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Ulnar nerve somatosensory evoked potentials duringadduction, abduction and external rotation of arm.A normal study

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Background : *Short latency somatosensory EPs have been used to identify lesions in the sensory pathways, but they do not indicate its nature. Their use has become an integral part of neurophysiological assessment. Unfortunately, there are many different techniques used in the registration of SEPs that make it very difficult to compare and contrast published studies.*

Objective : *To study normative ulnar SEPs data gained from stimulation at the wrist when the arm is in an adducted (neutral) position as well as in the abducted and external rotated (dynamic) position .*

Setting : *Evoked Potential Laboratory, Department of Rehabilitation Medicine, Faculty of Medicine, Chulalongkorn University.*

Research design : *Descriptive study*

Materials : *Thirty healthy subjects, 15 males and 15 females with age ranges from 20 to 45 were studied .*

Methods : *The ulnar nerve was stimulated transcutaneously at the wrist with stimulus intensity adjusted to produce a minimum twitch of*

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the innervated muscles when the arm was in the adducted position, and then in an abducted and externally rotated position. The potentials were recorded at the Erb's point, fifth cervical spine and contralateral somatosensory area of the scalp.

Results : *In the neutral arm position, the peak latencies of N9, N11, N13, N20 and interpeak latency of N9-13 were significantly shorter ($p< 0.01$) in females than in males as was the measurement of Erb's length and Erb– Cv length. But the amplitudes of N9, N13 and N20 were not statistically significantly different ($p > 0.01$). The ulnar SEPs results in the dynamic arm position were similar to the neutral arm position except for the interpeak latency of N9-13 and Erb –Cv length, which were not statistically significantly different. In females, the N9, N11, N13 latencies and Erb's length in the neutral arm position were statistically shorter ($p < 0.01$) when compared with the dynamic arm position. But in males only the N9 latency and Erb's length were shorter with a statistically significant difference ($p< 0.01$) in the neutral arm position by comparison with the dynamic arm position. There were highly significant correlations between height, Erb's length, Erb-Cv length and the latencies of major peaks along their pathways in both arm positions.*

Conclusion : *Results from a group of 30 healthy middle–aged persons provided normative data of ulnar SEPs in both neutral and dynamic arm positions which can be used to compare with the results gained from patients. This technique can be used for objective diagnosis of neurogenic Thoracic Outlet Syndrome.*

Key words : *Somatosensory Evoked Potential, Neutral position, Dynamic position, Erb's length, Erb-Cv length.*

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กฤษณา พิรเวช , เสก อักษรานุเคราะห์. การศึกษาค่าปกติของ somatosensory evoked potential ของเส้นประสาทอัลนาร์ ขณะแขนอยู่แนบลำตัว และแขนกางและหมุนออกนอกลำตัว. จุฬาลงกรณ์เวชสาร 2541 ก.ค; 42(7): 505-22

เหตุผลของการวิจัย : *Somatosensory evoked potential สามารถนำมาใช้ตรวจการทำงานและช่วยบอกตำแหน่งพยาธิสภาพของโรคทางระบบประสาทรับความรู้สึก แต่เนื่องจาก การตรวจนี้มีเทคนิคที่แตกต่างกันมากมาย จึงเป็นการยากที่จะนำค่าปกติที่เคยมีผู้รายงานไว้มาใช้ในการเปรียบเทียบผลการตรวจที่ได้จากผู้ป่วย ซึ่งอาจทำให้การแปลผลคลาดเคลื่อนได้*

วัตถุประสงค์ : *เพื่อศึกษาค่าปกติของ somatosensory evoked potential ของเส้นประสาทอัลนาร์ ขณะแขนอยู่แนบลำตัว และแขนกางและหมุนออกนอกลำตัว*

สถานที่ทำการศึกษา : *ห้องปฏิบัติการ evoked potential ของ ภาควิชาเวชศาสตร์ฟื้นฟู คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย*

รูปแบบการวิจัย : *การวิจัยเชิงพรรณนา*

กลุ่มประชากรที่ศึกษา : *กลุ่มอาสาสมัครปกติ จำนวน 30 คน เป็นเพศชาย 15 คน เพศหญิง 15 คน อายุระหว่าง 20 ถึง 45 ปี*

วิธีการศึกษา : *ทำการกระตุ้นเส้นประสาทอัลนาร์บริเวณข้อมือ โดยใช้ไฟขนาดที่ทำให้กล้ามเนื้อกระตุกเล็กน้อย ในขณะแขนอยู่แนบลำตัว หลังจากนั้นจึงให้กางแขนและหมุนออกนอกลำตัว โดยทำการกระตุ้นมือทั้งสองข้างสลับกัน แล้วบันทึกสัญญาณคลื่นไฟฟ้าที่บริเวณ Erb's point,กระดูกสันหลังคอระดับที่ 5 และบริเวณหนังศรีษะที่ตรงกับ somatosensory area ด้านตรงข้าม*

