Abstract

Surface electromyography (SEMG) dynamic protocols of testing of the activity potentials of the myotatic unit of the hip region have been used to define the muscular relationships of agonism & antagonism. The values of the correlation coefficients of the different muscles, computed through the hip ROM segments served to establish positive or negative relationships among hip muscles.

The concept of muscular agonism & antagonism was verified and brought to objective light with the SEMG dynamic investigation. Such testing was conducted for the hip region ROM in asymptomatic adult individuals.

Keywords

SEMG (surface electromyography), correlation coefficients, agonism (synergism), antagonism, hip ROM, flexion, external rotation, internal rotation, adduction, abduction, extension, adductor magnus, biceps femoris, gluteus maximus, TFL, rectus femoris, gluteus medius, vastus lateralis and vastus medialis.

Introduction

The concept and expressions of muscular agonism (synergism) and antagonism have not been questioned throughout the modern era of medicine. We tend to use these words almost indiscriminately to define a functional relationship among various muscles or segments of motion, usually within the same myotatic unit, but sometimes among muscles subtending different joints or regions.

The concept has not quite been questioned, nor clearly focused on or defined in any medical field. The closest anatomical definition may relate to the actual position of a given muscle on a bone & joint. We tend to describe muscles positioned on the opposite sides of a bone/ joint as “antagonists” and muscles positioned on the same side of a bone/ joint as “agonists or synergists”. There is no actual study available to demonstrate the functional relationship ascribed to those words.

The concept may further imply that one muscle, the protagonist or synergist, may move the joint in one direction during concentric contraction, e.g. hip flexion, while the “antagonist” may be “inhibited” during such motion. The corollary may apply to the opposite motion, e.g. hip extension where the former “antagonist” may perform now in concentric contraction while its “opposing” muscle may perform eccentrically. While this may be the case in some uncommon conditions such as stroke, it is not the case in asymptomatic individuals or in any individuals with intact central and peripheral innervation and musculature.

Furthermore, while the original concept may find some application in directly opposing joint/muscular motions like flexion & extension, the concept applies poorly to segments of motion such as rotation, abduction & adduction.

The advent of the ability to test the electrical activity of skeletal muscles with SEMG allowed for new vistas in kinesiologic research. The statistical applications of the objectively derived SEMG data of electrical amplitude potentials through the different segments of motion of a given joint like the hip and its subtending muscles allowed for the differentiation of muscular activity in asymptomatic or symptomatic conditions.

In the case of the hip region, one can test the myotatic unit muscles in asymptomatic vs. symptomatic conditions, e.g. pain & dysfunction. The present study examined the following muscles in asymptomatic individuals: adductor magnus, biceps femoris, gluteus maximus, TFL, rectus femoris, gluteus medius, vastus lateralis and vastus medialis. The muscles have been tested through the segmental motions of hip extension, flexion, external rotation, internal rotation, adduction and abduction.

The data of the amplitude potentials of these muscles through the hip region ROM in asymptomatic muscles were treated statistically further by comparing the muscles in terms of correlation coefficients (r) analysis.

The comparisons result in correlation data which are either positive or negative, according to the tendency of any muscle to become more or less active through a given segment of motion, especially by comparison with its neighbors from the same myotatic unit. Such data could then be clinically interpreted in terms of correlational relationships of muscular agonism (synergism) or antagonism.

The positive correlation coefficients are defined as muscular synergism or agonism.

Negative correlation coefficients define muscular antagonism. Stabilizer relationships are defined as those where the correlations are only minimal, i.e. $\pm \leq 0.10$.

Thus, the old concept of agonism & antagonism, never tested scientifically, could be objectified and re-interpreted in the light of the new technology. In a number of cases, the old assumptions were found to hold, in a number of other cases, they did not. The correlation coefficients among the muscles tested through major joints/ regions ROM have been calculated and published in a number of textbooks and articles. [1, 2, 3, 4, 5]

The present article describes the actual modality of the testing which allows for the statistical results that, in turn, define the functional inter-muscular and inter-segmental motion relationships of agonism & antagonism of the myotatic unit of the hip region in asymptomatic conditions.

Methods

An SEMG dynamic protocol of testing of the hip muscles through the hip region ROM has been utilized for the purpose of defining the muscular correlation coefficients described in the present article. The actual protocol has been described in detail in several publications. [4, 6]

-Participants: 36 asymptomatic individuals underwent the hip ROM testing with SEMG. The gender division was about equal. The age ranged between 19-69. Eight hip muscles were utilized for the testing: the adductor magnus (N=36), biceps femoris (N=39), gluteus maximus (N=35), TFL (N=36), rectus femoris (N=33), gluteus medius (N=36), vastus lateralis (N=36) and vastus medialis (N=33). The utilization through the testing was bilateral. All the participants were able to perform a full hip region ROM, with no joint or myofascial restrictions.[7, 8] The testing was performed at the effort level of minimal voluntary contraction. The position for hip extension was prone. The position for hip flexion, abduction, adduction, external & internal rotation was supine. The ROM was performed to the maximal degree possible for each participant.[9]

-Equipment: the testing has been conducted on Myovision 3000 SEMG equipment, 8 channels of SEMG.[6] The specifications of the equipment were as follows.[6]

Input Impedance:	1,000,000 MegOhms
Resolution:	10 Bit A/D
Safety:	5000 Volt optical Isolation
Power Supply:	UL Medical Transformer
Filtering:	25-5000 Hz Wideband
Range:	Scanning at 0.08 – 200 Microvolts
Calibration:	Lifetime through AutoCal

The testing was conducted after calibrating the equipment according to the manufacturer's instructions before each examination.

