoked response waveforms and a significantly greater reduction in responsiveness on the Augmenting Reducing Slope Measure, t(13) = 3.64, $p < .005$. Such was found characteristic of sensitive normal subjects in a prior study (Silverman, 1969). He interpreted these pre and post differences to indicate an increased sensitivity and receptivity to environmental stimulation and as selective inhibition when stimuli are increased.

The possible relationships between EEG evoked responses dealing with patterns of stimuli organization and those of EMG motor organization are intriguing. One could hypothesize that with greater receptivity to stimuli, post SI, there would follow neuromuscular changes to facilitate response. Because all behavioral responses stem from muscular contractions instigated by the alpha motor system with high frequency motor unit depolarization, then it should follow that higher frequency resting myograms and higher amplitude evoked responses would constitute a more sensitive receptive and responsive environmental interaction.

Following the same conceptual logic selective inhibition resulting from increased stimuli discovered in post SI evoked responses should relate to diminished high frequencies found in the EMG baseline in between bouts of motor activity after SI. Such an interface outlines a simple yet elegant prototype for behavior organization with improved integration of the motor response system interdependent upon increased organization of the sensory information processing system.

7) Power Density Spectra Frequency Analyses of lying and throwing EMG data revealed the greatest changes post SI in the low frequency spectra, **0–40 H_z** or the spinal level gamma system, which comprised the bulk of depolarization data (Tables II, III, Figure 7). In both lying and throwing the mean total of all channels showed a downward shift in the power of the low frequencies although neither reached significance. However, when these data were analyzed by locations in the body (channels) there were the following significant changes : Lying, arm $t(9) = 3.77$, $p < .01$, spine $t(9) = 4.71$, $p < .01$, hip $t(9) = 4.38$, $p < .01$; Throwing, arm $t(9) = 5.93$, $p < .001$, spine $t(9) = 5.45$, $p < .001$, hip $t(9) = 4.47$, $p < .01$. No significant changes occurred in the neck recordings.

The pattern of decreased power of the low frequencies in four of the six significant changes constitutes diminished general motor unit activity or greater neuromuscular relaxation after SI. An interesting fact was that the significant increases in low frequency power occurred in body limbs, the arms and the hips when moving.

These areas participate most dynamically in **environmental happenings** and as such may further substantiate the interdependency of the sensory information processing and the motor response systems.

8) Subjects significantly decreased the power of the frequencies of both stabilizing and moving muscles in, the lying state, post SI. Muscles which primarily stabilized body areas during throwing increased in action while those which move the limbs decreased. These are probably the most dramatic findings of this study which verify energy conservation and motor efficiency.

It is an accepted kinesiological principle that coordinated muscle function cannot be explained by isolated muscle contraction or by massed action. In every movement some muscles must stabilize to allow others to transfer force in a given direction. To move limbs effectively in space, one attachment of a muscle must be anchored, otherwise both levers of the joint move simultaneously, transferring force both inward to and outward from the body. In such cases, force is dissipated with neither efficient control of the body nor the object.