ผลการศึกษา : *จากการศึกษาพบว่า ค่าของ Ulnar SEPs ในเพศหญิง ขณะแขนอยู่แนบลำตัวมีค่าของ peak latency N9, N11, N13, N20 และ interpeak latency ของ N9 –13 น้อยกว่าในเพศชายอย่างมีนัยสำคัญ ($p < 0.01$) เนื่องจาก ระยะทางจากจุดกระตุ้นถึง Erb's point และความยาวของ Erb –Cv มีค่าน้อยกว่า ทำนองเดียวกับค่าที่ได้จากการกระตุ้นขณะกางแขนและหมุนออกนอกลำตัว ยกเว้นค่า interpeak latency ของ N9-13 และความยาวของ Erb-Cv ที่มีค่าน้อยกว่า แต่ไม่มีนัยสำคัญทางสถิติ เมื่อเปรียบเทียบค่าของ Ulnar SEPs ขณะแขน แนบลำตัวกับกางแขนและหมุนออกนอกลำตัว พบว่าในเพศหญิงมีค่า latency ของ N9, N11, N13 และระยะทางจากจุดกระตุ้นถึง Erb's point มีค่าน้อยกว่า ค่าที่ได้ขณะกางแขนอย่างมีนัยสำคัญ ส่วนในเพศชายพบว่ามีเพียงค่า latency ของ N9 และ ระยะทางจากจุดกระตุ้นถึง Erb's point ที่มีค่าน้อยกว่าอย่างมีนัยสำคัญทางสถิติ นอกจากนี้ยังพบว่า ความสูง, ระยะทางจาก*

		จุดกระตุ้นถึง Erb's point และความยาวของ Erb –Cv มีความสัมพันธ์กับค่า latency ของ N9, N13 และ N20 ของทั้งเพศชาย และเพศหญิง
สรุป	:	*ผลที่ได้จากการศึกษานี้สามารถนำมาใช้เป็นค่าปกติ และอ้างอิงกับผลที่ได้ จากการตรวจผู้ป่วย เพื่อประโยชน์ในทางคลินิก สำหรับห้องปฏิบัติการ evoked potential ที่โรงพยาบาลจุฬาลงกรณ์*

Short latency somatosensory EPs (SSEPs) have been studied and clinically utilized by many different investigators. Unfortunately, there are almost as many different techniques used in the registration of SEPs as there are investigators studying them. These factors create a methodological maze capable of discouraging even experienced EP practitioners and makes it very difficult to compare and contrast published studies. [1] It would be ideal if everyone using these techniques in the clinical field had established his or her own normative data. [2] It was the purpose of this investigation to study normative ulnar SEP data gained from stimulation with the arm in adducted (neutral) position as well as in the abducted and externally rotated (dynamic) position. This procedure is of clinical use in the diagnosis of nerve compression in the thoracic outlet syndrome.

Materials and Methods

Subjects

Thirty healthy subjects without histories of neurological disorders, neck problems or taking any medication were studied. There were 15 males and 15 females ranging from 20 to 45 year of age We selected this age range to avoid any influence of age on the latency. The range of height was 150-175 cm. Recording of the ulnar SEP was performed in a quiet, electrically shielded room at a constant temperature of 25^0 C. The subjects were tested in a supine position, resting comfortably with eyes closed but not allowed to sleep.

Stimulation and recording

A Neuropack 8 machine was used for this study. The ulnar nerve was stimulated transcutaneously at the wrist with the stimulus intensity adjusted to produce a minimum twitch of innervated muscles. We stimulated the nerve by using square wave pulses of 0.1 msec duration with a rate of 2 / sec. To record the SEP, silver-cup electrodes attached with collodion and filled with conductive jelly were used. The impedance of the recording electrode was kept below 5K ohms.Each SEP recording consisted of 1,000 averaging and was repeated for reproducibility of potentials. Amplifier bandpass was 20-3000 Hz. and analysis time was 70 msec with a sweep speed of 10 msec / division. The Erb's potentials (N9) were recorded with an active electrode 2 cm. above the midpoint of the clavicle (Erb's point) ipsilateral to the stimulation and a reference electrode at the contralateral side. The cervical potentials (N11, N13) were recorded with an active electrode at the fifth cervical spine and a reference electrode at the midfrontal (F_z, 10 to 20 system). The cortical potentials (N 20) were recorded with an active electrode at the contralateral somatosensory area (2 cm behind C_3 or C_4) and a reference electrode at the F_z. Potentials were recorded with the subject supine, initially with arms in the neutral position and subsequently in abducted and externally rotated (dynamic) positions (Figure.1). Both wrists were stimulated separately in all subjects. Skin temperature was maintained above 32 degrees C. in the forearm.

Measurement and analysis.