The SEMG electrodes were of the Ag/AgCl gel type. The electrode placements on the hip muscles were done in the standardized positions described in the textbooks.[10, 11]

-Procedure: the testing protocol was such that each segment of motion amplitude potential was measured through five repetitions of hip segmental activity and rest, each motion being tested through 7 seconds of activity at the minimal effort of contraction (eccentric or concentric minimal voluntary effort) and a 2 second period of ‘return to resting state’. The activity potentials were calculated from the average potentials of the five repetitive motions. The resting potentials were calculated as the average of the five ‘minimal tonus’ potentials. Each resting period lasted 9 seconds, in the inter-activity period.

The positioning of the individuals tested was performed according to the instructions given in standardized texts.[9, 10, 11] Hip extension has been tested in the prone position. All the other hip ROM segments have been tested in the supine position.

All persons tested agreed with the examination and were informed about its purpose and lack of invasiveness. The participants were instructed beforehand how to proceed with the testing. No participant had any hip region restrictions, myofascial or neuromuscular symptoms.

In summary, the data described and discussed below are a compilation of the statistics gathered from the testing of 284 muscles tested through 6 segments of hip ROM, each segment measured through 5 repetitions of full motion. The data derived from the motions of rotation and bending were averaged in terms of laterality. Thus, the data derive from a total of (284 x 6 x 5) = 8,520 measurements. The data consisted of activity & resting potentials calculated by the software in terms of microvolt RMS (µV RMS) SEMG values of amplitude domain.

The data obtained from the testing were utilized for the compilation of statistics for the purpose of establishing the correlation coefficients (r) necessary for the understanding of the inter-muscular and inter-segmental relationships of agonism and antagonism.

The following statistics were compiled from the data:

a) Similar statistics compiled for each muscle tested, (N);

b) Average activity potential amplitude values (µV RMS) of each hip segmental motion for each muscle, mean value for the 5 repetitions of each motion, mean value for the number of muscles (N);

c) Average of the minimal resting potential amplitude values (µV RMS) of each hip segmental motion for each muscle, mean value for the 5 repetitions of resting in-between each motion, mean value for the number of muscles (N);

d) Standard deviation (S.D.), standard error (S.E.) and lower & upper 95% confidence intervals (<95% & >95% C.I.) values for the average amplitude potentials of muscular hip segmental motions, for each muscle tested;

e) Statistics of correlation coefficients (C.C., r) among the eight hip muscles & six segments of motion tested.

Results

The results are tabulated in the tables below.

Table1. Activity potentials (µV RMS) data of 8 hip muscles tested through six hip ROM segments of motion with SEMG.

See Excel Table 1 at the end of the article

Table 1 shows the statistics of the activity potentials of hip muscular activity in the six segmental motions tested.

The data show that the biceps femoris muscle is the most active of the myotatic group tested at the minimum effort of motion level. The ranking in terms of overall amplitude of activity is the following: biceps femoris, vastus medialis, rectus femoris, TFL, vastus lateralis, adductor magnus, gluteus maximus and gluteus medius.

There is an obvious range of average segmental activity for each muscle tested. Of all values of the eight muscles, abduction of the biceps femoris shows the highest activity (27.6 µV RMS) amplitude and external rotation of the gluteus medius shows the lowest amplitudes (3.04 µV RMS).

The average amplitude of electrical activity potentials for the 8 muscle group moving through the hip region ROM was 8.5 µV RMS.

In general, the lower and upper 95% confidence intervals (C.I.) were 10.3% & 9.5% lower & higher respectively than the average amplitude values for the group.

The average activity/ rest ratio (A/R) for the group as a whole was 7.0. This represents the ratio of the overall segmental activity of the hip ROM for the 8 muscles above to the overall minimal resting potentials for the muscles tested.

The average minimal resting potential tonus for the group was 1.94 μV RMS, a well expected value for resting potentials for the skeletal muscles tested as a whole.[1, 9, 10]

An examination of the probability (Prob. > F) value for each motion tested showed a non-significant difference for the six segments of motion as a whole. The average Prob. > F value for the 8 muscles tested was 0.00021.

The process of normalization of the overall averages of amplitude potentials of each segment of motion to the average of the ROM group as a whole showed that the normalized segmental ranking (%) was as follows: abduction (160.5%), extension (136.2%), adduction (125.9%), flexion (78.5%), internal rotation (54.3%) & external rotation (44.6%) of the hip.

Table 2: Hip muscles correlation coefficients

See Excel Table 2 at the end of this article

Table 2 shows the positive and negative correlation coefficients calculated from the comparisons muscle to muscle through the six segments of hip ROM tested with SEMG for the 8 muscles.

It may be of note that each muscle showed a different pattern in terms of correlation coefficients, i.e. agonism or antagonism with the other muscles in the hip myotatic unit.

Gluteus maximus showed the highest synergism (agonism) with gluteus medius (r= 0.98) and the least with rectus femoris (r=0.25). It showed one antagonist correlation, with TFL (r=-0.35). Gluteus maximus showed two stabilizing correlations with vastus lateralis & medialis at r=0.05 and –0.05 respectively.

