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Research Article

EVALUATION OF IRRADIATION BY SCAPULAR PNF PATTERNS ON FOREARM MUSCLES USING SURFACE ELECTROMYOGRAPHY IN HEALTHY FEMALES

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ABSTRACT
Proprioceptive Neuromuscular Facilitation (PNF) is a concept of treatment in which the basic philosophy considers that every human, including those with disabilities, has an untapped existing potential. Among the proprioceptive neuromuscular facilitation principles, resistance and irradiation procedures are considered most effective as resisting the stronger movements of the patient gives maximum benefit to the patient. The quantifiable information regarding the bioelectrical state of a muscle is hidden in the time-varying spatial distribution of potentials in the muscle, and can be recorded through an electromyographic recording. Scapula is involved in both motion and stability of the shoulder; as well as in functional activities such as rolling, overhead activities, transfers, reaching down, crossing midline, throwing activities etc. The main objective of the study was to investigate and measure the irradiation of individual pure scapular proprioceptive neuromuscular facilitation patterns on forearm flexor and extensor muscles and assist in identification and selection of the scapular proprioceptive neuromuscular facilitation patterns that maximize or minimize the electromyographic activity of wrist flexor and extensor muscles. The sample population was randomly divided into four groups A, B, C and D of 25 subjects each and was subjected to an individual pure scapular proprioceptive neuromuscular facilitation pattern, namely anterior elevation, posterior depression, posterior elevation and anterior depression respectively. The resulting irradiation was measured by recording the onset of activity of the forearm flexor and extensor muscles separately for each group using surface electromyography. Data was meaningfully assorted through calculations of Mean and Standard Deviation. Thereafter, paired 't' test was applied within groups A, B, C and D whish showed statistically significant results at 5% level of significance. Also, ANOVA was applied between the groups A, B, C and D which showed results that were statistically non significant.

Keywords: *Proprioceptive Neuromuscular Facilitation, Irradiation, Electromyography*

INTRODUCTION
Proprioceptive neuromuscular facilitation (PNF) is an approach to therapeutic exercise that combines functionally based diagonal patterns of movement with techniques of neuromuscular facilitation to evoke motor responses and improve neuromuscular control and function. This widely used approach to exercise was developed during the 1940s and 1950s by the pioneering work of Kabat, Knott, and Voss. Their work integrated the analysis of movement during functional activities with then current theories of motor development, control, and learning and principles of neurophysiology as the foundations of their approach to exercise and rehabilitation. Long associated with neuro-rehabilitation, PNF techniques also have widespread application for rehabilitation of patients with musculoskeletal conditions that result in altered neuromuscular control of the extremities, neck, and trunk. PNF techniques can be used to develop muscular strength and endurance; facilitate stability, mobility, neuromuscular control, and coordinated movements; and lay a foundation for the restoration of function. PNF techniques are useful throughout the continuum of rehabilitation from the early phase of tissue healing when isometric techniques are appropriate to the final phase of rehabilitation when high-speed, diagonal movements can be performed against maximum resistance. Hallmarks of this approach to therapeutic exercise are the use of diagonal patterns and the application of sensory cues—specifically proprioceptive, cutaneous, visual, and auditory stimuli—to elicit or augment motor responses. The patterns of movement associated with PNF are

composed of multi-joint, multi-planar, diagonal and rotational movements of the extremities, trunk and neck. Multiple muscle groups contract simultaneously. Embedded in this philosophy and approach to exercise is that the stronger muscle groups of a diagonal pattern facilitate the responsiveness of the weaker muscle groups (Kisner and Colby, 2007).

Although, the diagonal patterns can be used with various forms of mechanical resistance (e.g., free weights, simple weight-pulley systems, elastic resistance, or even an isokinetic unit), the interaction between the patient and therapist, a prominent feature of PNF, provides the greatest amount and variety of sensory input, particularly in the early phases of re-establishing neuromuscular control. Kabat and Knott developed techniques that use natural patterns of movement and thus stimulate the nervous system more effectively in the rehabilitation process (Houglam, 2005).

Motor function can be improved using Proprioceptive Neuromuscular Facilitation (PNF) (Voss and Ionta, 1985). The basic procedures of PNF were influenced by the works of Sir Charles Sherrington, a pioneer in research on spinal cord and motor control (Molnar and Brown, 2010). Numerous academic researchers supported this by indicating that among the basic procedures for proprioceptive neuromuscular facilitation, it is the Motor Irradiation (MI) which allows that weak and impaired muscles are activated by strong and preserved muscles. The spread of the motor response is proportional to the intensity, the duration of the stimulus and independent of sex, age or the presence of activity in untrained muscle or in the muscle group of application of PNF. In order to determine quantitatively and accurately the existence of spread of muscle response by virtue of irradiation, accurate equipment must be used. Several authors used electromyography (EMG) to evaluate the irradiation produced by PNF because is possible to record the activity of motor units that are recruited during muscle contractions. He also recognised that the concepts of PNF are followed rigorously worldwide (Nunes *et al.,* 2016).

Among the proprioceptive neuromuscular facilitation principles, resistance and irradiation procedures are considered most effective, as resisting the stronger movements of the patient gives maximum benefit to the patient. Irradiation is the spread of the response to stimulation. The magnitude of that facilitation is related directly to the amount of resistance. Proprioceptive reflexes from contracting muscles increase the response of synergistic muscles at the same joint and associated synergists at neighbouring joints. This facilitation can spread from proximal to distal and from distal to proximal. Antagonists of the facilitated muscles are usually inhibited. If the muscle activity in the agonists becomes intense, there may be activity in the antagonistic muscle groups as well through co-contraction. He also discussed that scapula is involved in functional activities such as rolling, overhead activities, transfers, reaching down, crossing midline, throwing activities etc. The scapula patterns are activated either for motion or stabilization within the upper extremity patterns and all the upper extremity patterns and scapula motions integrate together. The scapular patterns occur in two diagonals, namely, Anterior Elevation-Posterior Depression; and Posterior Elevation-Anterior Depression. While scapular elevation patterns are associated with arm flexion patterns, the scapular depression patterns are associated with arm extension patterns. Exercise of the scapula important for treatment of the neck, the trunk, and the extremities. The scapular muscles control or influence the function of the cervical and thoracic spine. Proper function of the upper extremities requires both motion and stability of the scapula. Exercise of the scapula can facilitate arm motion and stability by resisting scapular motion and stabilization, since the scapula and arm muscles reinforce each other (Adler *et al.*, 2003).

Scapular and glenohumeral musculature provide dual roles of mobility and stability for the shoulder girdle (Brumitt and Dale, 2009). The shoulder rehabilitation strategies should address proximal dysfunction in the kinetic chain first by targeting scapulothoracic dyskinesis (Kibler, 1998). The scapular diagonal patterns of proprioceptive neuromuscular facilitation, like all normal human functional motions are multi-planar and the scapular movements occur through mass movement patterns (Alter, 2004).

Irradiation is governed by the principle of training specificity that is, isometric or dynamic, and eccentric contractions cause greater strength gains when compared to concentric contractions (Clark and Patten, 2013). This strength gain can be propagated to the ipsilateral agonist muscle, to contralateral limb or having origin in trunk and irradiate for the lower and / or upper limbs. Irradiation is a useful principle for patients with muscle weakness in areas that cannot be directly worked or strengthened upon (Abreu *et al.*, 2015).

Irradiation is an effort for the functional mechanical stability, from a biomechanical view. PNF is used in therapeutic exercise as a special functional treatment approach. Its aim is to make the motion more effective, to improve the functions for everyday activities. Manual resistance is used, which stimulates the neuromuscular system and the propriocepters (Nemeth and Steinhausz, 2008).

Proprioceptive neuromuscular facilitation approach to therapeutic exercise suggests that the overflow effects would be in the inadequate muscular pattern. However, experimental evidence of what that inadequate pattern is lacking (Pink, 1981). The quantifiable information regarding the bioelectrical state of a muscle is hidden in the time-varying spatial distribution of potentials in the muscle, and can be recorded through an electromyographic recording (Henneberg, 2000). Electromyography (EMG) is an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the state of muscle fibre membranes. It is the electrical manifestation of the neuromuscular activation associated with a contracting muscle (Basmajin and De Luca, 1985).

Electromyography is the discipline that deals with the detection, analysis and use of the electrical signal that emanates from contracting muscles. Electromyography provides easy access to physiological processes that cause a muscle to generate force, produce movement, and accomplish the countless functions that allow us to interact with the world around us. The EMG signal is the electrical manifestation of the neuromuscular activation associated with a contracting muscle. The signal represents the current generated by the ionic flow across the membrane of the muscle fibres that propagates through the intervening tissues to reach the detection surface of an electrode located in the environment. It is a complicated signal that is affected by the anatomical and physiological properties of muscles and the control scheme of the nervous system, as well as the characteristics of the instrumentation used to detect and observe it (De Luca, 1997).