In all subjects, observations in the different arm positions were repeated several times to determine the reproducibility of potentials and the variations of latency of individual components. Latencies were measured from the stimulus artifact to the peak

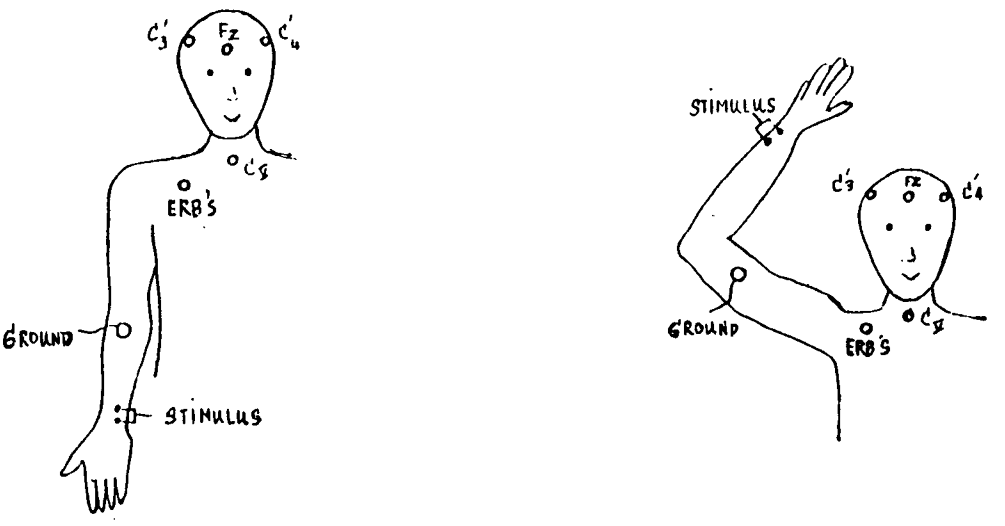


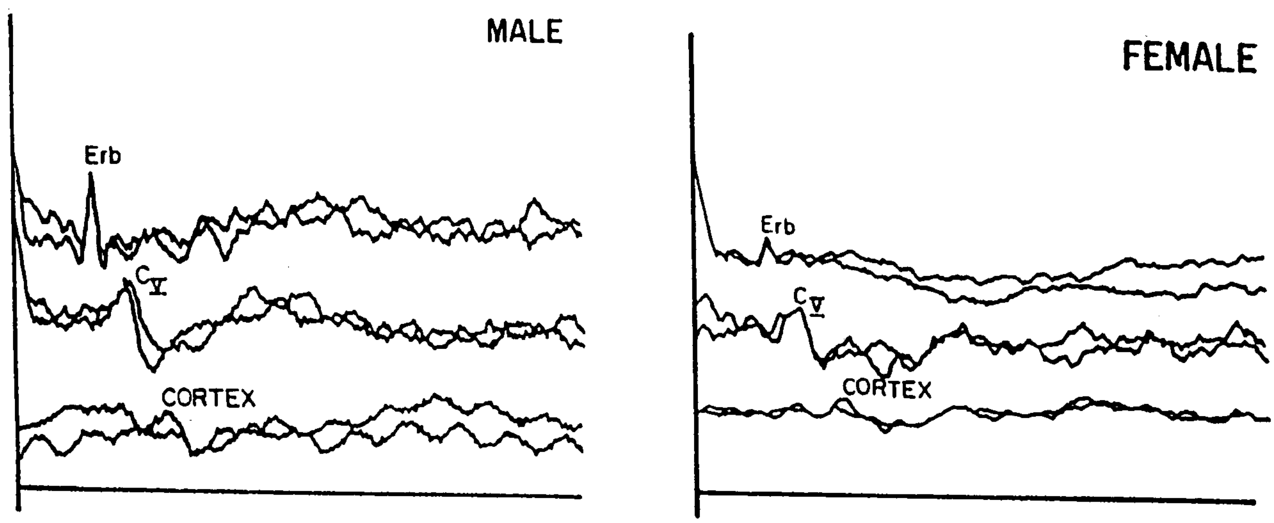
Figure 1. A. Arm in neutral position B. Arm in dynamic position

Erb's point corresponds to active surface electrode over the brachial plexus, Cv corresponds to active surface electrode over cervical vertebra 5 and C3'or C4' corresponds to contralateral "hand" area of the scalp. Fz is the reference surface electrode.

negativity of the responses. The amplitudes at the Erb's point (N9) , cervical spine (N13) and scalp (N20) were measured from negative peak to the following positive peak. At the end of the testing the following measurements were made by using plastic tape :1. Erb's length - distance from the stimulation cathode electrode to Erb's point; 2. Erb - CV length - distance from Erb's point to CV spinous process; 3. body height. The Erb's length and Erb-CV length were measured with the arm in neutral and subsequently in dynamic position.

