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NORMATIVE DATA OF SHORT LATENCY SOMATOSENSORY EVOKED POTENTIAL IN THAI SUBJECTS : CORRELATION WITH HEIGHT

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ABSTRACT

Measurements of short latency somatosensory evoked potentials (SSEPs), a new non-invasive electrophysiological technique, are very useful in the assessment of the proprioceptive afferent system in man. Normative data for the Thais are not presently available. In this study, the latencies of SSEPs in 112 neurologically normal Thias, 18-74 years of age, were investigated. There were 58 males (average age of 41.7 years and height of 164.3 cm) and 54 females (average age of 32.6 years and height of 158.9 cm). The latencies of brachial plexus (N9), cervical cord (N13) and cortical (N19 and P22) potentials in adults (18-40 years old) following right median nerve stimulation were (mean ± S.D.) 8.05 ± 0.194 ms, 11.652 ± 0.635 ms, 16.683 ± 1.017 ms, and 22.089 ± 2.314 ms, respectively. Similarly, following right ulnar nerve stimulation, the latencies at the corresponding levels of the same age group were 8.357 ± 0.521 ms, 12.077 ± 0.720 ms, 17.055 ± 1.224 ms and 21.683 ± 2.091 ms, respectively. The latencies of the cortical potentials (N27, P32 and N45) following right tibial nerve stimulation were 28.104 ± 4.4 ms, 34.746 ± 2.347 ms, and 44.522 ± 4.368 ms, respectively. There were no differences in these latencies following nerve stimulation on the right sides. However, stimulation of the ulnar nerve produced a longer latency of SSEPs than that induced by the median nerve. There was a close correlation between body heights and the latencies in all the nerves studied (r = 0.3-0.6, P<0.05). The latencies in the older age groups, 41-60 years and 61-74 years old, were longer than the adult group.

Key words : Short latency somatosensory evoked potentials, afferent nerve stimulation, cortical potential, height

INTRODUCTION

Short-latency somatosensory evoked potentials (SSEPs) are compound sensory action potentials evoked by peripheral nerve stimulation. Their components are originated from different sites along the proprioceptive-posterior column to the somesthetic cerebral cortex. SSEPs can be recorded from the head, neck and back. The latencies of SSEPs are very useful in the assessment of neurological disorders (Halliday & Wakefield, 1963; Halliday, 1978; Jones, 1979; Chiappa et al., 1980; Stohr et al., 1982). The technique is non-invasive and reproducible. However, a reliable diagnosis of neurological abnormalities requires the availability of normative data.

Most studies have concentrated on the Caucasians of 20-50 years old (Matthews et al., 1974; Jones, 1977; Halliday, 1978; Hume & Cant, 1978; Kritchevsky & Wiederholt, 1978; Chiappa et.al., 1980; Allison, 1982; Allison et al., 1982; Allison et al., 1983; Hume et al., 1982: Stohr et al., 1982). Available normative data of the Asians were limited to the Taiwanese (Chu & Hong, 1985; Chu, 1986) and the Japanese (Kimura & Yamada, 1982; Kakigi, 1987; Tonada et al., 1988). There has been no comprehensive description of normal values in correlation with height for SSEPs over a wide range of age in the Thais. The present study attempted to fulfil this need.

MATERIALS AND METHODS

Subjects

There were one hundred and twenty Thai subjects, sixty males and sixty females ranging in age from 18-74 years. All these subjects were interviewed and examined physically by one of the authors. They were included in this study if neurological examinations were normal and excluded if there was either family or personal history of neurological diseases, drugs abuse, alcoholism, trauma, bone fractures and alteration of sensations. Eight subjects were excluded by such a history and four were removed from the study after neurological examinations. Hence, fifty eight males and fifty four females were enrolled. They were seated in an electrically shielded room maintained at 24-28°C. Skin temperature of both extremities were kept constant at 34-35°C and monitored by a thermistor.