Electromyography (EMG) is a technical resource developed for evaluating and recording electrical activity produced by contractions of striated skeletal muscles. By recording electromyographic data it is possible to infer the variations in polarization of the muscle fibre membranes located between the recording electrodes and measure muscle activity for a particular task or posture (Christie *et al.*, 2009). Surface EMG (sEMG) is the more common method of measurement, since it is non-invasive and allows for continuous measurement (Subbu and Weiler, 2015).

MATERIALS AND METHODS

The research design of current study was experimental design. The subjects were selected through Simple Random Sampling Technique. The source of data was from among the female volunteer college students from All Saints Institute of Medical Sciences and Research, Ludhiana, Punjab.

For this purpose of eligibility, an inclusion criterion was set up as under:

- Female college students with age group 18-30 years
- Sedentary, who performed less than 20 minutes of physical activity in less than 3 days/week, in the last six months (Jakicic *et al.*, 2003)
- Baseline Manual Muscle Test (MMT) score equal to/greater than 4 for the following muscles:

Levator Scapulae, Rhomboids, Serratus Anterior, Latissimus Dorsi, Trapezius, Pectoralis Major and Minor.

At the same time, it became imperative to list out an exclusion criteria, as stated under:

- Individuals with history of cardiopulmonary problems requiring medical treatment
- Individuals with baseline Blood Pressure (BP) above 140/90mmHg
- Individuals reporting pain in shoulder or scapular region in the last six weeks
- Individuals with history of biomechanical/functional problems pertaining to shoulder and scapular region such as dislocation, subluxation, dyskinesis of scapula
- Individuals with recent history of rotator cuff tear/repair

- Individuals with history of an unhealed fracture or nerve damage of upper extremity
- Sensory motor dysfunction pertaining to the upper extremity

The Independent Variables in this research were hence designated as under:
Scapular Proprioceptive Neuromuscular Facilitation Patterns

- Scapular Anterior Elevation
- Scapular Posterior Depression
- Scapular Posterior Elevation
- Scapular Anterior Depression

Whereas, the Dependent Variable was indicated in the form of Electromyographic Activity of the given forearm muscles as under:

- Maximum Voluntary Isometric Contraction (MVIC), measure of the strength of the muscle.
- Peak Amplitude, the peak value during the whole cycle of all the trials.

Based on the inclusion and exclusion criteria, 100 female volunteer college students between age group of 18-30 years were selected by simple random sampling technique. Ethical and Informed consent was obtained. All selected subjects were randomly divided into four groups A, B, C and D i.e. 25 volunteers in each group. A lecture was held to ensure clear familiarity with the scapular motion patterns being administered, 48 hours prior to the study, for each group. In addition, to make sure that the participants understood and maintained the motion accurately, trial practices were carried out three times, before conducting the experiment.
Each of the groups was assigned to be representing one pure scapular proprioceptive neuromuscular facilitation movement to be tested upon them, namely

- Group A - Scapular Anterior Elevation
- Group B - Scapular Posterior Depression
- Group C - Scapular Posterior Elevation
- Group D - Scapular Anterior Depression

The recording instrument was securely arranged on a broad counter top. The apparatus set up was initiated by inserting a battery into the battery compartment. Lead wires were inserted into Channel A and into the reference plug hole of the equipment. The unit was then switched on and EMG mode was selected. A fibre optic cable was inserted to connect the unit's PC Database System to the computer available to line up the EMG onto the computer screen. All power cords were positioned well away from human entanglement and / or wet surfaces (Drewes, 2000). Through, the looped menu available on the unit; EMG parameters such as sound volume, work/rest time, number of trials, wide or narrow band setting and channel B on/off were adjusted as under:

- Sound volume was adjusted to moderate.
- Work/Rest time was set up at 5sec/ 20sec.
- The number of trials set up was three.
- Electrodes placed on the arms use WIDE BAND setting.
- Channel B was turned off. (Neurotrac ETS Operators Manual)

For the purpose of skin preparation, subjects were instructed to shave excess hair from the skin across the forearm. Alcohol rub was used to clean skin and remove dirt, oil or dead skin. For initial observations, the subject was seated in a comfortable and relaxed position (Rash and Quesada, 2006).
The attachment site of the active surface electrode for the forearm flexor (wide) bundle was on the ventral aspect of the forearm, approximately 5 cm distal to the elbow; while that of the reference electrode was 3-4 cm apart along the direction of the muscle fiber. The attachment site of the active surface electrode for the forearm extensor (wide) bundle was on the dorsal aspect of the forearm, approximately 5 cm distal to the elbow; while that of the reference electrode was 3-4 cm apart along the direction of the muscle fiber. The type of electrode placement for surface electromyographic activity recording is quasi-specific for behavioral test of flexion of wrist, and extension of wrist respectively. The wide placement, in case of forearm flexors, ensured volume-conducted pick up for flexor digitorum superficialis (FDS), flexor

digitorum profundus (FDP), flexor carpi radialis, flexor carpi ulnaris and flexor pollicis longus. The wide placement in case of forearm extensor muscle bundle ensured volume-conducted pick-up for extensor digitorum, extensor carpi radialis and extensor carpi ulnaris (Criswell, 2011).

The next step was to perform Maximum Voluntary Contraction (MVC) Normalization, prior to the test trials for each subject in all groups. This was performed because the amplitude (microvolt scaled) data in an EMG recording are strongly influenced by the given detection condition and can vary between electrode sites, subjects and even day to day measures of the same muscle site. The normalization to reference value, e.g. the maximum voluntary contraction (MVC) value of a reference contraction was one solution to overcome this "uncertain" character of micro-volt scaled parameters. The basic idea was to "calibrate the microvolts value" to a unique calibration unit with physiological relevance, the "percent of maximum innervations capacity" in that particular sense. This MVC innervation level served as reference level (=100%) for all forthcoming trials.

The MVC contractions were performed for each investigated muscle group separately, against static resistance. To produce a maximum innervation, a good fixation of all involved segments was done. The test position to arrange a MVC exercise for forearm flexor and extensor muscle bundles was a seated position with a stable forearm support arranged in front. Manual resistance was used to offer resistance to the contraction (Konrad, 2005).

The next procedure conducted was performing the pure scapular PNF pattern in each group. The MVC Peak value and the PNF Peak value was duly noted via the surface electromyography activation of the forearm flexor and extensor bundles separately during this stage. The % MVC was also calculated. Following which, it was compiled and analyzed using randomized block design of 4x2 with total of 8 groups (Gupta *et al.*, 2014).

Group A: Group A was tested for Scapular Anterior Elevation proprioceptive neuromuscular facilitation pattern. The subjects were instructed to adopt a sitting position on the chair. The scapular movement performed was upward and forward movement in a line aimed approximately at the subject's nose. The inferior angle of scapula moves away from the spine. The line of resistance was an arc following the curve of the subject's body. Irradiation resulting from scapular PNF pattern Anterior Elevation was recorded as shown in figure 1.

Figure 1: Resistance to Scapular Anterior Elevation in Seated Position

Group B: Group B was tested for Scapular Posterior Depression proprioceptive neuromuscular facilitation pattern. The subjects were instructed to adopt a sitting position on the chair. The scapular movement performed was a downward (caudal) and backward (adduction) movement, towards the lower thoracic spine, with the inferior angle rotated toward the spine. The line of resistance was an arc following the curve of the subject's body. Irradiation resulting from scapular PNF pattern Posterior Depression was recorded as shown in figure 2.

Figure 2: Resistance to Scapular Posterior Depression in Seated Position

Group C: Group C was tested for Scapular Posterior Elevation proprioceptive neuromuscular facilitation pattern. The subjects were instructed to adopt a sitting position on the chair. The scapular movement pattern will be upward (cranially) and backward (adduction) movement in a line aimed at the middle of the top of the patient's head with the inferior angle rotating away from the spine. The glenohumeral complex moved posteriorly and rotated upward. The resistance followed the curve of the subject's body. Irradiation resulting from scapular PNF pattern Posterior Elevation was recorded as shown in figure 3.

Figure 3: Resistance to Scapular Posterior Elevation in Seated Position

Group D: Group D was tested for Scapular Anterior Depression proprioceptive neuromuscular facilitation pattern. The subjects were instructed to adopt a sitting position on the chair. The movement of scapula is downward and forward, in a line aimed at the opposite anterior iliac crest. The scapula moved forward with the inferior angle in the direction of the spine. The resistance followed the curve of the subject's body. Irradiation resulting from scapular PNF pattern Anterior Depression was recorded as shown in figure 4.