Results

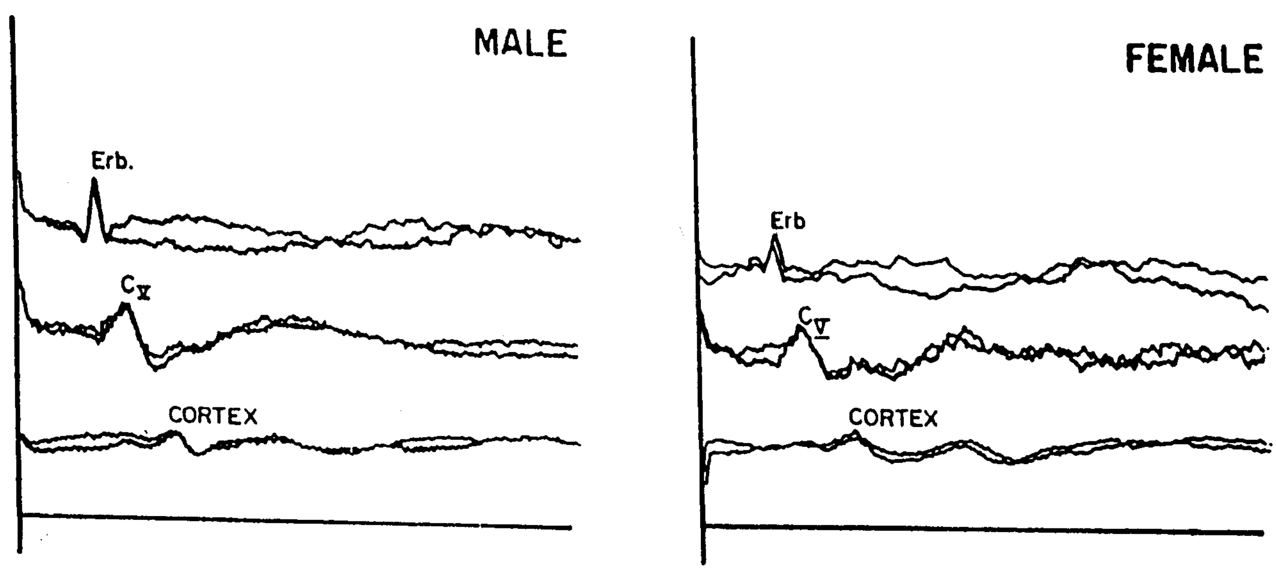
Sixty ulnar nerves were studied in 30 healthy volunteers, 15 males and 15 females with mean ages of 31.6 ± 1.9 and 27.9 ± 4.1 respectively. Satisfactory results were obtained in all subjects. The ulnar responses during neutral and dynamic arm positioning are shown in figures 2 (a) and (b). In the neutral arm position in both males and females, the maximal latency differences of N9, N11, N13, N20 and the interpeak latencies of N9-13 and N13-20 between right and left side were not more than 1.0 msec. And also maximal amplitude differences of N9, N13 and N20 between both sides were not more than 50% (Table 1,2). When compare males to females, the latencies of N9 , N11 , N13 , N20 peaks and the interpeak latency of N9-13 were shorter in females than in males with statistical significance ($p < 0.01$) and also the measurement of Erb's length and Erb - CV length (Table 3). But there was no statistically sigificant difference in the amplitude of N9, N13 and N20 ($P > 0.01$) (Table 4). The ulnar SEP results in dynamic arm positioning were similar to neutral arm positioning when either comparing between both sides in each sex (Table 5,6) or females with males except for the interpeak latency of N9-13



A. Male

B. Female

Figure 2. Normal ulnar SEP elicited by wrist stimulation in arm adducted (neutral) position in male and female.



A. Male

B. Female

Figure 3. Normal ulnar SEP elicited by wrist stimulation in arm abducted and externally rotated (Dynamic) position in male and female.

Table 1 a. Mean latency of ulnar somatosensory evoked potential in neutral arm position in males.

	Male	Right-Left latency difference	
	Mean (msec) ± *S.D.*	*Mean (msec)* ± *S.D.*	*Min.-Max.*
N 9	10.30 ± 0.64	0.00 ± 0.42	0 - 0.92
N11	12.27 ± 0.64	0.02 ± 0.46	0 - 0.84
N13	14.27 ± 0.64	0.05 ± 0.42	0 - 0.98
N20	19.79 ± 0.82	0.07 ± 0.65	0.14 - 0.98
INTERPEAK N 9-13	3.96 ± 0.31	0.04 ± 0.43	0.08 - 0.70
INTERPEAK N13-20	5.53 ± 0.52	0.16 ± 0.53	0.14 - 0.98
ERB'S LENGTH (cm)	58.48 ± 2.65		
ERB'S – CV (cm)	13.85 ± 1.19		
HEIGHT (cm)	167.40 ± 5.46		

Table 1 b. Mean latency of ulnar somatosensory evoked potential in neutral arm position in females.

	Female	Right-Left latency difference	
	Mean (msec) ± *S.D.*	*Mean (msec)* ± *S.D.*	*Min.-Max.*
N9	9.31 ± 0.39	0.05 ± 0.25	0 - 0.42
N11	11.21 ± 0.43	0.13 ± 0.31	0 - 0.56
N13	12.87 ± 0.46	0.09 ± 0.35	0 - 0.78
N20	18.20 ± 0.54	0.03 ± 0.41	0.14 - 0.94
INTERPEAK N 9-13	3.55 ± 0.29	0.03 ± 0.31	0 - 0.92
INTERPEAK N13-20	5.33 ± 0.39	0.06 ± 0.31	0 - 0.56
ERB'S LENGTH (cm)	53.47 ± 2.36		
ERB'S – CV (cm)	12.93 ± 1.02		
HEIGHT (cm)	156.53 ± 3.94		

Table 2. Mean amplitude of ulnar somatosensory evoked potential in neutral arm position in males and females.

	MALE		FEMALE	
	Mean (uV) ± S.D.	*Max.Rt.-Lt. Difference*	*Mean (uV) ± S.D.*	*Max.Rt.-Lt. Difference*
N9	2.66 ± 0.82	43.7 %	3.50 ± 1.52	47.6 %
N13	2.33 ± 0.72	48.5 %	3.07 ± 1.24	36.2 %
N20	2.68 ± 1.05	44.4 %	3.86 ± 1.89	44.8 %

Table 3. Mean latency of ulnar somatosensory evoked potential in neutral arm position compare males with females.