Stimulation of nerves

For the safety of the subjects and to minimize stimulus artefact, the stimulator output was isolated from ground via an appropriate stimulus isolation unit. In addition, large band or plate electrodes placed between stimulating and recording electrodes were connected to ground to reduce stimulus artefact and to enhance safety in the event of isolator failure by restricting the flow of current to the subject's limb. The output to ground leakage current was less than 10 uA.

Monophasic rectangular pulses of 500 μs duration at 5/sec generated from a stimulator attached to a Neuromatic 2000 C Evoked Potential Recorder (Dantec, Denmark) was delivered to the median, ulnar and posterior tibial nerves on both sides. Stimulating electrodes were placed over the wrist crease and the ankle. The cathode was proximal to the anode to produce catelectrotonic stimulation. The system band pass was 20-3000 Hz with 200-500 averaged pulses for each stimulation. Standard skin electrodes with impedance less than 10 k ohms were placed as shown in Fig.1.

Electrodes No. 1 and 2 were placed at the Erb's point on each side, i.e., within the angle formed by the posterior border of the clavicular head of the ster-

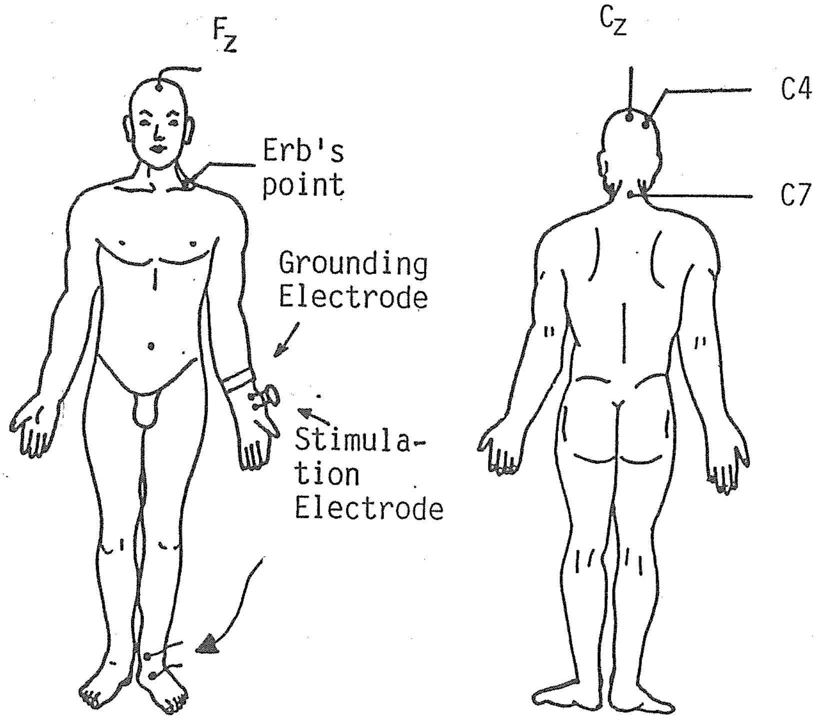

Figure 1. Placements of electrodes used to measure SSEPs of the median nerve, the ulnar nerve and the tibial nerve. N9 was recorded from Erb's point; N13 at C9; N19 and P22 at 2 cm behind C4; N27, P32 and N45 at Cz using Fz as the wrist to stimulate the median and ulnar nerves. Tibial nerve was stimulated at the ankle.

nocleidomastoid and the clavicle, 2-3 cm above the clavicle. The clavicular head of this muscle is readily visualized when the subject flexes his head against manual pressure on the forehead by a technologist. (Stimulation of Erb's point produced abduction of the arm and flexion of the forearm). Left and right Erb's point electrodes were designated electrode No. 1 and 2, respectively.

Electrode No. 3 was placed on the cervical spine, over the seventh cervical vertebra (C7). This last spinal process is easily identified as the most prominent spine at the base of the neck, when the neck is flexed.