Figure 4: Resistance to Scapular Anterior Depression in Seated Position

Irradiation: The electromyographic signals were recorded via work-rest statistics of surface electromyography (Neurotrac^{TM} ETS, Verity Medical Ltd., Hampshire, United Kingdom) by two unipolar sticky surface electrodes (1.5 cm X 2.5 cm) and one unipolar (1.5cm X 2.5cm) reference electrode. Following the 'start' cue to the command corresponding to each pure scapular proprioceptive neuromuscular facilitation pattern, the subject performed action and maintained it against optimal manual resistance for 5 seconds. The action was repeated 3 times. The rest time between each action was 20 seconds.

Description of Measurement Tool

Electromyography: Computerized surface electromyography is a reliable tool for determining the onset of muscle activity (Di Fabio, 1987).

Electromyographic signal from the wide flexor and extensor group were recorded with standard amplitude parameters, such as peak and calculated %MVC to measure the irradiation resulting from individual scapular proprioceptive neuromuscular facilitation patterns using Neurotrac^{TM} ETS (Verity Medical Ltd., Hampshire, United Kingdom).

NeuroTrac^{TM} ETS is manufactured in compliance with the Medical Device Directive MDD93/42/EEC under the supervision of SGS, Notified Body number 0120 (ISO9001:2000, CE 0120, ISO 13485:2003).

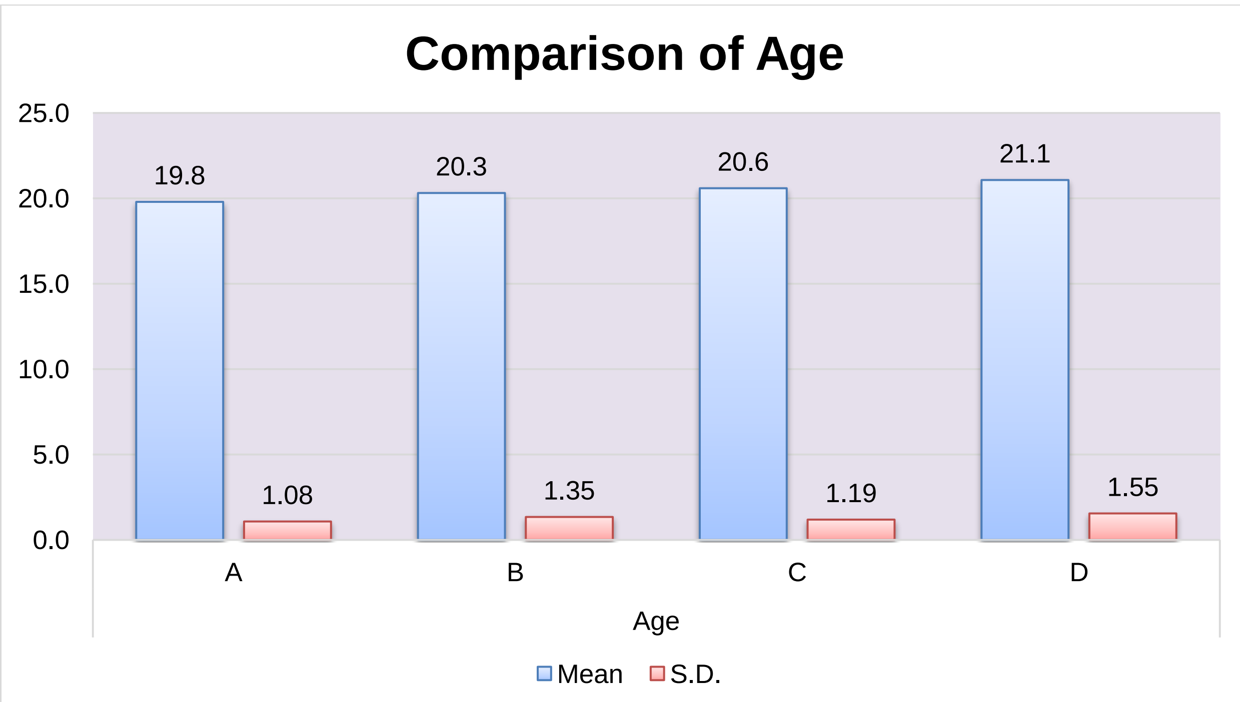
RESULTS AND DISCUSSION

Data was meaningfully assorted through calculations of Mean and Standard Deviation. The factors of age and BMI were examined first to determine their potential effects on the outcome of the study. Both these factors were found to be non-significant statistically as the subject groups were very homogenous with less variability among these different characteristics.

Table 1: Comparison of Age between Groups A, B, C and D

ANOVA	Age (Years)			
	Group A	Group B	Group C	Group D
Mean	19.8	20.3	20.6	21.1
S.D.	1.08	1.35	1.19	1.55
F value	2.536			
Result	Non Significant			

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 1 denoted the result of one way ANOVA for comparison of age between groups A, B, C and D. The Mean±SD value of Group A is 19.8±1.08, the Mean±SD value of Group B is 20.3±1.35, the Mean±SD value of Group C is 20.6±1.19 and the Mean±SD value of Group D is 21.1±1.55. The F value is 2.536, which is statistically non significant at p>0.05.



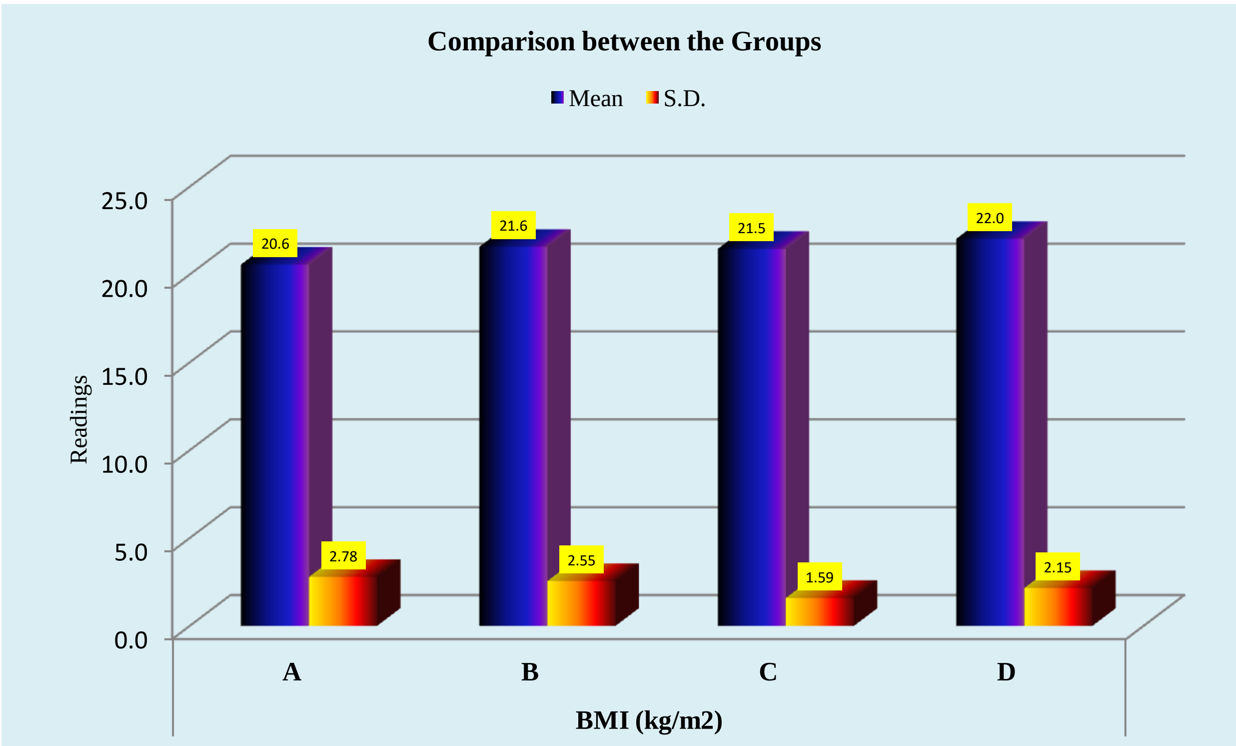
Graph 1: Comparison of Age between Groups A, B, C and D.

Table 2: Comparison of BMI (kg/m^2) between Groups A, B, C and D

ANOVA	BMI (kg/m2)			
	Group A	Group B	Group C	Group D
Mean	20.6	21.6	21.5	22.0
S.D.	2.78	2.55	1.59	2.15
F value	1.762			
Result	Non Significant			

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 2 denotes the result of one way ANOVA for comparison of BMI between groups A, B, C and D. The Mean±SD value of Group A is 20.6±2.78, the Mean±SD value of Group B is 21.6±2.55, the

Mean±SD value of Group C is 21.5±1.59 and the Mean±SD value of Group D is 22.0±2.15. The F value was 1.762, which is statistically non significant at p>0.05.