	MALE	FEMALE	
	Mean (msec) ± S.D.	*Mean (msec) ± S.D.*	*P Value*
N9	10.30 ± 0.64	9.31 ± 0.39	.000
N11	12.27 ± 0.64	11.21 ± 0.43	.000
N13	14.27 ± 0.64	12.87 ± 0.46	.000
N20	19.79 ± 0.82	18.20 ± 0.54	.000
INTERPEAK N 9-13	3.96 ± 0.31	3.55 ± 0.29	.001
INTERPEAK N13-20	5.53 ± 0.52	5.33 ± 0.39	.243
ERB'S LENGTH (cm)	58.48 ± 2.65	53.47 ± 2.36	.000
ERB'S – CV (cm)	13.85 ± 1.19	12.93 ± 1.02	.000
HEIGHT (cm)	167.40 ± 5.46	156.53 ± 3.94	.000

Table 4. Mean amplitude of ulnar somatosensory evoked potential in neutral arm position compare males with females.

	MALE	FEMALE	
	Mean (uV) ± S.D.	*Mean (uV) ± S.D.*	*P Value*
N 9	2.66 ± 0.82	3.50 ± 1.52	.068
N13	2.33 ± 0.72	3.07 ± 1.24	.054
N20	2.68 ± 1.05	3.86 ± 1.89	.045

Table 5 a. Mean latency of ulnar somatosensory evoked potential in dynamic arm position in males.

	Male	Rt - Lt. Latency difference	
	Mean (msec) ± S.D.	*Mean (msec) ± S.D.*	*Min..- Max.*
N 9	10.57 ± 0.77	0.03 ± 0.46	0.14 - 0.98
N11	12.49 ± 0.83	0.13 ± 0.62	0.00 - 0.99
N13	14.41 ± 0.73	0.11 ± 0.37	0.00 - 0.68
N20	19.98 ± 0.83	.0.01 ± 0.54	0.00 - 0.98
INTERPEAK N 9-13	3.84 ± 0.39	0.06 ± 0.34	0.00 - 0.70
INTERPEAK N13-20	5.56 ± 0.48	0.10 ± 0.47	0.00 - 0.98
ERB'S LENGTH (cm)	60.40 ± 2.64		
ERB'S – CV (cm)	13.85 ± 1.20		
HEIGHT (cm)	167.40 ± 5.46		

Table 5 b. Mean latency of ulnar somatosensory evoked potential in dynamic arm in females.

	Female	Rt.-Lt. Latency difference	
	Mean (msec) ± S.D.	*Mean (msec) ± S.D.*	*Min..– Max.*
N 9	9.62 ± 0.39	0.11 ± 0.31	0.00 - 0.56
N11	11.39 ± 0.53	0.30 ± 0.38	0.14 - 0.82
N13	13.12 ± 0.48	0.11 ± 0.47	0.14 - 0.84
N20	18.36 ± 0.46	0.13 ± 0.62	0.14 - 0.98
INTERPEAK N 9-13	3.51 ± 0.24	0.18 ± 0.31	0.00 - 0.70
INTERPEAK N13-20	5.24 ± 0.43	0.02 ± 0.37	0.00 - 0.84
ERB'S LENGTH (cm)	55.40 ± 2.39		
ERB'S – CV (cm)	12.93 ± 1.02		
HEIGHT (cm)	156.53 ± 3.94		

Table 6. Mean amplitude of ulnar somatosensory evoked potential in dynamic arm position in males and females.

	MALE		FEMALE	
	Mean (uV) ± S.D.	*Max.Rt.-Lt. Difference*	*Mean (uV) ± S.D.*	*Max.Rt.-Lt. Difference*
N 9	3.21 ± 1.22	42.1 %	3.67 ± 1.62	47.7 %
N13	2.55 ± 0.76	39.4 %	3.16 ± 1.29	40.0 %
N20	2.68 ± 0.95	44.7 %	4.30 ± 2.22	46.8 %

and Erb - CV length which were shorter in females but not with statistical significance (p>0.01) (Table 7,8). In females , the N9, N11 , N13 latencies and Erb' s length in the neutral arm position were statistically significantly shorter (p<0.01) when compared with dynamic arm positioning (Table 9) . But in males the N9 latency and Erb's length were shorter with statistically significant difference (p<0.01) in the neutral arm position by comparison with dynamic arm position (Table 10).In both neutral and dynamic arm positionings there were highly significant correlations between height, Erb ' s length, Erb - CV length and the latencies of major peaks along their pathways : N9 at the Erb's point, the N13 in the cervical SEP and the N 20 in the cortical SEP .The N9-13 interpeak latency in neutral arm positioning was significantly correlated with height (P<0.01) (Figure 4,5) whereas N13-20 interpeak latency was not correlated in any arm position (Figure 6,7). These findings indicated that central conduction time was not correlated with height, and that the peripheral nerve conduction to N9, N13 and N20 latencies is mainly responsible for the latency - height relationship.