After SI, an ideal pattern existed in throwing, an

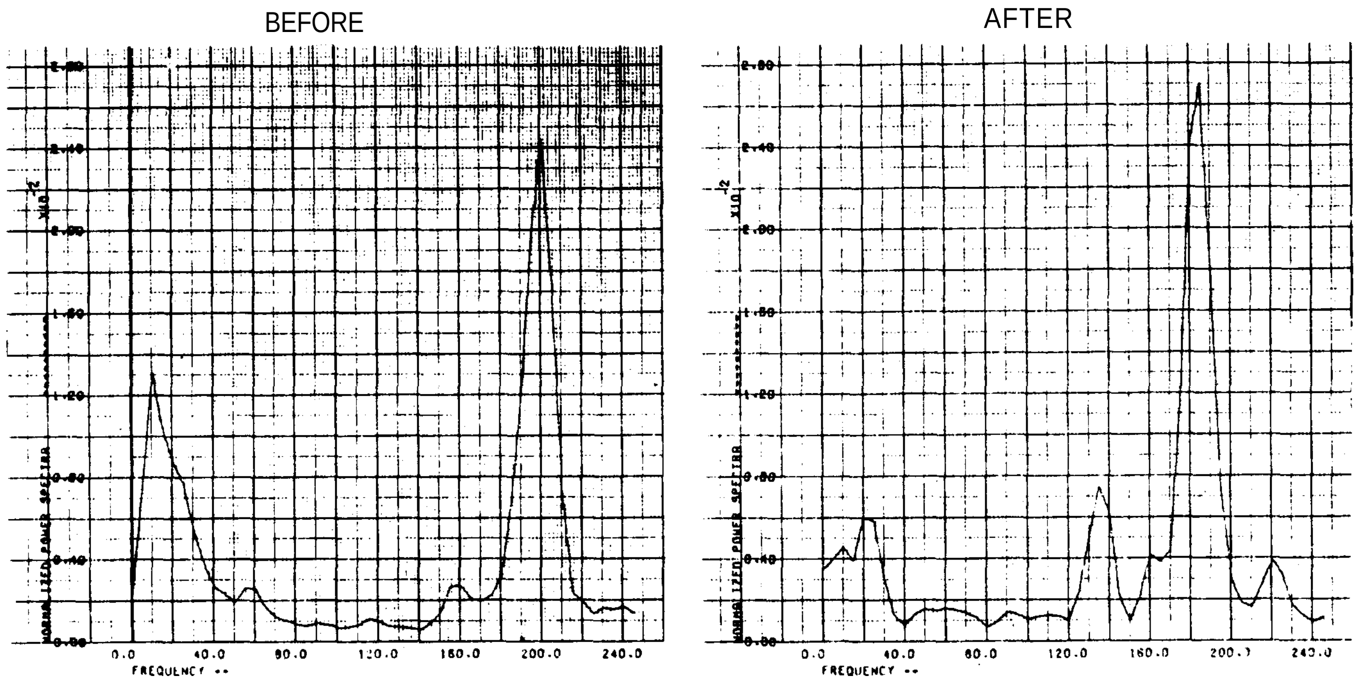

FIGURE 7 Power density spectra frequency analysis of all muscles (lying).

example of vigorous transference of force to an object. The *t* ratios showed an increase in the action of stabilizing muscles (neck and spine) $t(9) = 2.80$, $p < .05$ (Table IV). Likewise, the slight but insignificant decrease in the power exerted by the moving muscles (hip and arm) was in the improved direction, $t(9) = 1.46$ (Table IV). When more force is transferred to an object through better mechanical efficiency, less contraction is required.

Equally important during lying, the frequency power of stabilizing (spine) and moving muscles (arm-hip) both decreased significantly after SI, spine, $f(9) = 10.$, $p < .001$, and arm-hip, $f(9) = 4.15$, $p < .01$ (Table IV). It is notable that the greatest change occurred in the deep holding muscles of the spine and neck, those that commonly continue residual tension even in inactive states, contributing to nerve irritation and common muscular complaints.

These two findings indicate that after SI subjects were at greater rest during inactivity, and they increased their mechanical efficiency by improved stabilization when vigorously moving.

9) Data indicate that Structural Integration had a positive, yet selective effect upon normalizing the energy of subjects based upon their pre SI individual energy patterning.

Finding 7 reported significant low band frequency change of the entire sampling of three out of four muscles after SI. Some of the most interesting evidence of this study lies in the frequency patterns of the cluster groups discovered by Silverman, et al., (1973). Inspection of the mean frequency scores of each cluster group during lying and throwing displayed changes which’ did not follow a linear pattern but rather tended toward a norm.

Table VI reveals the following information:

a) Clusters with the smallest mean total low frequencies pre, increased in the power of low frequencies post SI. Cluster Group III, lying; Cluster Group II, throwing.

b) Clusters with the largest mean total low frequencies pre, decreased in low frequencies post SI. Cluster I, lying, throwing; Cluster II, lying.

c) The cluster with the smallest mean total high band frequencies before, increased in high frequencies after SI. Cluster I, lying.

d) The clusters with the largest mean low and high band frequencies while lying, decreased in both after SI. Cluster I, II.

e) The cluster with the smallest mean in high and low frequency bands pre, increased in both bands post SI. Cluster III, lying.

Due to the limited samples in each cluster, no further statistical procedures were warranted. However, the configuration of change is noteworthy.