Graph 2: Comparison of BMI (kg/m^2) between Groups A, B, C and D

Table 3: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Extensor Bundle within Group A

Extensors Group-A	Mean	Standard Deviation	t-Value	Result
MVC Peak	2079.96	529.08	7.075	Significant
PNF PEAK (AE)	1454.12	625.32		

p value > 0.05 Non Significant
p value < 0.05 Significant

Table 3 shows paired t- test results for comparison of MVC Peak and PNF Peak values observed on forearm extensor bundle within Group A. The Mean±SD value for MVC Peak was 2079.96±529.08 and for PNF Peak was 1454.12±625.32. The t value obtained was 7.075 which was statistically significant at p<0.05.

Table 4: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Extensor Bundle within Group B

Extensor Group-B	Mean	Standard Deviation	t Value	Result
MVC Peak	2149.72	432.00	11.385	Significant
PNF PEAK (PD)	1339.96	377.18		

p value > 0.05 Non Significant
p value < 0.05 Significant

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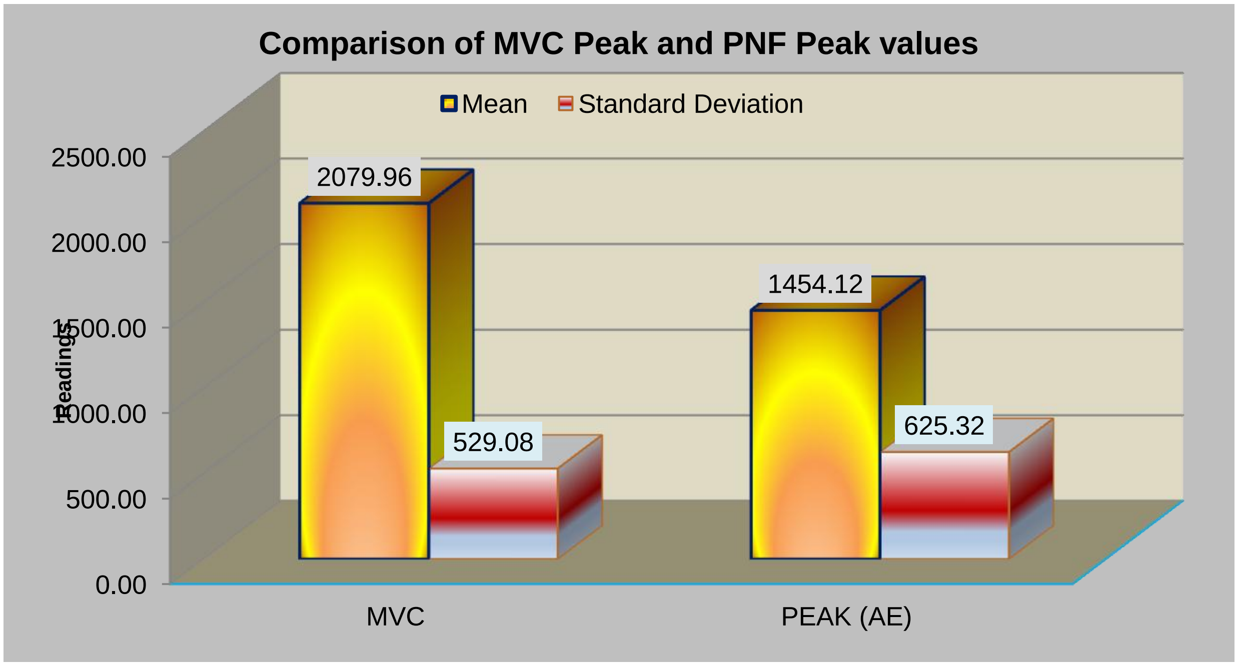
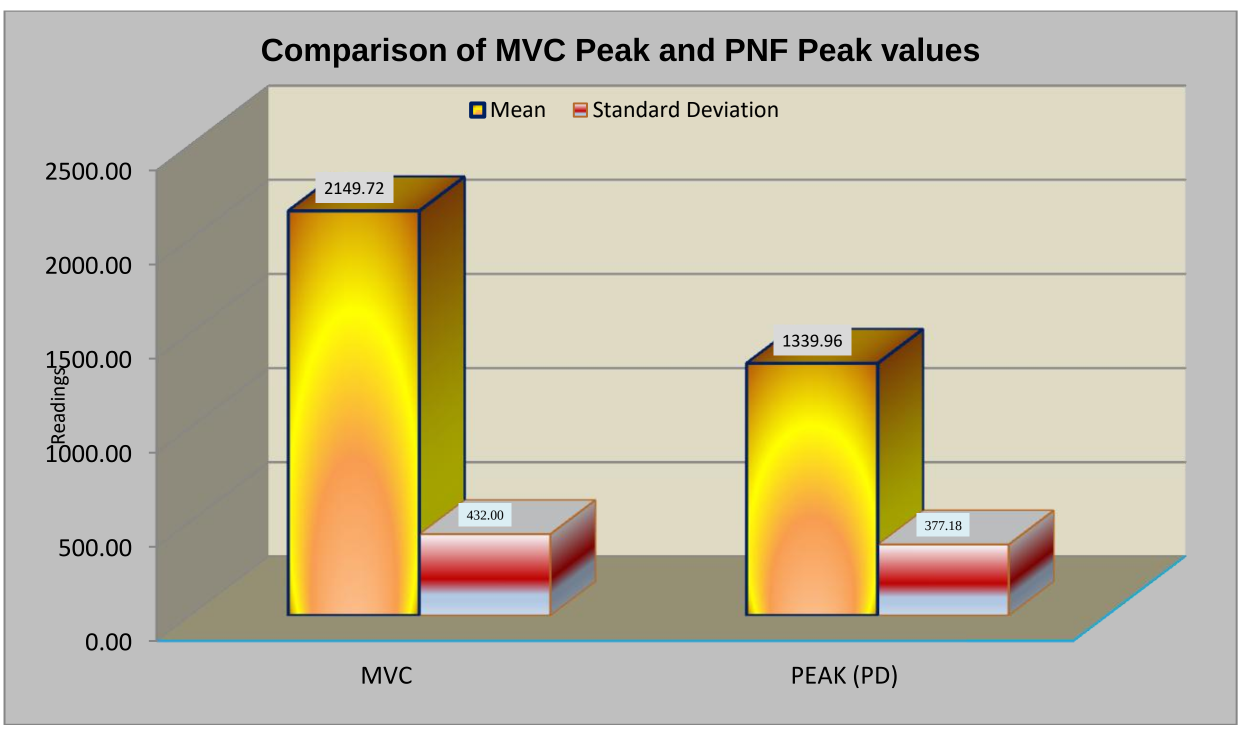
Table 4 shows paired t- test results for comparison of MVC Peak and PNF Peak values observed on forearm extensor bundle within Group B. The Mean±SD value for MVC Peak was 2149.72±432.00 and for PNF Peak was 1339.96±377.18. The t value obtained was 11.385 which was statistically significant at $p<0.05$.



Graph 3: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Extensor Bundle within Group A