Discussion

Short - latency somatosensory evoked potentials recorded after electrical stimulation of peripheral nerve fibers represent the activity of afferent volleys in large fast -conducting fibers chiefly mediating impulses from receptors for light touch , propioception and pinprick.[3] The main clinical reason to record SEP is to identify and localize a lesion involving the somatosensory pathways but with unknown nature. In SEP findings , attention is directed at the latency and amplitude of individual components , the interpeak latencies , and the configuration of the response . Interside differences in latency, interpeak latency and amplitude are also examined . In SEP studies, prolonged latency is often used as one of the indices of abnormality. [4] The distance between the stimulating and recording electrodes is an important factor in the SEP latency measurement. The major negative peck (N13) latency of the cervical potential is highly correlated with height or arm length. [5] Our study clearly showed that Erb's length ,Erb - CV length and height were highly correlated with the N9 , N11 , N13 , and N20 latencies in both arm positions and N9 - 13 interpeck latency in the neutral arm position (Table 12). The results confirmed the findings of Synek et al., [6] Sunwoo et al [5] and Nai-Shin Chu et al [7] whom studied quite similar to us but Sunwoo stimulated the digital ulnar nerve at the fifth digit (Table 13). In both arm positionings, the N9, N11, N13 , and N20 latencies in females were statistically significantly shorter than in males as the Erb 's length and Erb - CV length were statistically shorter with significance. When the neutral and dynamic arm positions in both sexes were compared, the latency of N9 was statistically shorter in the neutral arm positioning because of the Erb's length difference and intermittent compression and/or stretching of peripheral nerves caused by physiologic and anatomical changes in the dynamic position. Our study clearly showed that a similar comparison is essential in ulnar SEP latency measurements using a linear regression line. The measured latencies of the various major peaks of the ulnar SEP should be compared with the expected norm according to the patient's height and arm positioning. On the other hand , the central conduction time (N13 - 20) is not affected by height in any SEP. Thus the interpeak of N13-20 can be used as an index of conduction measurement without any adjustment for height.

Table 7. Mean latency of ulnar somatosensory evoked potential in dynamic arm position compare males with females.

	MALE	FEMALE	
	Mean (msec) ± *S.D.*	*Mean (msec)* ± *S.D.*	*P Value*
N 9	10.57 ± 0.77	9.62 ± 0.39	.000
N11	12.49 ± 0.83	11.39 ± 0.53	.000
N13	14.41 ± 0.73	13.12 ± 0.48	.000
N20	19.98 ± 0.83	18.36 ± 0.46	.000
INTERPEAK N 9-13	3.84 ± 0.39	3.51 ± 0.24	.010
INTERPEAK N13-20	5.56 ± 0.48	5.24 ± 0.43	.268
ERB'S LENGTH (cm)	60.40 ± 2.64	55.40 ± 2.39	.000
ERB'S – CV (cm)	13.85 ± 1.20	12.93 ± 1.02	.032
HEIGHT (cm)	167.40 ± 5.46	156.53 ± 3.94	.000

Table 8. Mean amplitude of ulnar somatosensory evoked potential in dynamic arm position compare males with females.

	MALE	FEMALE	
	Mean (uV) ± *S.D.*	*Mean (uV)* ± *S.D.*	*P Value*
N 9	3.21 ± 1.22	3.67 ± 1.62	.384
N13	2.55 ± 0.76	3.16 ± 1.29	.121
N20	2.68 ± 0.95	4.30 ± 2.22	.015

Table 9. Mean latency of ulnar somatosensory evoked potential compare between neutral and dynamic arm position in female.

	NEUTRAL	DYNAMIC	Min - Max Neutral - Dynamic	P Value
	Mean (msec) ± *S.D.*	*Mean (msec)* ± *S.D.*	Latency Difference	
N9	9.31 ± 0.39	9.61 ± 0.39	0.0 - 0.46	.000
N11	11.21 ± 0.43	11.39 ± 0.53	0.0 - 0.64	.007
N13	12.87 ± 0.46	13.12 ± 0.48	0.0 - 0.64	.000
N20	18.20 ± 0.54	18.35 ± 0.46	0.0 - 0.98	.012
INTERPEAK N 9-13	3.55 ± 0.29	3.50 ± 0.24	0.0 - 0.51	.306
INTERPEAK N13-20	5.33 ± 0.39	5.23 ± 0.43	0.0 - 0.77	.132
ERB'S LENGTH (cm)	53.47 ± 2.36	55.40 ± 2.39		.000
ERB'S – CV (cm)	12.93 ± 1.02	12.93 ± 1.02		1.00

Table 10. Mean latency of ulnar somatosensory evoked potential compare between neutral and dynamic am position in male.

	NEUTRAL	DYNAMIC	Min - Max Neutra - Dynamic	P Value
	Mean (msec) ± *S.D.*	*Mean (msec)* ± *S.D.*	Latency Difference	
N9	10.30 ± 0.64	10.57 ± 0.77	0.0 - 0.77	.000
N11	12.27 ± 0.64	12.48 ± 0.82	0.0 - 0.73	.017
N13	14.27 ± 0.64	14.41 ± 0.73	0.0 - 0.67	.074
N20	19.78 ± 0.82	19.97 ± 0.83	0.1 - 0.77	.010
INTERPEAK N 9-13	3.97 ± 0.31	3.84 ± 0.39	0.0 - 0.74	.128
INTERPEAK N13-20	5.53 ± 0.52	5.55 ± 0.48	0.0 - 0.84	.739
ERB'S LENGTH (cm)	58.48 ± 2.65	60.40 ± 2.64		.000
ERB'S – CV (cm)	13.85 ± 1.20	13.85 ± 1.20		1.00

Table 11. Correlation coefficients between height, Erb's length and latencies of the major peaks of ulnar SEP_s in neutral and dynamic arm position.