Electrodes No. 4 and 5 were located over the scalp on both sides, 2 cm posterior to the C3 and C4 positions of the 10-20 International System of Electroencephalography electrode placement.

Electrode No. 6 was attached to the scalp over the midline frontal region (F_z placement of the 10-20 system).

Electrode No. 7 was placed over the midline vertical region of the scalp and referred to as C_z.

The stimulus polarity was a negative constant current. The intensity of stimulation was adjusted to produce minimal twitches of the thumb, little finger and big toe.

Recording of SSEPs

The instrument used to record SSEPs was the Neuromatic 2000 C, a fully equipped 2-channel neuromyograph for clinical electromyography and evoked responses. It is a microcomputer-controlled instrument comprising an active electrode box with patient isolated inputs, microcomputer averagers, a monitor, a loudspeaker, chart recorders with microcomputer-linked printer and stimulators for somatosensory evoked responses.

The following montages were derived from four pairs of the surface electrodes placed over the scalp, neck and shoulder girdle.

1. Electrode No. 4 as an active electrode with electrode No. 6 as the reference electrode : this montage revealed biphasic waves of the left hemisphere following right median and right ulnar nerve stimulations. The first peak and trough of the biphasic waves were designated N19 and P22, respectively (Fig. 2) N19 was generated from the thalamocortical radiation neurons of the brain while P22 was originated from the hand somesthetic area of the cerebral hemisphere. Similarly, electrodes No. 5 and 6 demonstrated cortical activities following left median and ulnar nerve stimulations.

2. Electrode No. 3 as an active electrode and electrode No. 6 as the reference electrode : the spinal cord volume conduction potentials with three-peak waves were shown. These three components were labelled Nll, N13 and N14, respectively. However, not all three components were simultaneously observed, only the highest wave, N13, was usually found.

3. Electrode No. 1 as an active electrode and F_z as the reference electrode : the brachial plexus compound sensory potential with large-peak wave called N9 was found. Similarly, the right brachial plexus potential with the same designation N9 was recorded from electrodes No.2 and Fz.

4. Electrode No. 7 as an active electrode and electrode No. 6 as the reference electrode : the W shaped electrical waves originated from the leg area of the cerebral hemisphere were observed. The three components were labelled as N27, P32 and N45, respectively. Many lines of evidence suggest that N27 may be derived from thalamocortical neurons and P32 from the leg somesthetic hemisphere. The origin of N45 was not well documented. This wave was usually found following tibial nerve stimulation.

All components of SSEPs evoked by stimulation were recorded using averaging technique. This technique visualized the electrical responses that had constant latency to each stimulation. All noise artefacts were diminished following repeated stimulation. Hence, the outstanding wave was clearly demonstrated. The latencies were measured from the stimulus artefact to the peak of evoked responses using the Neuromatic time marker. At least 2 averages were obtained to ensure test reproducibility.

Analysis of data

Every components of SSEPs were easily indentified by the aforementioned averaging techique. The noise artefacts were diminished and the evoked respones clearly exhibited. The upward deflection component of the evoked response was called negative wave or N wave. The downward deflection was called positive wave or P wave. Each N and P wave was designated by a number, e.g. N9, P22, N45 etc. The numbers were latencies in ms at which the waves were usually found. The latencies were measured twice from the stimulus artefact to the peak of N or P waves by the Neuromatic time marker. The following latencies were measured; N9, N13, N19, P22, N27, P32 and N45. They were recorded and analysed in correlation to body height by a microcomputer and the statistical package of Social Science Soft Ware (SPSS). The body height was recorded in standing position.

Statistical analyses

The latencies were considered abnormal if they were 2 SD beyond the mean. The differences between right and left stimulations were analysed by two-tail paired Student's t-test, and was significant if $P < 0.05$. Correlations between latencies and height were assessed by Pearson's coefficient of correlation.