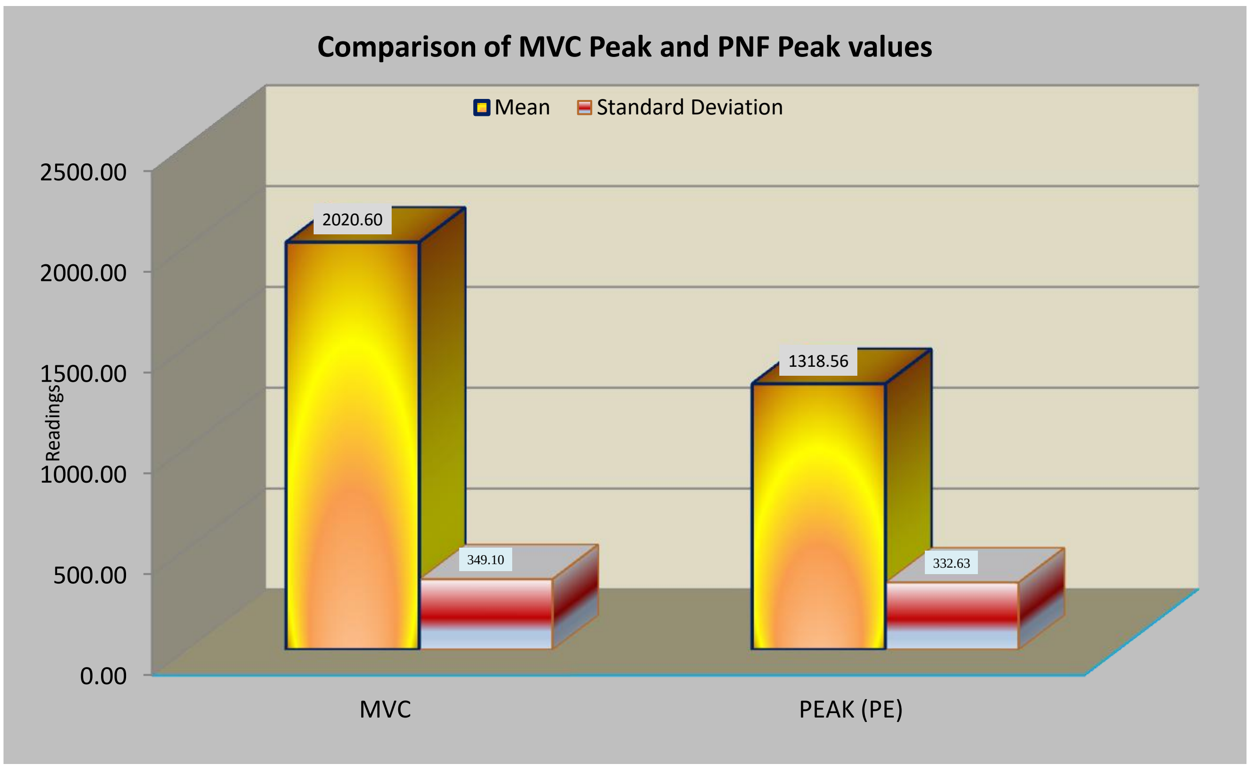


Graph 4: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Extensor Bundle within Group B

Table 5: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Extensor Bundle within Group C

Extensor Group-C	Mean	Standard Deviation	t Value	Result
MVC Peak	2020.60	349.10	11.573	Significant
PNF PEAK (PE)	1318.56	332.63		

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 5 shows paired t- test results for comparison within MVC Peak and PNF Peak values observed on forearm extensor bundle for Group C. The Mean±SD value for MVC Peak was 2020.60±349.10 and for PNF Peak was 1318.56±332.63. The t value obtained was 11.573 which was statistically significant at $p<0.05$.



Graph 5: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Extensor Bundle within Group C

Table 6: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Extensor Bundle within Group D

Extensor Group-D	Mean	Standard Deviation	t value	Result
MVC Peak	1949.84	372.57	10.001	Significant
PNF PEAK (AD)	1261.68	273.43		

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 6 shows paired t- test results for comparison of MVC Peak and PNF Peak values observed on forearm extensor bundle within Group D. The Mean±SD value for MVC Peak was 1949.84±372.57 and for PNF Peak was 1261.68±273.43. The t value obtained was 10.001 which was statistically significant at $p<0.05$.

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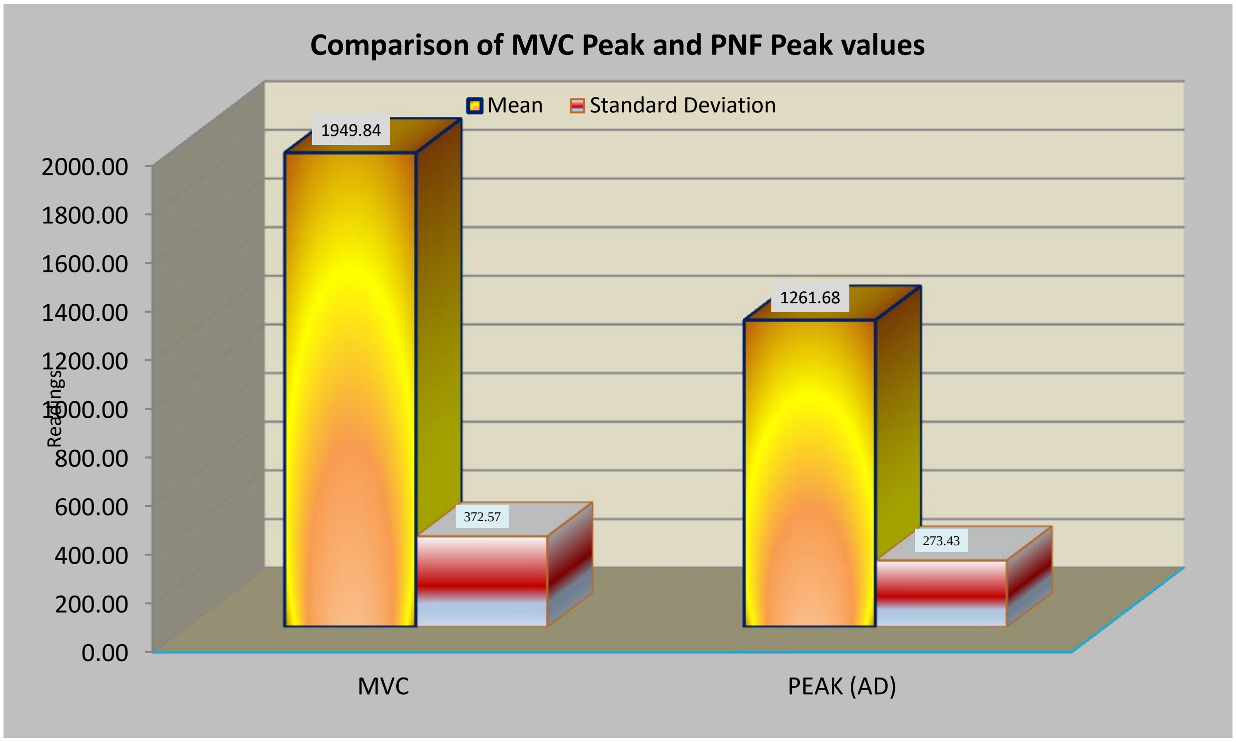
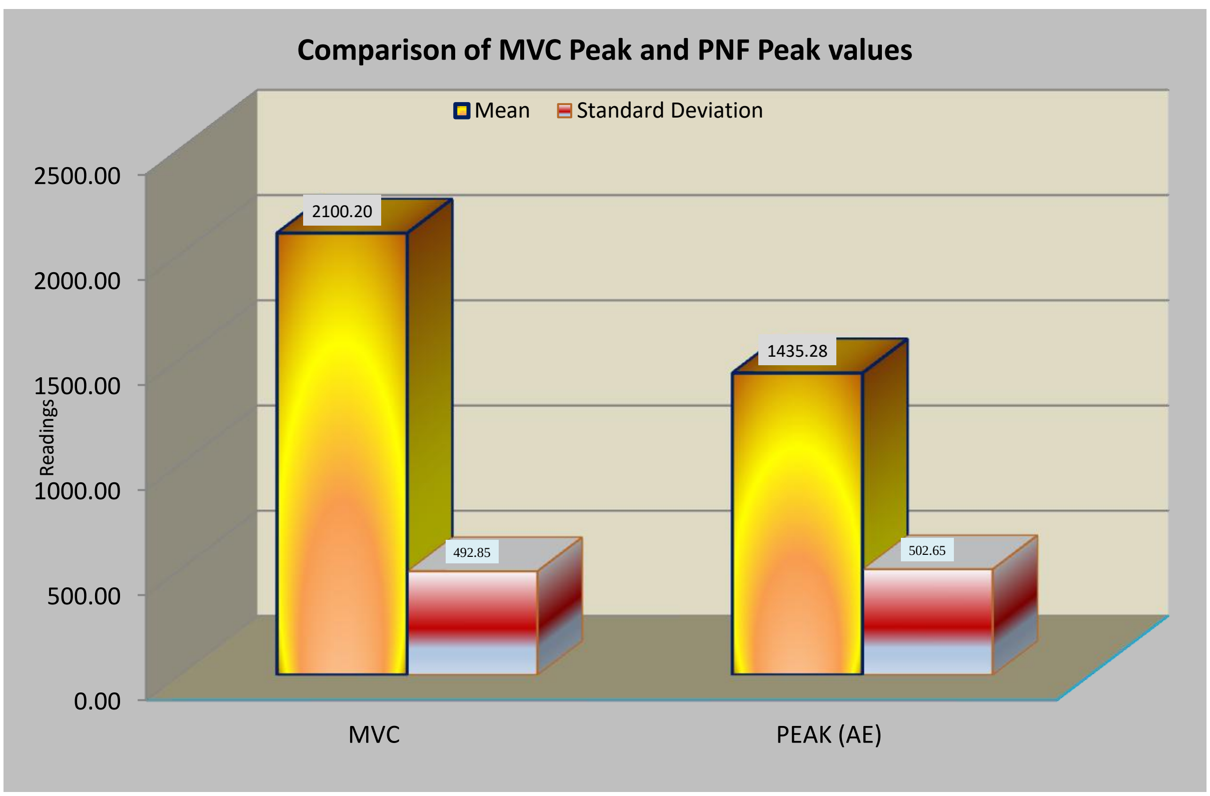