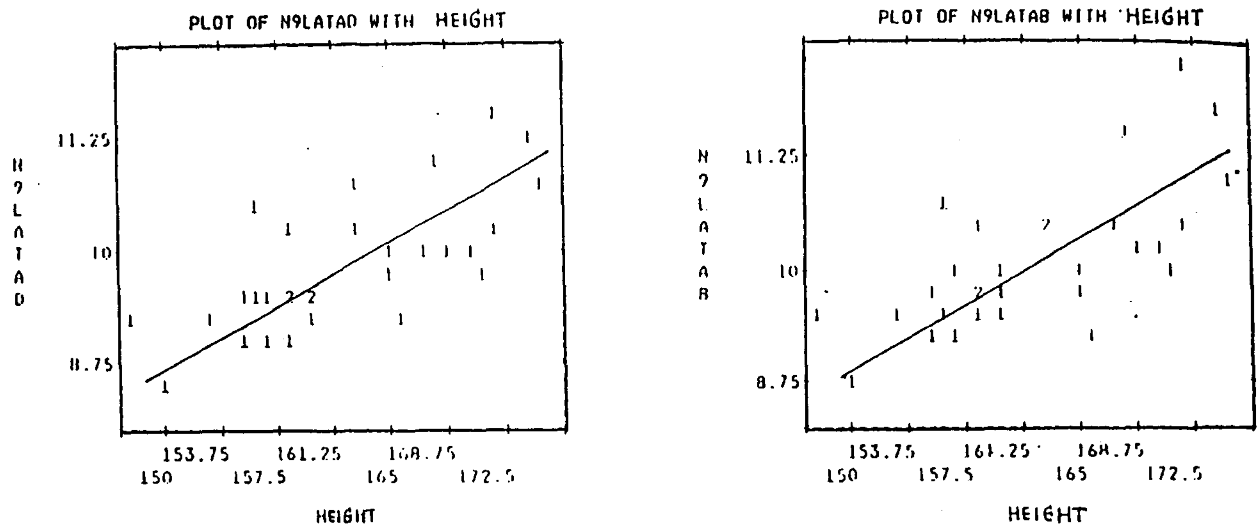
	Height (cm)		*Erb's length (cm)*	
Peak latency	*Neutral*	*Dynamic*	*Neutral*	*Dynamic*
N9	0.7382	0.6803	0.8345	0.8371
N13	0.7397	0.7365	0.7168	0.8045
N20	0.7850	0.7187	0.7708	0.8235
N 9-13 interpeak	0.4380	0.3687	- 0.1335	0.2109
N13-20 interpeak	0.3072	0.2070	0.3082	0.1284

Table 12. Correlation coefficients between height and ulnar SEP_S in neutral arm position compare between Piravej et al , Sunwoo et al, and Nai-shin Chu et al.

Peak latency (msec)	*Piravej's*	*Sunwoo's*	*Nai-Shin Chu's*
N9	0.7382	0.7750	0.8293
N13	0.7397	0.7890	0.8495
N20	0.7850	0.8810	
N 9-13 interpeak	0.4380	0.5750	
N13-20 interpeak	0.3072	0.3510	

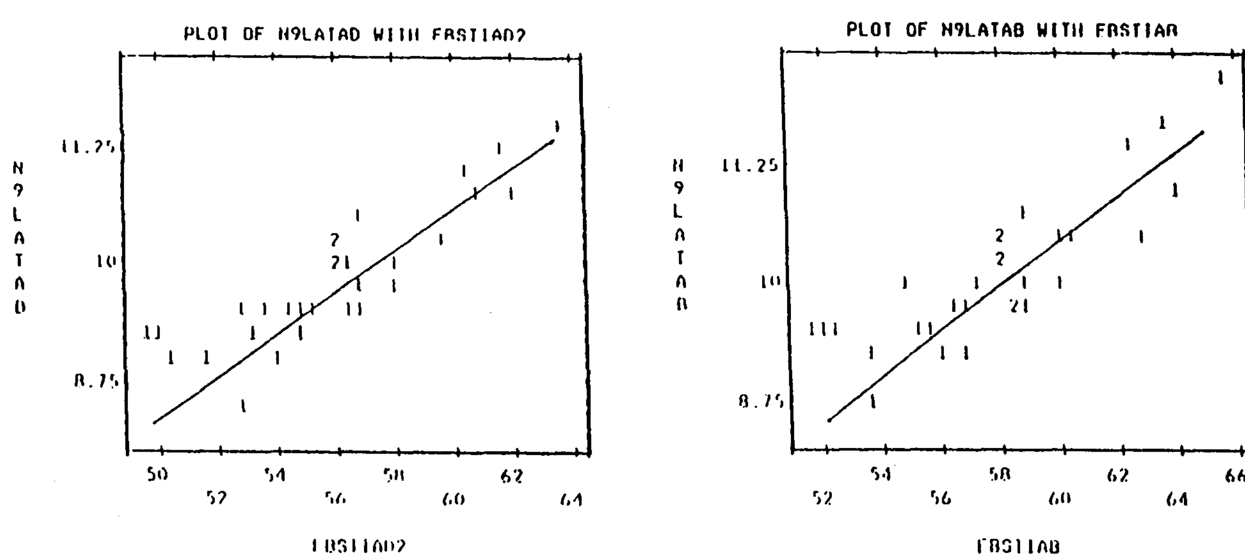
Table 13. Correlation coefficients between Erb's length and ulnar SEP_S in neutral arm position compare between Piravej et al and Nai-shin Chu et al .