Biceps femoris showed the highest agonist relationship, r=0.88 with gluteus medius and its lowest agonist relationship, r=0.11 with vastus medialis. It showed no antagonist relationship with any muscle in the group. It showed a stabilizing relationship with TFL (r=-0.02).

Rectus femoris showed the highest agonist relationship, r=0.91 with the vastus medialis and its lowest agonist relationship, r= 0.18 with gluteus medius. It showed no antagonist relationship and no stabilizing relationship with any muscle in the group.

TFL showed the highest agonist relationships, r=0.91 with the vastus lateralis and medialis. Its lowest agonist relationship, r= 0.59 with adductor magnus. It showed moderate antagonist relationships, r=-0.35 and r=-0.34 with the gluteus maximus and medius. It showed a stabilizing relationship with biceps femoris, r=-0.02.

Vastus lateralis showed the highest agonist relationships, r=0.91 with the vastus medialis and TFL. It showed the lowest agonist relationship, r=0.35 with biceps femoris. It showed no antagonist relationships It showed two stabilizing relationships with the gluteus medius and maximus, r=0.07 and r=0.05 respectively.

Adductor magnus showed the highest agonist relationship, with rectus femoris, r=0.84 and its lowest agonist relationship with biceps femoris, r=0.41. It had no antagonist or stabilizing relationships with the other muscles tested.

Gluteus medius showed the highest agonist relationship, with gluteus maximus, r=0.98 and its lowest with rectus femoris, r=0.18. It had one antagonist relationship with TFL, r=-0.34. It had two stabilizing relationships, with vastus medialis and lateralis at r=-0.10 and r=0.07 respectively.

The hip muscles tested with SEMG in the present study are anatomically located on the posterior, anterior, lateral and medial aspects of the hip and thigh. In theory, the extensor & flexor groups should have had clear antagonistic relationships according to the old dogma.

However, the old dogma took into consideration only the motions of flexion, extension, abduction & adduction while other motions such as internal or external rotation were ignored. Thus, the old theory could not withstand the stresses of actual scientific testing.

Table 3: Average SEMG amplitude potentials (μV RMS) of the 8 muscles tested with SEMG through the hip region ROM segments

See Excel Table 3 at the end of this article

Table 3 shows the average values of the SEMG amplitude potentials of the 8 muscles tested through the hip ROM. The extension segment has the highest amplitude potentials range difference among the motions. The external rotation motion showed the lowest amplitude potentials range difference, in this study performed in the supine or prone position at the minimal voluntary contraction level of effort.

Within each segment of motion one can find different patterns of effort for each muscle tested. Large amplitude potentials differences were found in the case of the biceps femoris and vastus medialis. Adductor magnus, gluteus maximus & medius showed only small differences in the activity amplitude potentials among the six hip motions.

Table 4: Correlation coefficients of the hip ROM segments of 8 muscles tested with SEMG

See Excel Table 4 at the end of this article

Table 4 shows the correlation coefficients among the six hip region segments of motion as derived from the testing of the adductor magnus, biceps femoris, gluteus maximus, TFL, rectus femoris, gluteus medius, vastus lateralis and vastus medialis muscles with the SEMG dynamic protocol. The data show only positive correlations coefficients (r). The highest positive correlation between two motions was found between adduction and external rotation. The lowest was found between internal and external rotation. Most of the correlations among the six different hip motions were of stabilizing type.

Chart 1 depicts the amplitude potentials of the 8 muscles tested through the hip ROM. It is clear that the biceps femoris and vastus medialis could be grouped separately from the other muscles tested in terms of the overall pattern of relatively high levels of amplitude potentials achieved in the six hip motions tested. No muscle tested showed a rather uniform pattern of activity, the closest exception being the adductor magnus. Each muscle showed at least one or two relatively low amplitudes of segmental motions. The most active muscle was the biceps femoris and the least active was the gluteus medius.

Chart 2 depicts the pattern of energy of amplitude potentials required for each muscle & motion as noted when ranked from high energy to low energy expenditure. Normalization of the values was calculated via the ratio (%) of each value from the eight muscles and six motions by dividing it to the average value of the group as a whole, i.e. 8.5 μV RMS. The slope descends rather abruptly after the 5th muscles/motions and then rather smoothly for the rest of the 48 muscle/motion values.

The implications of the meaning of this graph in terms of the rehabilitation and ergonomic fields are discussed below.

Discussion

The data shown in Tables 1-4 and bar graphs 1 & 2 aim at re-defining the old concepts of muscular agonism (synergism) and antagonism in the realm of the hip muscles tested through the classic ROM segments.[7, 12, 13] In this study, the hip ROM tested with SEMG was conducted in the prone position for the hip extension segment of motion and in the supine position for the other 5 segments. The testing was performed at the minimal effort of contraction level (minimal voluntary contraction).

The aim of the study was to define statistically the amplitude potential values through the activity and resting phases of the dynamic testing. The data were first computed in terms of averages of amplitude potentials from the 5 repeated motions and resting phases compiled from each of the six segments of motion. In terms of the calculation of the correlation coefficients, necessary for the interpretation in clinical terms of the concept of muscular agonism &

antagonism, the values were computed further in terms of positive and negative correlation coefficient statistics, as calculated from the amplitude potentials values of energy expended by the various hip muscles through the classic ROM of the hip, as tested with SEMG dynamic studies.