Graph 6: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Extensor Bundle within Group D



Graph 7: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Flexor Bundle within Group A

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Table 7: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Flexor Bundle within Group A

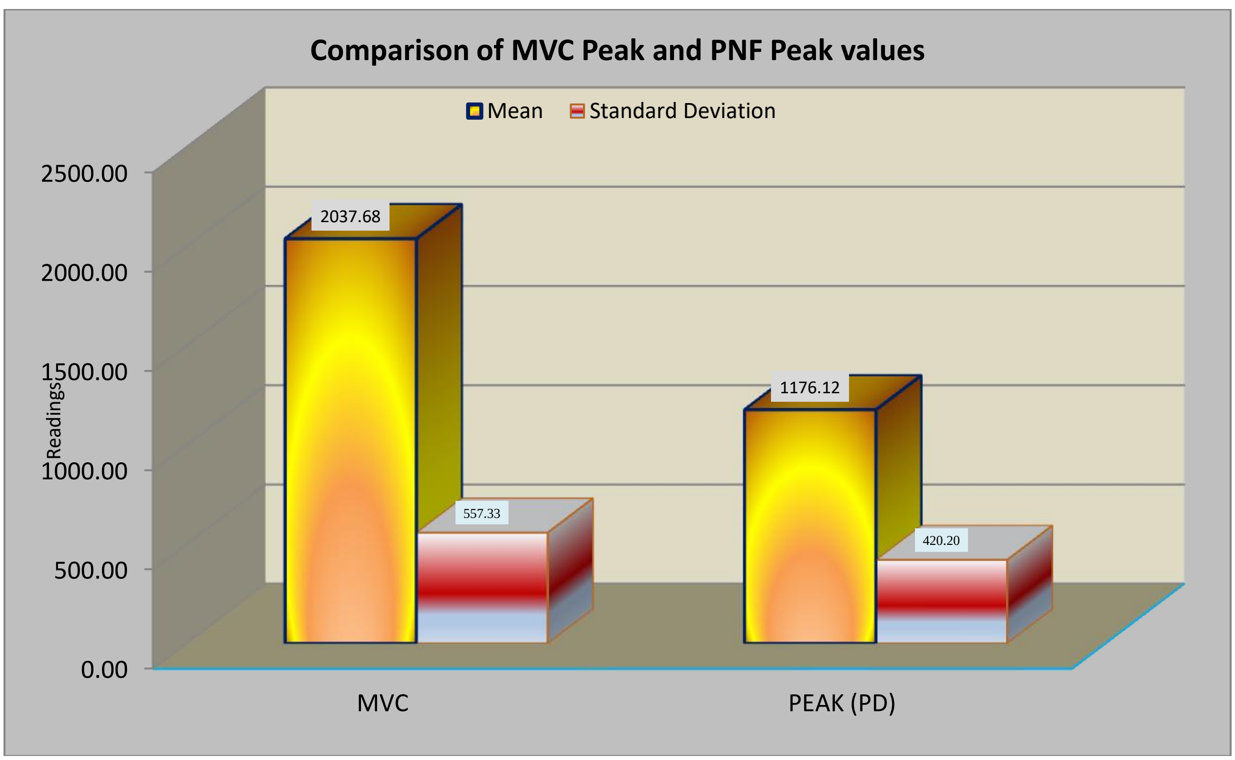
Flexor Group-A	Mean	Standard Deviation	t Value	Result
MVC Peak	2100.20	492.85	7.991	Significant
PNF PEAK (AE)	1435.28	502.65		

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 7 shows paired t- test results for comparison of MVC Peak and PNF Peak values observed on forearm flexor bundle within for Group A. The Mean±SD value for MVC Peak was 2100.20±492.85 and for PNF Peak was 1435.28±502.65. The t value obtained was 7.991 which was statistically significant at $p<0.05$.

Table 8: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Flexor Bundle within Group B

Flexor Group- B	Mean	Standard Deviation	t Value	Result
MVC Peak	2037.68	557.33	7.883	Significant
PNF PEAK (PD)	1176.12	420.20		

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 8 shows paired t- test results for comparison of MVC Peak and PNF Peak values observed on forearm flexor bundle within Group B. The Mean±SD value for MVC Peak was 2037.68±557.33 and for PNF Peak was 1176.12±420.20. The t value obtained was 7.883 which was statistically significant at $p<0.05$.



Graph 8: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Flexor Bundle within Group B

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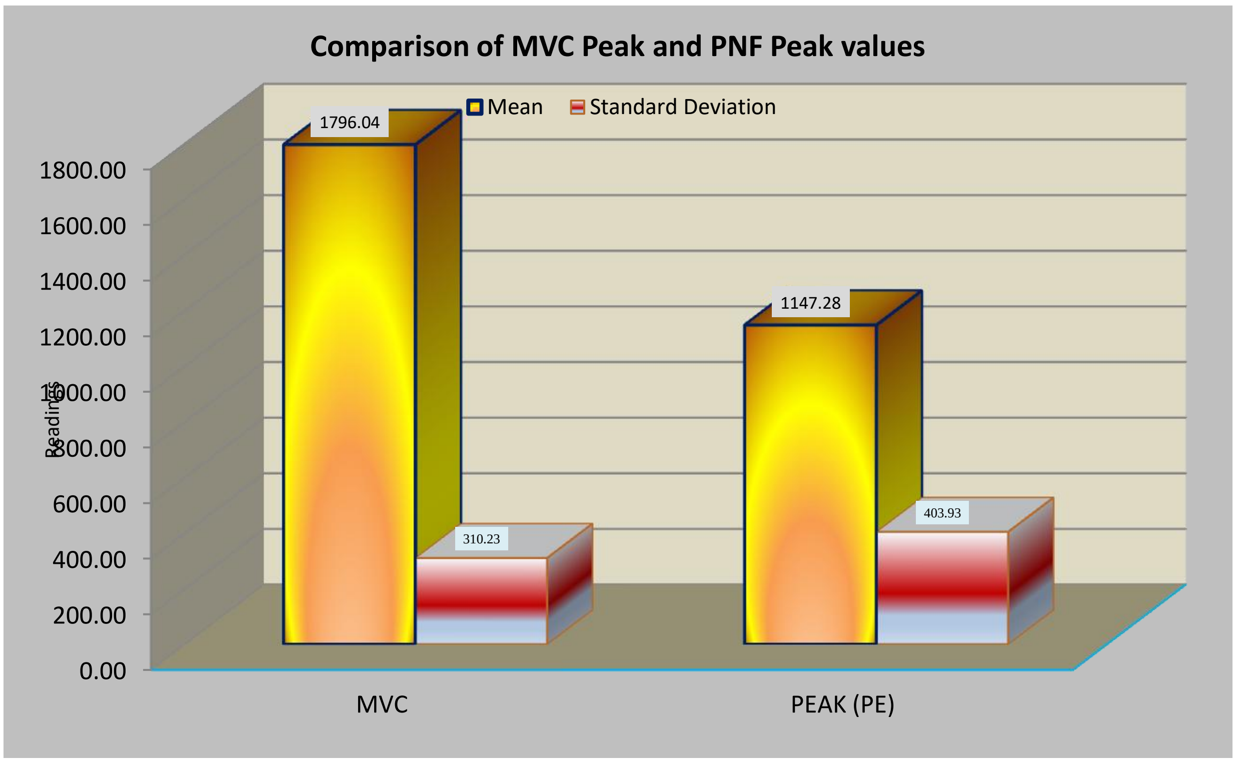
Table 9: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Flexor Bundle within Group C

Flexor Group-C	Mean	Standard Deviation	t Value	Result
MVC Peak	1796.04	310.23	8.427	Significant
PNF PEAK (PE)	1147.28	403.93		

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 9 shows paired t- test results for comparison of MVC Peak and PNF Peak values observed on forearm flexor bundle within Group C. The Mean±SD value for MVC Peak was 1796.04±310.23 and for PNF Peak was 1147.28±403.93. The t value obtained was 8.427 which was statistically significant at p<0.05.



Graph 9: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Flexor Bundle within Group C

Table 10: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Flexor Bundle within Group D

Flexor Group-D	Mean	Standard Deviation	t value	Result
MVC Peak	2037.24	425.12	9.533	Significant
PNF PEAK (AD)	1244.12	243.85		

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 10 shows paired t- test results for comparison of MVC Peak and PNF Peak values observed on forearm flexor bundle within Group D. The Mean±SD value for MVC Peak was 2037.24±425.12 and for PNF Peak was 1244.12±234.85. The t value obtained was 9.533 which was statistically significant at p<0.05.