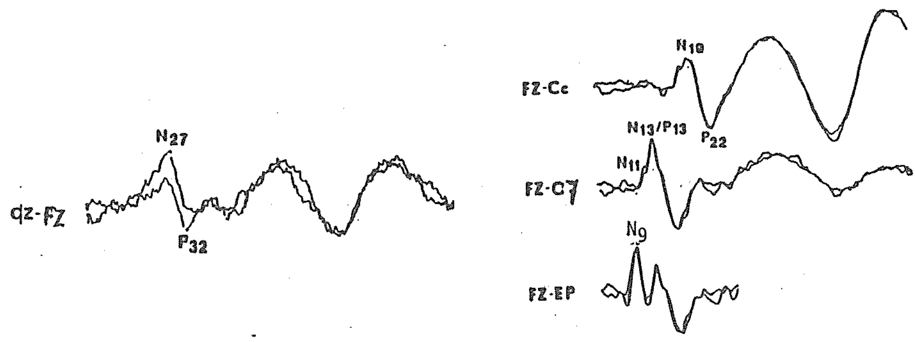

Figure 2. Representatives of short latency somatosensory evoked potentials (SSEPs) following right tibial nerve and median nerve stimulations. Tracing on the left was leg somesthetic area SSEPs of the left hemisphere following right tibial nerve stimulation. There were three components, the first biphasic wave was referred to as N27 and P32. The right tracings were SSEPs recorded from the right brachial plexus (N9), seventh cervical cord (N13) and hand somesthetic area (N19, P22) of the left hemisphere following right median nerve stimulation. Ulnar nerve stimulation also elicited similar SSEPs as those of the median nerve except that the latencies were significantly longer.

RESULTS

Representatives of the short latency somatosensory evoked potentials to median, ulnar and tibial nerve stimulations were illustrated in Fig. 2. The N9, N13, N19 and P22 represented evoked responses at the levels of brachial plexus, cervical cord and cerebral cortex, respectively. The N27 and P32 reflected leg somesthetic cortical area responses.