A review of pertinent literature finds the expressions of muscular agonism and antagonism as functional, historical expressions without specific definitions.[12, 13]

The Gray's Anatomy textbook does not even contain the words in its index.[12]

The Stedman's Medical Dictionary defines agonist as "*denoting a muscle in a state of contraction, with reference to its opposing muscle, or antagonist."* The definition of antagonist is "*that which opposes or resists the action of another; denoting certain muscles…. that tend to neutralize or impede the action or effect of other muscles, etc.*

The definition of associated antagonist is that of "*one of two muscle or groups of muscles which pull in nearly opposite directions, but which, when acting together, move the part in a path between their diverging lines of action*".[13]

While the definitions above are enticing, they do not necessarily reflect objective functional relationships. Just noticing the anatomic position of a given muscle does not reflect necessarily on its activity through the range of motion (ROM) of the primary joint of action or region of activity. A study of the data in Table I show that **all** the eight hip region muscles are active through the six classic segments of hip ROM.

The data in Table 3 point clearly to the fact that each muscle tested has its own pattern of energy expenditure through the hip ROM, as determined by the testing performed with the SEMG dynamic protocol. Theoretical expectations were that any given muscle would expend more energy in movements requiring a concentric contraction rather than an eccentric one.

If that were the case in reality, then the rectus femoris would have expended more energy during flexion (12.2 μV) than extension (13.3 μV). This was not the case. Both abduction (17.9 μV) and adduction (17.2 μV) required almost the same amount of energy expenditure. Internal rotation (7.9 μV) required more than double the energy of motion compared to external rotation (3.4 μV), whereas both motions are torsions rather than eccentric or concentric contractions. Therefore, the theoretical expectation does not prove to be true in reality. The same would apply to all the other muscles tested in the group.

The dictionary definition, reflective of the old thought, considers agonism & antagonism only within the perspective of two opposing motions. Yet, with the exception of the knee, all other major joints have a larger number of classic segments of motion.[9, 10] In the case of the hip, the classic range of motion involves the unequal balance of abduction (50°) and adduction (35°), flexion (135°) and extension (20°) as well as the internal (30°) and external (45°) rotation. The muscles of the hip are indeed found on the anterior aspect, e.g. rectus femoris, posterior aspect, e.g. biceps femoris, gluteus maximus and medius, lateral aspect, e.g. TFL & vastus lateralis and medial aspect, e.g. vastus medialis and adductor magnus. The muscles tested within the framework of this study are not all the hip muscles, however, they are quite representative of the overall hip and thigh musculature. Thus, since the opposing motions are not equal, it would be difficult to begin with to see a perfect opposition or antagonism.

Until the advent of SEMG dynamic studies and protocols, it was rather difficult to identify and measure the activity pattern of discrete muscles within a myotatic unit and within a given joint or region classic ROM.

This modern technique allows for the simultaneous bilateral measurement of the electrical potentials of amplitude values of different muscles through a given set of segments of motions. Thus, one can identify the pattern of electrical amplitude of potentials for any segment of motion tested for a group of muscles such as a myotatic unit. This may apply equally well to asymptomatic muscles whose activity and resting potentials (μV RMS) have been described in the tables above and to symptomatic & dysfunctional muscles described elsewhere.[1]

The 8 hip muscles tested with SEMG described above are strongly representative of the hip/thigh myotatic unit in terms of primary tendinal insertion & vector of action as well as direct inter-connecting fascia.

The ranking pattern from high to low shown in Tables 1 & 3 in terms of the muscles tested and the hip segments of motion has relevance both in terms of ergonomic planning and in terms of muscular rehabilitation or optimization.

It is relevant to note that there is a difference of 427% in the average activity amplitude pattern between the highest and lowest ranking muscle, i.e., the biceps femoris and the gluteus medius, whereas there is only a difference of 360% in terms of the highest and lowest segments of motion ranking, i.e., abduction and external rotation.

Thus, a clinician involved in the hip region muscle rehabilitation, may consider appropriately those findings in terms of neuromuscular rehabilitation investigation and planning.[1, 9, 10, 11, 14, 15, 16, 17, 18, 19]

Table 4 represents the correlation coefficients (r) calculated from the segmental data of the 8 muscles tested through the hip region ROM with SEMG.

If the respected old time definition of antagonism between two motions were to hold, then the hip motions of flexion & extension should have shown a negative correlation, corresponding with the concept of antagonism. However, the correlation showed an r = 0.02, which is by definition, a stabilizing correlation, not even a synergistic correlation. Therefore, the reality of having 8 muscles directing joint activity through the two motions supercedes the theoretical concept of antagonism, based on the anatomical observations of muscular positions on opposite sides of a given bone and acting “primarily” in concentric or eccentric contraction. In fact, thirteen of the fifteen correlations are just within the framework of stabilizing relationships and only two correlations, i.e. between adduction & external rotation and internal rotation & external rotation are weak agonistic correlations. As the data in Table 1 and 3 show, the 8 muscles act through the six segments of hip region motion, either in concentric, eccentric or in a rotational (torsional) contraction.