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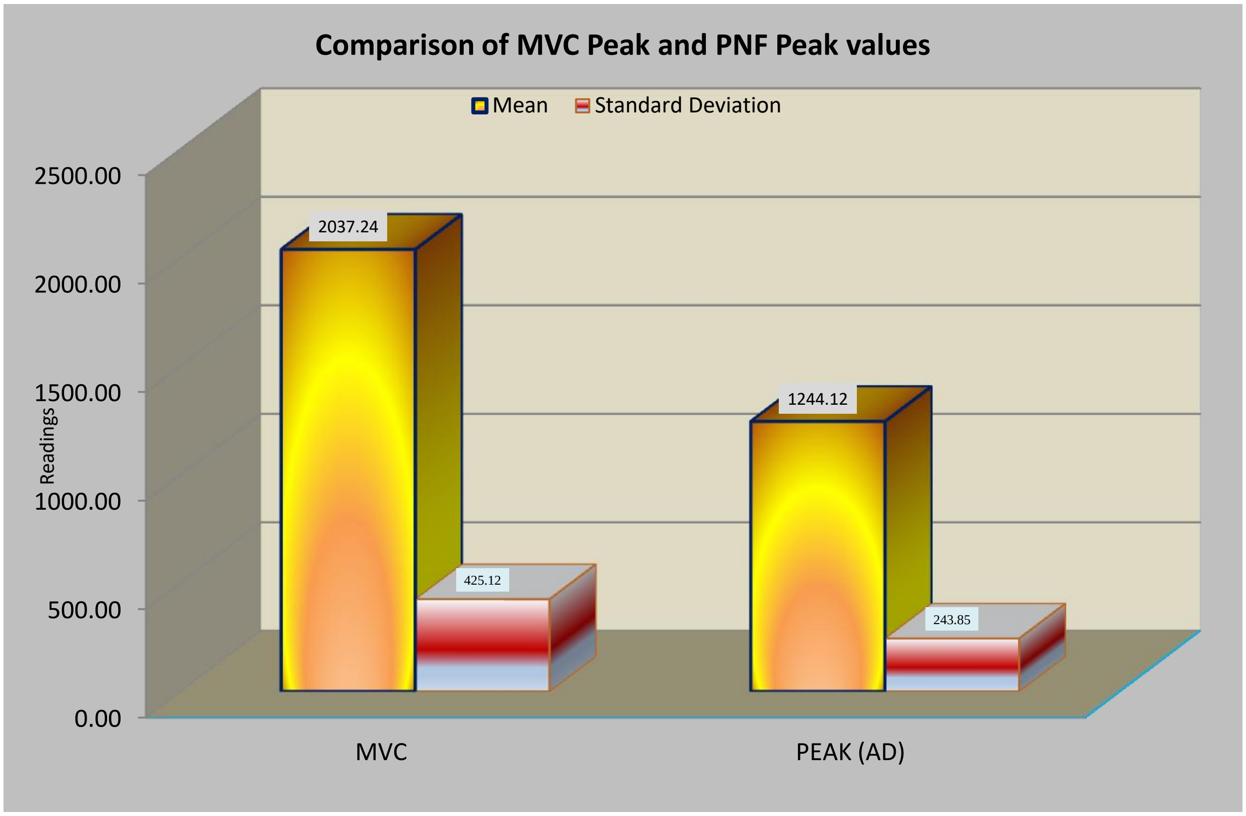
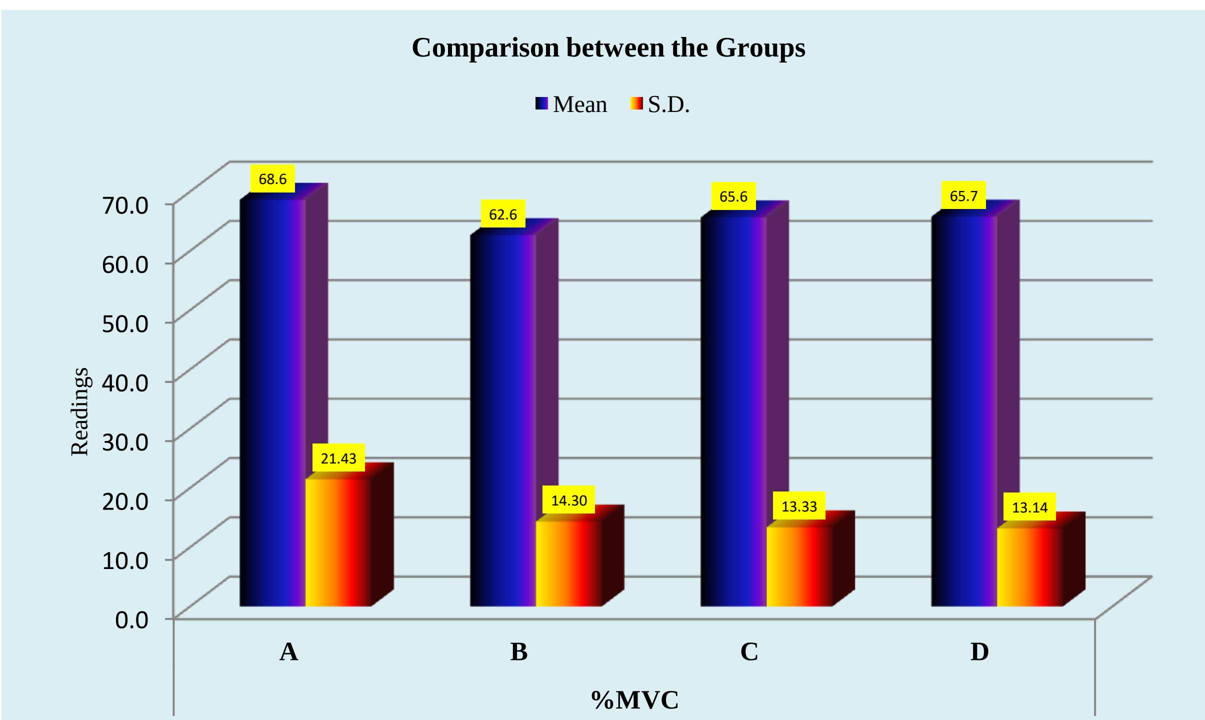


Graph 10: Comparison of Mean and Standard Deviation of MVC Peak and PNF Peak Values Observed on Forearm Flexor Bundle within Group D

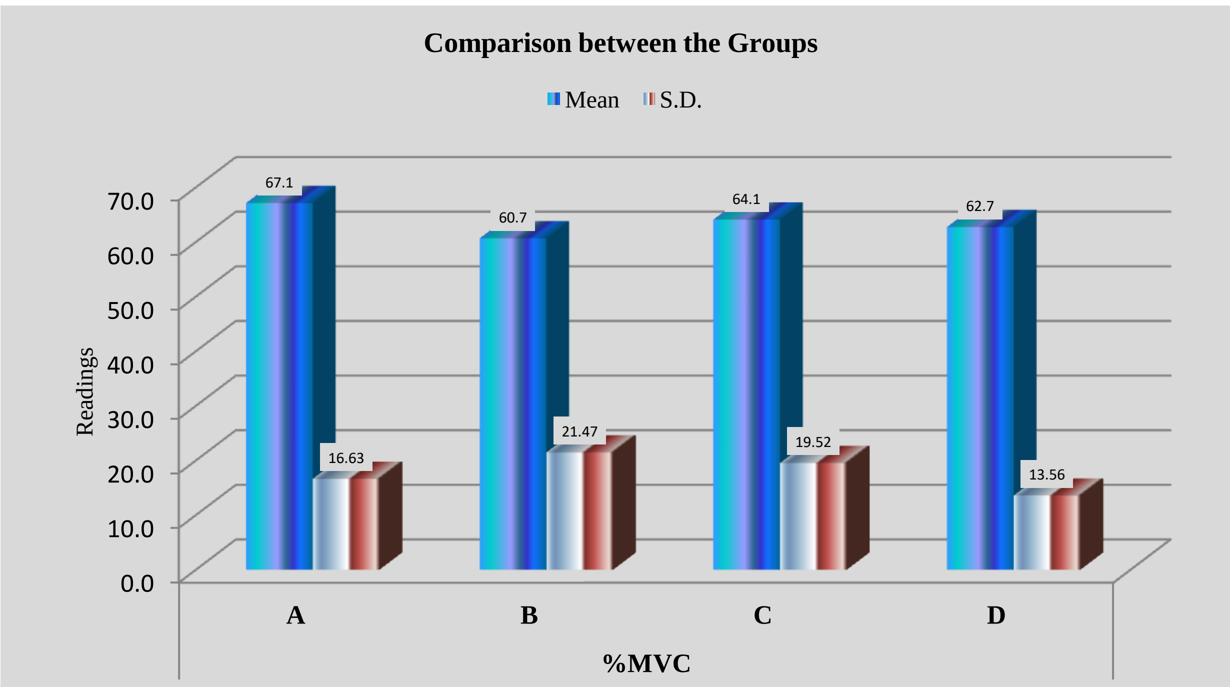


Graph 11: Comparison of Mean and Standard Deviation for the % MVC Values between Groups A, B, C and D for Forearm Extensor Bundle