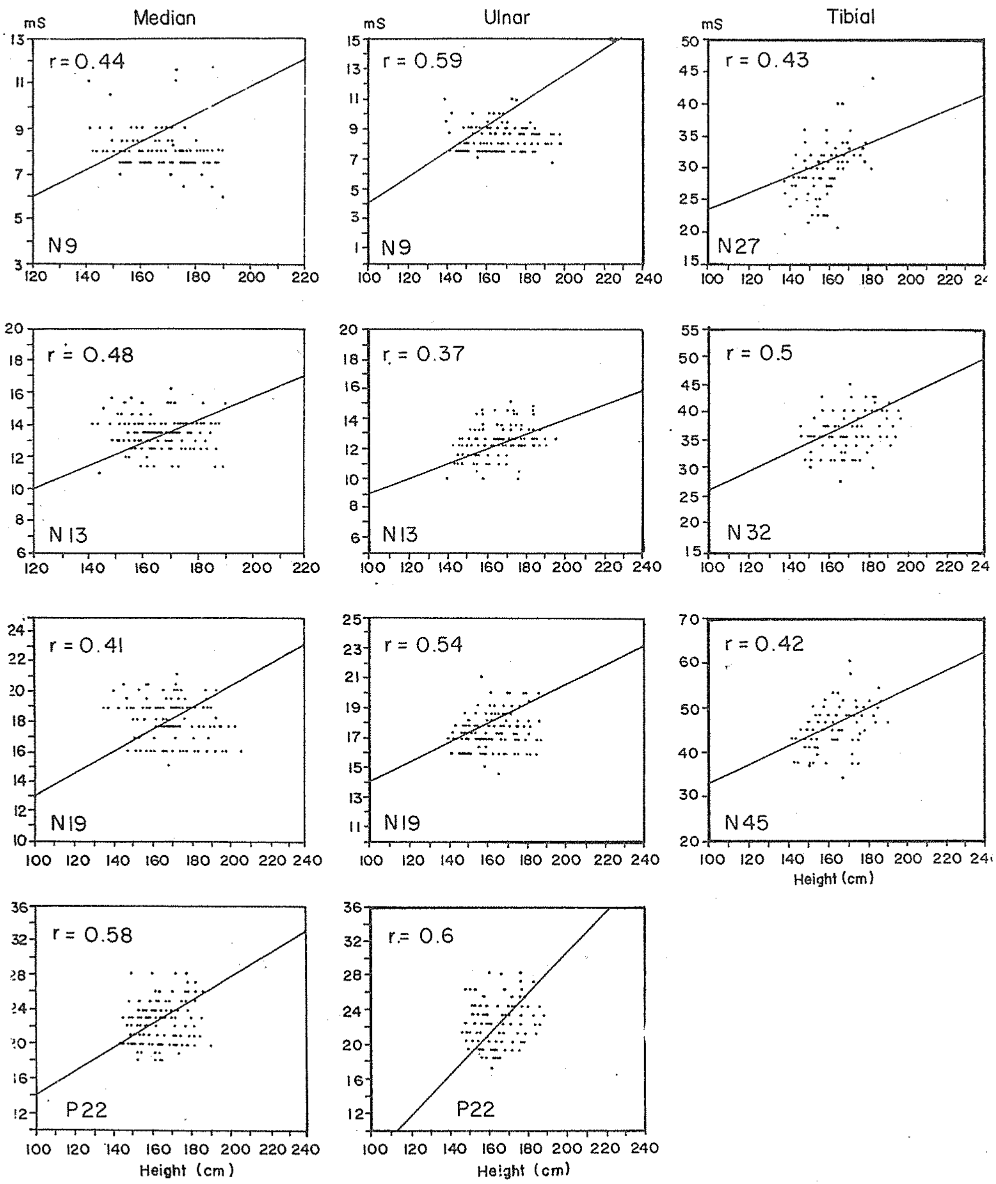

Figure 3. Correlations between height and absolute latencies of all components of SSEPs. The correlation coefficients varied from 0.37-0.6. The abscissa is height in cm and ordinate is latency in ms.

Latency values of the SSEPs following stimulations of the median, ulnar and tibial nerves on both sides are shown in Table 1. There were no differences in conduction times of the left and right nerves. However, the latencies following ulnar nerve stimulation was significantly longer ($P<0.01$) than those after stimulation of the median nerve on the same side.

The latencies of all components of SSEPs following stimulations of median, ulnar and tibial nerves in the aged groups, i.e. 41-60 and 61-74 years, were significantly higher than those in the adult group (Table 1).

Table 1. Short latency somatosensory evoked potentials (SSEPs) following median, ulnar and tibial nerve stimulation. The numbers are mean (SD). The latencies between right and left are not significantly different ($P < 0.005$), but those following ulnar nerve stimulation are significantly longer than after median nerve ($P < 0.01$).