Thus, the old concept can no longer be considered valid in the case of the hip ROM, in the face of the reality of muscular electrical activity, which represents the energy expenditure through the range of motion. Therefore, those results document the fact that scientific verification of energy expenditure of muscles in motion with SEMG testing should be done to understand the true meaning of muscular agonism and antagonism within the framework of concentric vs. eccentric contraction.

The four tables from the results section aim to redefine the concepts of muscular agonism (synergism) and antagonism. The data show clearly that the muscles of a primary myotatic unit are active through any primary joint segment of ROM, whether they act in a concentric or eccentric contraction. The data rebuke the old concept that the "agonist is active" and the "antagonist is inhibited" through the concentric contraction of the agonist. Those old concepts do not correspond to the reality shown by the SEMG dynamic studies and, in fact, have never been demonstrated by any in vivo studies of any kind.

The data show not only the dynamic, functional relationships among the 8 muscles of the hip region myotatic unit but also among the six segments of motion tested.

Table 2 shows that of the 28 possible correlational relationships there are 2 antagonist relationships among the muscles tested, 21 agonist (synergist) and 5 stabilizer relationships.

Thus, the hip region ROM is imbalanced in terms of agonist & antagonist relationships among the muscles tested.

What are the potentials applications of the new knowledge from the data described in this article in the field of hip muscular dysfunction and pain?

Studies have shown that dysfunctional muscles presenting with loss of strength and pain generally show high levels of amplitude potentials both at rest and during motion.[1] This has been shown to be the case in over 500 different muscles from various parts of the body, including the hip.[1, 20]

When treated statistically in comparison with non-symptomatic muscles, those dysfunctional muscles show > 25% higher amplitude potentials both at rest and during any segment of motion. Physiological logic could document that muscles that are overworking and utilizing more energy than normal may fatigue earlier. Fatigue itself can promote both pain and general weakness and secondary deconditioning.

Thus, if a clinician finds SEMG derived amplitude potentials abnormally high at rest and during different segments of a given primary joint ROM, the relationship between that given muscle and the other muscles in its primary myotatic unit may be different than expected, according to the present data.

Thus, the clinician would have the objective, numerical realization of the need to rehabilitate the given muscle in terms of various therapy modalities, including pain management and SEMG/biofeedback. The endpoint of such therapy should be in symptomatic terms that the given muscle should no longer show weakness or pain and in SEMG testing terms that it should show resting and activity potentials within the expected range.[21] In terms of the hip region muscles, normalization of such values would be compatible with lack of symptoms and normal hip strength.[1, 20]

Within the ergonomic field, the specialist will aim to construct machinery or work environments that conform to the application of the least effort through hip motions performed by the above muscles. In a practical vein, one would want to build machinery that would utilize the biceps femoris, vastus medialis, rectus femoris, TFL, vastus lateralis, adductor magnus, gluteus maximus & medius preferably in minimal effort hip external rotation and avoiding abduction and extension. Within the ergonomic/ sports arena, one would want to involve the muscles in such a way that they react with the least amount of electrical effort through the hip ROM, paralleled by the least amplitude potentials.

Thus, the athletic trainer may utilize the data from Tables 1 & 3 as the databases for comparison with the hip muscular effort performed before training by the participants and aim to reduce that effort as far as possible to within the limits shown.

The same argument applies within the ergonomic or athletic fields in terms of the correlation coefficients noted on Tables 2 & 4. One can compare the pre-training data of correlation coefficients of the hip muscles & motions to the data shown on those tables and aim at improving the overall correlational values either among muscles or among the hip segments of motion tested to conform to those shown in the tables and / or improve on them.

The limitations of the present study are twofold: (1) the overall accuracy of the potential amplitude results will increase as more muscles in the same group will be tested simultaneously in the future; (2) the hip myotatic unit comprises several more muscles, which need to be tested within the same framework. When all the muscles that could be tested with SEMG will be studied, the added weight of those data will increase the accuracy of the conclusions in line with the present study.

Conclusions

In summary, the old concept of muscular and hip region motion relationships of agonism & antagonism has been revisited in new light. SEMG dynamic protocols have been utilized to demonstrate the actual electrical amplitude potentials derived from the movements & activity of each hip muscle affecting the hip through each classic hip region ROM. The results demonstrated a number of 21 positive, 2 negative correlations and 5 stabilizer correlations (r) among the hip muscles tested through the six segments of hip motion. The results were clinically interpreted in terms of agonism & antagonism among the 8 muscles tested.

When the data were calculated in terms of the correlation coefficients (r) among the six segments of motion, it resulted in only positive correlations, of agonist type.

Thus, the old concept of muscular or hip region motion agonism & antagonism has been modernized and objectivized with the technique of SEMG dynamic testing of the muscles pertaining to a primary hip myotatic unit.

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Table 1: Activity potentials (µV RMS) data of 8 hip muscles tested through six hip ROM segments of motion with SEMG.