Table 11: Comparison of Mean and Standard Deviation for the % MVC Values between Groups A, B, C and D on Forearm Extensor Bundle

ANOVA (Extensor)	%MVC			
	Group A	Group B	Group C	Group D
Mean	68.6	62.6	65.6	65.7
S.D.	21.43	14.30	13.33	13.14
F value	0.582			
Result	Non Significant			

p value > 0.05 Non Significant
p value < 0.05 Significant
Table 11 reports the result of one-way ANOVA for comparison of mean and standard deviation for the %MVC values between Groups A, B, C and D on forearm extensor bundle. The Mean±SD value for %MVC of group A was 68.6±21.43; for group B was 62.6±14.30; for group C was 65.6±13.33 and group D was 65.7±13.14 respectively. The F value for one way ANOVA was 0.582 which was statistically non significant at p>0.05.



Graph 12: Comparison of Mean and Standard Deviation for the % MVC Values between Groups A, B, C and D for Forearm Flexor Bundle

Table 12: Comparison of Mean and Standard Deviation for the % MVC Values between Groups A, B, C and D for Forearm Flexor Bundle

ANOVA (Flexor)	%MVC			
	Group A	Group B	Group C	Group D
Mean	67.1	60.7	64.1	62.7
S.D.	16.63	21.47	19.52	13.56
F value	1.036			
Result	Non Significant			

p value > 0.05 Non Significant
p value < 0.05 Significant

Table 12 reports the result of one-way ANOVA for comparison of mean and standard deviation for the %MVC values between Groups A, B, C and D on forearm flexor bundle. The Mean±SD value for %MVC of group A was 67.1±16.63; for group B was 60.7±21.47; for group C was 64.1±19.52 and group D was 62.7±13.56 respectively. The F value for one way ANOVA was 1.036 which was statistically non significant at p>0.05.

In the present study, while evaluating the irradiation effect by scapular PNF patterns on forearm muscles, effective irradiation was observed in both flexor and extensor muscle bundles in each of the groups tested. It was observed from the parametric paired t-test results, that the t-value derived by irradiation generated response on the extensor muscle bundle showed more variations in each of the four scapular PNF movements with respect to the t-values derived by response on the flexor bundle. It was also observed that on comparison between four groups of scapular PNF motions, amidst the irradiation effect upon flexor and extensor muscle bundle, no particular PNF motion exhibited significant difference in affinity for isolating greater activation on either muscle bundles.

The data was analysed in two stages. Initially, the data was analysed using the paired t-test on MVC peak and PNF peak values to evaluate for the existence of irradiation within the group. Within group A, the t value for peaks in extensor muscle bundle and flexor muscle bundle was 7.075 and 7.991 respectively, which is statistically significant. Within group B, the t value for peaks in extensor muscle bundle and flexor muscle bundle was 11.385 and 7.883 respectively, which is statistically significant. The t value for peaks in extensor muscle bundle and flexor muscle bundle within group C was 11.573 and 8.427 respectively, which is statistically significant. The t value for peaks in extensor muscle bundle and flexor muscle bundle within group D was 10.001 and 9.533 respectively, which is statistically significant.

In the present study, while evaluating the irradiation effect by scapular PNF patterns on forearm muscles, effective irradiation was observed in both flexor and extensor muscle bundles in each of the groups tested. Irradiation is the spread of reflex impulse response about a focus. The reflex affect spreads over larger and larger field, irradiating in various directions from a focus of reflex-discharge which takes effect on the limb itself. The more intense the spinal reflex; the wider is the spatial extent of motor discharge from its focus. It was argued that this is because the afferent neurone, on entering the central organ, the spinal cord, enters a vast network of conduction of paths interlacing in all directions. The receptive neurone conducting the impulse can be traced breaking up into many divisions that pass into many directions and through various distances. It may be noteworthy to mention that in order to understand the physiology of the nervous system, it is important to keep in mind that by histology it is found to be continuous throughout its entire extent. Irradiation spread follows both; the Law of homonymous conduction and the Law of bilateral symmetry. In this way, the motor paths, at any given time, accord in a united pattern for harmonious synergy, cooperating for one effect (Sherrington, 1911).

Results can also be supported by the findings of Panin and associates who demonstrated that overflow is not limited to contralateral agonists or antagonists but is widespread throughout all four extremities during resisted movements at the knee or elbow (Souza *et al*., 2014).

Whenever unilateral exercise of large muscle groups is performed against heavy resistance, wide spread postural readjustment always occur and these call forth the synergistic co-contraction of many muscle groups involving the trunk and remote extremity as well as those of the opposite limb (Hellebrandt, 1951).

During voluntary movement, the level of descending excitation onto lower motor neurons varies in direct relation to the intended strength of contraction. Higher levels of descending excitation translate into higher frequencies of motor unit impulse activity. If stronger effort of voluntary movement is made, then more motor units are recruited or 'willed' into excitation by the activity in descending interneuronal pathways originating on brain's motor cortex (Drewes, 2000).

As the conscious effort increases, in response to resistance, the spike frequency in small motor unit's increases, resulting in a consequent progressive recruitment of larger motor units into spiking. This phenomenon is supported by the Henneman's Size Principle (Cram and Kasman, 1998). Thus, irradiation is supported by two complementary and co-existing mechanisms: the spike frequency of motor units already active and recruitment of additional (larger) units.

It was observed from the parametric paired t-test results, that the t-value derived by irradiation generated response on the extensor muscle bundle showed more variations in each of the four scapular PNF movements with respect to the t-values derived by response on the flexor bundle.

This may be because of the muscle mechanical properties; that is the isometric length tension relationship, and the skeletal muscle architecture. One of the most fundamental properties of skeletal muscle is that the amount of force it generates depends on its length. Wrist extensor muscles operate at longer sarcomere lengths when compared with flexor muscles. Also, the most important architectural parameter is fibre length within a muscle. This is because muscle fibre length permits greater excursion of a particular muscle as well as a muscle's 'packing' strategy (Leiber and Ward, 2011).

One way ANOVA was applied for inter-group comparison of the measure of strength between the four groups, to compare the level of activation through irradiation principle of PNF. The F value for one way ANOVA on forearm extensor muscle bundle and on forearm flexor bundle was 0.582 and 1.036 respectively, both of which were not significant statistically, with the level of significance fixed at 5%.

This study observed that on comparison between four groups of scapular PNF motions, irradiation effect upon flexor and extensor muscle bundle, no particular PNF motion exhibited significant difference in affinity for isolating greater activation on either muscle bundles (Beaule *et al.,* 2014). This could be because scapular positioning and movement are products of synchronous firing to achieve optimal length–tension relationships between the primary scapular stabilizers, specifically in muscles that compose the scapular upward rotation force couple: upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA). Sufficient scapular strength and control, requires the subject to incorporate more functional attitudes using multiple planes and body segments in the kinetic chain, to facilitate correct muscle activation and function needed for activity-specific movements (Kibler, 1998). This functional approach be incorporated by clinicians into rehabilitation practices as information regarding scapular muscle activation relative to other muscles in a ratio (Kibler *et al.,* 2008). Scapular muscle-activation ratios and individual muscle activation were similar in healthy control participants when performing the unloaded multiplanar, multijoint functional exercises tested (Moeller *et al.,* 2014).

Another possible reason for all four scapular patterns exhibiting similar irradiation response in both flexor and extensor muscle bundles could be traced to the type of resistance offered. While the selection of the PNF movement pattern to incorporate into a rehabilitation program to activate the desired muscle is an important consideration, the selection of resistance to achieve the appropriate intensity and type of muscle activation is also vital. The lack of mastery of the patterns when performed by the subject could be one more plausible contributor to this outcome.

Therefore, the results of this study show there was significant variation in the occurrence of irradiation in both extensor and flexor muscle groups by scapular PNF patterns. Hence, all scapular PNF patterns can be employed for utilizing the irradiation principle to recruit both flexor and extensor muscle bundles.

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