Peak latency (msec)	*Piravej's*	*Nai-Shin Chu's*
N 9	0.8345	0.8816
N13	0.7168	0.8034



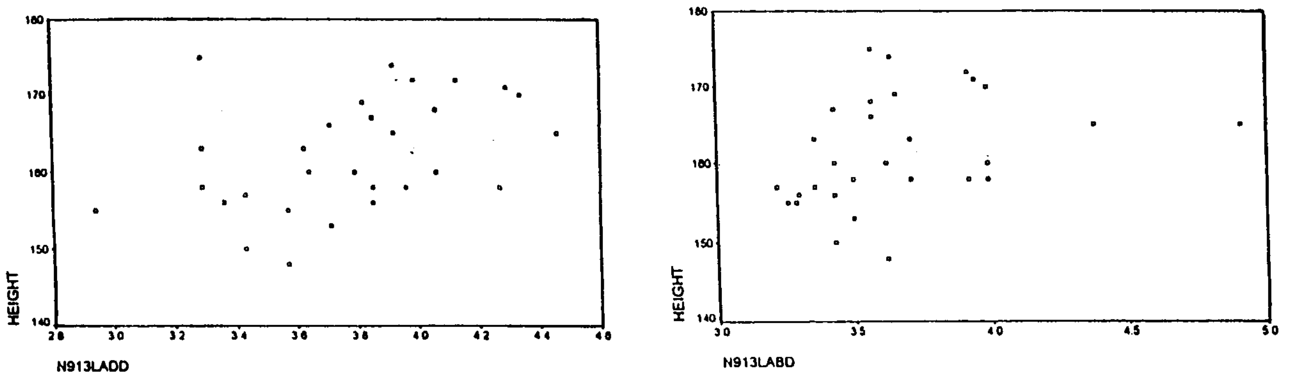
A. Neutral position B. Dynamic position

Figure 4. Relationship between height and the latency of N9 in neutral and dynamic arm positions in male and female.



A. Neutral position B. Dynamic position

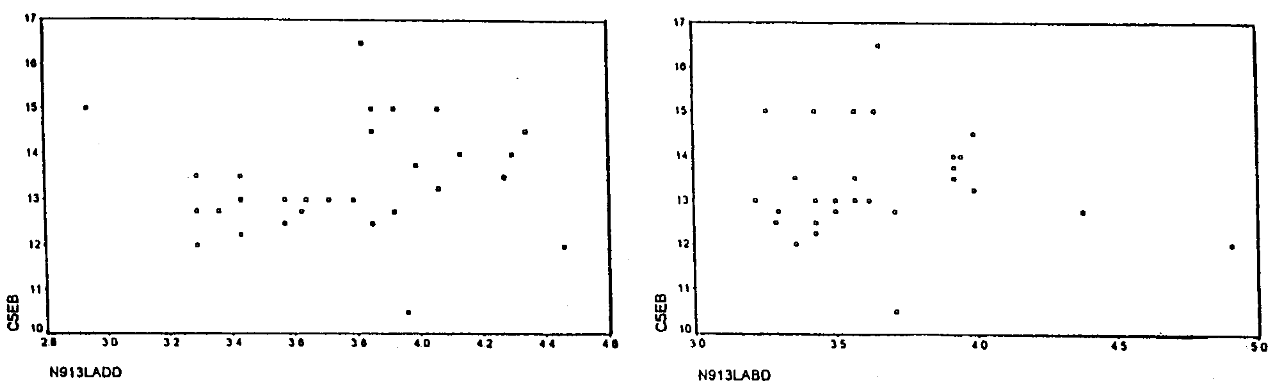
Figure 5. Relationship between Erb's length and the latency of N9 in neutral and dynamic arm positions.



A. Neutral position

B. Dynamic position

Figure 6. Relationship between height and the interpeak latency of N9-13 in neutral and dynamic arm positions.



A. Neutral position

B. Dynamic position

Figure 7. Relationship between Erb's--CV length and the interpeak latency of N9-13 in neutral and dynamic arm positions.

Conclusion

The techniques for performing ulnar SEPs in both neutral and dynamic arm positioning were described. Results from a group of 30 healthy middle-aged persons were presented in detail to provide normative data for comparison with results gained from patients. Results of these techniques could be used for objective diagnosis of neurogenic Thoracic Outlet Syndrome.[7]

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