Muscle N = 39	**Avg**	**SD**	**SE**	**< 95% CI**	**> 95% CI**	**A/R avg**	**Norm**
Biceps Femoris						**13.4**	
Flexion	10.1	3.6	0.58	8.9	11.2		50.1%
Extension	42.4	6.6	1.1	40.3	44.4		210.2%
Abduction	27.6	8.7	1.4	24.8	30.3		136.9%
Adduction	12.5	2.8	0.45	11.6	13.4		62.0%
Internal Rotation	16	9.5	1.5	13	19.01		79.3%
External Rotation	12.4	5.7	0.92	10.5	14.2		61.5%
Avg Activity	20.2	6.2	1.0	18.2	22.1		
Min Rest	1.5	1.05	0.13	1.2	1.7		
Muscle N = 33	**Avg**	**SD**	**SE**	**< 95% CI**	**> 95% CI**	**A/R avg**	**Norm**
Vastus Medialis						**12.4**	
Flexion	18.6	3.7	0.61	17.4	19.8		107.3%
Extension	12.2	2.7	0.44	11.3	13.1		70.4%
Abduction	36.7	9.1	1.5	33.8	39.7		211.7%
Adduction	28.9	7.4	1.2	26.6	31.3		166.7%
Internal Rotation	3.8	2.6	0.43	2.9	4.6		21.9%
External Rotation	3.8	1.3	0.21	3.4	4.2		21.9%
Avg Activity	17.3	4.5	0.73	15.9	18.8		
Min Rest	1.4	1.2	0.27	0.85	2		
Muscle N = 33	**Avg**	**SD**	**SE**	**< 95% CI**	**> 95% CI**	**A/R avg**	**Norm**
Rectus Femoris						**8.0**	
Flexion	12.2	3.1	0.54	11.2	13.3		101.8%
Extension	13.3	3.7	0.65	12.1	14.6		111.0%
Abduction	17.9	4.05	0.7	16.5	19.3		149.4%
Adduction	17.2	3.6	0.63	15.9	18.4		143.5%
Internal Rotation	7.9	2.9	0.51	6.9	8.9		65.9%
External Rotation	3.4	1.1	0.19	3.1	3.8		28.4%
Avg Activity	12.0	3.1	0.5	11.0	13.1		
Min Rest	1.5	1.4	0.14	1.2	1.8		
Muscle N = 36	**Avg**	**SD**	**SE**	**< 95% CI**	**> 95% CI**	**A/R avg**	**Norm**
TFL						**9.1**	
Flexion	7.7	2.4	0.4	6.9	8.5		65.3%
Extension	5.3	1.7	0.28	4.8	5.9		45.0%
Abduction	24.3	9.4	1.6	21.2	27.4		206.2%
Adduction	19.7	5.1	0.85	18	21.4		167.2%
Internal Rotation	8	3.7	0.62	6.8	9.2		67.9%
External Rotation	5.7	1.5	0.25	5.2	6.2		48.4%
Avg Activity	11.8	4.0	0.7	10.5	13.1		
Min Rest	1.3	0.95	0.1	1.1	1.5		

Table 1: Activity potentials (µV RMS) data of 8 hip muscles

tested through six hip ROM segments of motion with SEMG. (Continued)

Muscle N = 36	**Avg**	**SD**	**SE**	**< 95% CI**	**> 95% CI**	**A/R avg**	**Norm**
Vastus Lateralis						**5.4**	
Flexion	3.3	1.2	0.2	2.8	3.7		43.6%
Extension	7.7	2.6	0.44	6.9	8.6		101.8%
Abduction	16.1	4.1	0.68	14.8	17.5		212.8%
Adduction	12.9	3.9	0.65	11.7	14.2		170.5%
Internal Rotation	2.7	0.45	0.07	2.6	2.9		35.7%
External Rotation	2.7	0.5	0.08	2.5	2.8		35.7%
Avg Activity	7.6	2.1	0.4	6.9	8.3		
Min Rest	1.4	0.94	0.22	0.97	1.8		
Muscle N = 36	**Avg**	**SD**	**SE**	**< 95% CI**	**> 95% CI**	**A/R avg**	**Norm**
Adductor Magnus						**1.7**	
Flexion	5.8	2.4	0.4	5	6.5		85.1%
Extension	8.6	3.6	0.6	7.4	9.8		126.2%
Abduction	8.2	3.6	0.6	7.1	9.4		120.3%
Adduction	10.1	3.7	0.62	8.9	11.3		148.2%
Internal Rotation	3.5	1.8	0.3	2.9	4.1		51.3%
External Rotation	4.7	0.95	0.16	4.4	5.1		68.9%
Avg Activity	6.8	2.7	0.4	6.0	7.7		
Min Rest	4.04	3.7	0.45	3.2	4.9		
Muscle N = 35	**Avg**	**SD**	**SE**	**< 95% CI**	**> 95% CI**	**A/R avg**	**Norm**
Gluteus Maximus						**3.6**	
Flexion	6.6	0.57	0.1	6.4	6.8		106.7%
Extension	16.7	3.6	0.61	15.5	17.9		270.1%
Abduction	4.2	1.8	0.31	3.6	4.8		67.9%
Adduction	4.3	1.4	0.23	3.9	4.8		69.5%
Internal Rotation	2.5	0.44	0.07	2.4	2.6		40.4%
External Rotation	2.8	0.58	0.01	2.6	3		45.3%
Avg Activity	6.2	1.4	0.2	5.7	6.7		
Min Rest	1.7	1.8	0.17	1.4	2.04		
Muscle N = 36	**Avg**	**SD**	**SE**	**< 95% CI**	**> 95% CI**	**A/R avg**	**Norm**
Gluteus Medius						**2.1**	
Flexion	3.5	0.9	0.15	3.2	3.7		77.4%
Extension	11.4	3.4	0.57	10.3	12.5		252.0%
Abduction	3.6	0.73	0.12	3.3	3.8		79.6%
Adduction	3.1	0.76	0.13	2.8	3.3		68.5%
Internal Rotation	2.5	0.53	0.09	2.3	2.7		55.3%
External Rotation	3.04	0.58	0.1	2.9	3.2		67.2%
Avg Activity	4.5	1.2	0.2	4.1	4.9		
Min Rest	2.15	3.6	0.41	1.3	3		