If Structural Integration, as the title implies, does in fact organize the body parts into a harmonious whole, such could not occur without similar alterations in the dynamic aspect of body integrity-the muscular energy system. It would follow that reorganization should progress simultaneously based upon the nature of the structural misalignment and the neuromuscular imbalance as well. The latter is suggested in the frequency alterations of the cluster groups toward greater balance. Validation of this inference will require larger sampling.

10) Comparison of pre and post observational data recorded by audio telemetry on the EMG tapes provided the following conclusions after SI:

a) Movements were smoother, larger, and less constrained.

b) There were less extraneous movements.

c) Spatial excursions were more dynamic and energetic.

d) Posture was improved with a more erect carriage and less obvious strain to maintain held positions.

CONCLUSIONS

The neuromuscular changes after Structural Integration-while not conclusive in all parameters -are consistent, extensive, and directly support the general hypotheses of this study: that alterations will occur in patterns of energy release and in the frequency of muscle depolarization, leading to improved motor capacity. To produce such numerous changes in the myograms some form of reorganization must have taken place in the central nervous system, possibly a functional alteration in the neural chain of command exercised in volitionary coordinated motor functioning. Such speculation is supported by the fact that the pattern of muscle depolarization is a mirror image of the central nervous behavior.

Furthermore, neuromuscular findings point to the gamma spinal level system as the intervening system, probably even the mediating one. Improved reciprocal innervation, changes in low frequency firing of motor units, decreased random depolarization, a more modulated gradient slope, decreased base line ‘between contractions, less muscular stabilization during rest, and greater stabilization during activities all discovered in this study follow the known contribution of the gamma system in organizing and controlling the execution of movement (Brazier, 1968 ; Boyd, 1964). The possibility of changes in the spinal system raises questions about the mechanisms. It is not known if increased resiliency of connective tissue has an unloading effect upon muscular spindles or if secondary effects occur via Golgi Tendon Organs providing tendons are realigned by manipulative procedures. But since both are activated by mechanical stretch, it seems plausible that the state of the surrounding connective tissue would affect the reactivity of some components of the gamma system.

One further connection relative to the organization of the central nervous system needs reiteration.

> The muscle spindle efferent system is under control from higher centers in the brain stem, cerebrum and cerebellum and is one of the several examples of centrifugal control of input through the central nervous system at the receptor level (Brazier, 1968: 131-32).

This feedback loop as a closed system confirms spinal level interaction with higher centers. It is our opinion that the procedures of Structural Integration involving manipulation of the myofascial tissue have a profound effect upon central nervous system organization toward balanced and decreased energy expenditure that should come to the attention of neurophysiologists who seek to explain energy changes by their organization rather than by pure energy changes alone. Evarts (1973) has commented that

> it seems possible that understanding the human nervous system, even its most complex intellectual functions may be enriched if the operation of the brain is analyzed in terms of its motor output rather than in terms of its sensory input.

The decrease in low frequency and increase in high frequency spectra of the myogram during a resting state after SI, when viewed with increased amplitudes of evoked response waveforms and reduction in responsiveness on the Augmenting Reducing Slope found with the same subject (Silverman, 1973). has many practical and conceptual ramifications. Both are interpreted as improved receptivity and responsiveness to environmental stimuli.

The co-contraction of agonists and antagonists with random action potentials in between bouts of rhythmic contraction found in high anxiety subjects (Hunt, 1974) has a striking similarity to pre SI patterns. Similarly, the pattern of low anxiety subjects parallels that of post SI subjects. While no direct inferences are indicated, these objective clues tie with subjective reports of emotional release after SI to warrant further study.

Finally, cluster groups obtained by EEG measurements show a trend toward normalization in frequency distribution and energy outputs after SI. The indication that structural realignment and neuromuscular reorganization are reciprocal and as such proceed towards balance based upon the nature of the deviation also justifies further study.

In conclusion, this neuromuscular evaluation of Structural Integration has raised more questions and caused more speculations concerning human motor behavior and its emotional and perceptual corollaries than it has answered. Nonetheless, one major conclusion is warranted. All evidence points to improved organization and greater balance in the neuromuscular system with extensive positive implications for motor efficiency. If these prevail, the widespread effects upon vitality and well-being could be profound.

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