Table 1: Activity potentials (μV RMS) data of 8 hip muscles
tested through six hip ROM segments of motion with SEMG. (Continued)

Muscle N = 284	Avg	SD	SE	< 95% CI	> 95% CI	A/R avg	Norm
Average Muscular Potentials						7.0	
Flexion	8.48	2.23	0.37	7.73	9.19		78.5%
Extension	14.70	3.49	0.59	13.58	15.85		136.2%
Abduction	17.33	5.19	0.86	15.64	19.03		160.5%
Adduction	13.59	3.58	0.60	12.43	14.76		125.9%
Internal Rotation	5.86	2.74	0.45	4.98	6.75		54.3%
External Rotation	4.82	1.53	0.24	4.33	5.31		44.6%
Avg Activity	10.79	3.13	0.52	9.78	11.81		
Min Rest	1.94	1.92	0.23	1.48	2.39		

Table 2: Hip muscles correlation coefficients (r) among the 8 muscles tested with SEMG

Muscles	Biceps Femoris	Gluteus Maximus	Gluteus Medius	Rectus Femoris	TFL	Vastus Lateralis	Vastus Medialis
Adductor Magnus	0.41	0.42	0.40	0.84	0.59	0.82	0.75
Biceps Femoris		0.81	0.88	0.33	-0.02	0.35	0.11
Gluteus Maximus			0.98	0.25	-0.35	0.05	-0.05
Gluteus Medius				0.18	-0.34	0.07	-0.10
Rectus Femoris					0.77	0.87	0.91
TFL						0.91	0.91
Vastus Lateralis							0.91

Table 3: Average SEMG amplitude potentials (μV RMS) of the 8 muscles tested with SEMG through the hip ROM segments

		Hip Region ROM Segments						
Muscle	*Minimum Rest*	*Abduction*	*Extension*	*Adduction*	*Flexion*	*Internal Rotation*	*External Rotation*	*Avg*
Biceps Femoris	1.5	27.6	42.4	12.5	10.1	16	12.4	***12.8***
Vastus Medialis	1.4	36.7	12.2	28.9	18.6	3.8	3.8	***8.7***
Rectus Femoris	1.5	17.9	13.3	17.2	12.2	7.9	3.4	***7.8***
TFL	1.3	24.3	5.3	19.7	7.7	8	5.7	***7.1***
Vastus Lateralis	1.4	16.1	7.7	12.9	3.3	2.7	2.7	***2.9***
Adductor Magnus	4.0	8.2	8.6	10.1	5.8	3.5	4.7	***4.7***
Gluteus Maximus	1.7	4.2	16.7	4.3	6.6	2.5	2.8	***4.0***
Gluteus Medius	2.2	3.6	11.4	3.1	3.5	2.5	3.04	***3.0***
Average	***1.9***	***17.3***	***14.7***	***13.6***	***8.5***	***5.9***	***4.8***	***8.5***

Table 4: Correlation coefficients of the hip ROM segments of the 8 muscles * tested with SEMG

ROM segment	Extension	Abduction	Adduction	Internal Rotation	External Rotation
Flexion	0.02	0.08	0.01	0.09	0.01
Extension		0.07	0.01	0.0001	0.04
Abduction			0.09	0.0001	0.0003
Adduction				0.0004	0.21
Internal Rotation					0.20

CHART 1

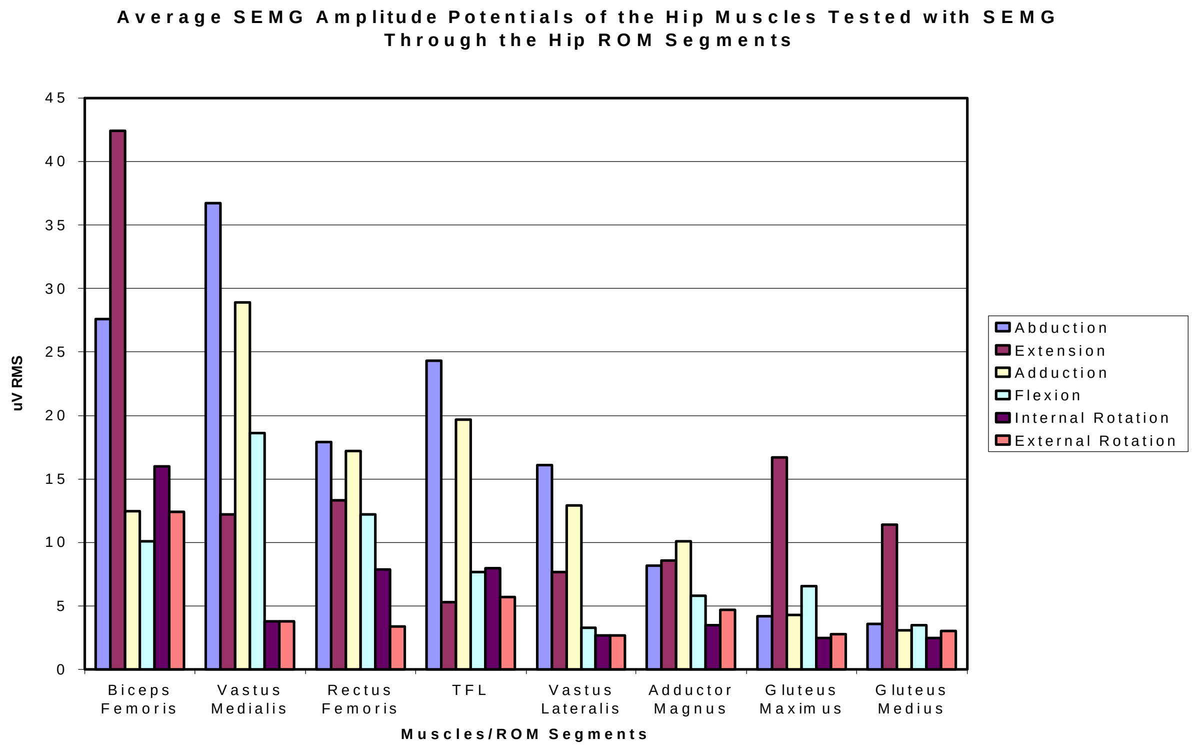
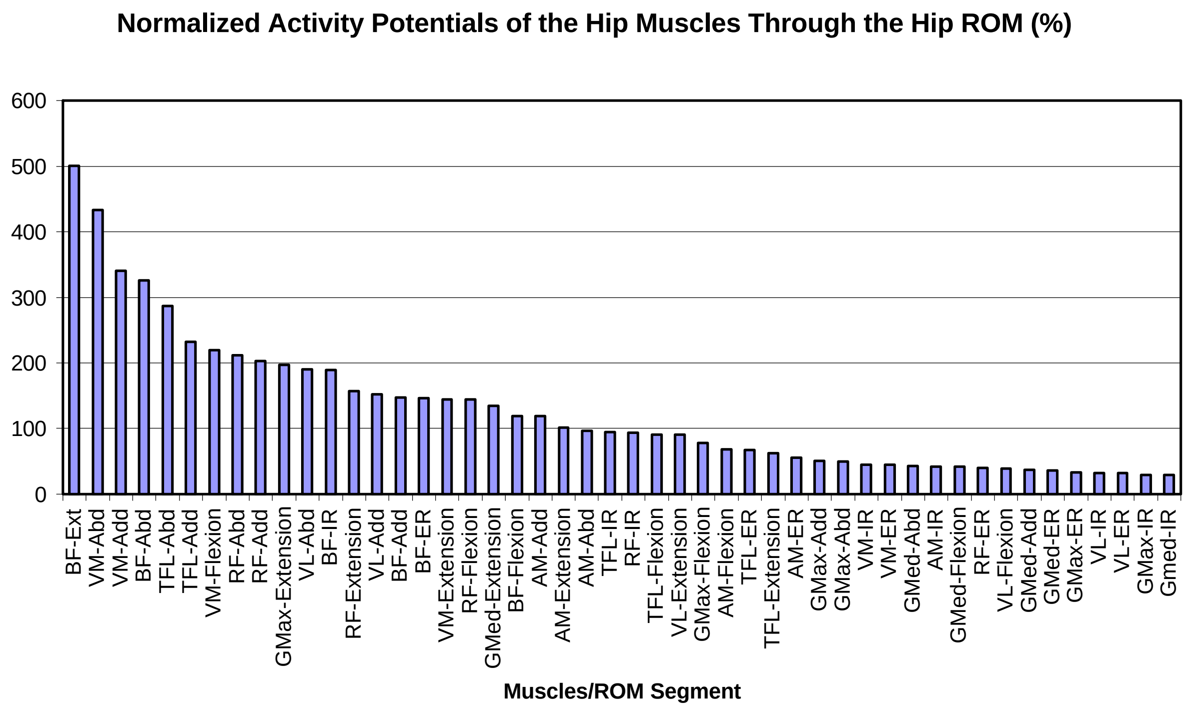


CHART 2


Normalized Activity Potentials of the Hip Muscles Through the Hip ROM (%)
600
500
400
300
200
100
0
BF-Ext
VM-Abd
VM-Add
BF-Abd
TFL-Abd
TFL-Add
VM-Flexion
RF-Abd
RF-Add
GMax-Extension
VL-Abd
BF-IR
RF-Extension
VL-Add
BF-Add
BF-ER
VM-Extension
RF-Flexion
GMed-Extension
BF-Flexion
AM-Add
AM-Extension
AM-Abd
TFL-IR
RF-IR
TFL-Flexion
VL-Extension
GMax-Flexion
AM-Flexion
TFL-ER
TFL-Extension
AM-ER
GMax-Add
GMax-Abd
VM-IR
VM-ER
GMed-Abd
AM-IR
GMed-Flexion
RF-ER
VL-Flexion
GMed-Add
GMed-ER
GMax-ER
VL-IR
VL-ER
GMax-IR
Gmed-IR
Muscles/ROM Segment