Age group (year)	Nerve stimulation		Latencies						
			N9	N13	N19	P22	P27	P32	N45
18-40 n = 62	R	median	8.050 (0.194)	11.652 (0.635)	16.683 (1.017)	22.089 (2.314)	-	-	-
		ulnar	8.357 (0.521)	12.077 (0.720)	17.055 (1.224)	21.683 (2.091)	-	-	-
		tibial	-	-	-	-	28.104 (4.444)	34.746 (2.347)	44.522 (4.368)
	L	median	8.036 (0.277)	11.533 (0.723)	16.747 (0.902)	22.074 (2.012)	-	-	-
		ulnar	8.318 (0.465)	11.844 (0.770)	16.953 (1.368)	21.683 (2.006)	-	-	-
		tibial	-	-	-	-	29.176 (3.689)	34.85 (3.689)	34.857 (1.817)
41-60 n = 40	R	median	8.251 (0.483)	11.892 (0.632)	17.282 (1.413)	22.667 (1.722)	-	-	-
		ulnar	8.592 (0.733)	12.341 (0.223)	17.577 (1.350)	23.064 (2.001)	-	-	-
		tibial	-	-	-	-	31.000 (3.857)	36.368 (4.283)	44.867 (3.214)
	L	median	8.264 (0.409)	11.695 (0.665)	17.180 (1.144)	23.026 (2.254)	-	-	-
		ulnar	8.578 (0.706)	12.313 (0.756)	17.641 (1.386)	23.128 (2.179)	-	-	-
		tibial	-	-	-	-	30.063 (3.215)	36.885 (3.812)	44.467 (2.334)
61-74 n = 10	R	median	9.000 (0.570)	12.000 (1.871)	19.833 (4.309)	26.200 (5.675)	-	-	-
		ulnar	9.333 (1.506)	12.400 (1.817)	19.000 (1.549)	24.800 (3.033)	-	-	-
		tibial	-	-	-	-	33.000 (5.196)	38.667 (2.658)	47.500 (1.732)
	L	median	9.333 (1.862)	12.400 (1.673)	18.667 (1.751)	23.800 (2.588)	-	-	-
		ulnar	9.700 (1.718)	12.625 (1.601)	19.000 (1.871)	24.200 (1.924)	-	-	-
		tibial	-	-	-	-	33.000 (5.888)	40.000 (3.688)	47.250 (1.500)

R = right, L = left

SSEPs latencies and body height

Fig. 3 shows a linear correlation between each component of SSEPs and body height after stimulation of the median, ulnar and tibial nerves. The correlation coefficients (r) varied between 0.37 and 0.6. All correlations were highly significant ($P<0.001$) except those after tibial nerve stimulation, which had p values <0.01, $= 0$ and < 0.02 for the waves N27, N32 and N45, respectively.

Correction factor for height

Since all components of SSEPs were linearly related with heights of the subjects (Fig. 3) correction factors for height were derived from the correlation regression analysis. Table 2 shows such a linear equation for each component of SSEPs.

Table 2. SSEPs latency in relation to height H = Height in metre; L = absolute latency; a,b = constant.

Nerve	L	aH + b
median	N9	0.44 H + 7.36
	N13	0.48 H + 12.36
	N19	0.41 H + 17.36
	P22	0.58 H + 21.4
ulnar	N9	0.59 H + 8.36
	N13	0.37 H + 11.36
	N19	0.54 H + 17.2
	P22	0.60 H + 20.36
tibial	N27	0.43 H + 29.36
	P32	0.50 H + 36.2
	N45	0.42 H + 44.36

Discussion

Many studies both in animals and neurological patients disclosed that N9 was a compound action potential at the level of brachial plexus. N13 complexes were pre-and postsynaptic spinal volley compound action potentials of cuneate nucleus while there were reliable pieces of evidence that N19 was generated from the thalamocortical radiation and P22 from the somatosensory cortex. The waves N27 and P32 represented activities of the thalamocortical projection and the leg area of the somatosensory cortex, respectively. All evoked responses generated within 180 ms and called short latency somatosensory evoked potentials (SSEPs) are mediated via the posterior column-medial lemniscal pathway (Halliday & Wakefield, 1963). It has been shown that these latencies depend on age, races, sex, body height, body temperature and the placement of electrodes (Halliday, 1978; Shearer & Dustman, 1980). The present study kept skin temperature and electrode placements according to the American Electroencephalography Society Guidelines in EEG and evoked potential (1986).

Although every nerve can be stimulated to elicit SSEPs, only the median, ulnar and tibial nerves were frequently stimulated at the wrist and ankle. Since the ulnar nerve comprises smaller number of fast myelinated fibres compared to the median nerve (Chu & Hong, 1985), SSEPs'latencies following ulnar nerve stimulation were,therefore, significantly longer than those obtained from median nerve stimulation (Table 1).

At present, studies of SSEPs in the Asian countries are very limited, only studies in Taiwan and Japan have been published. The latencies of every component of SSEPs in this study were shorter than those in the previous studies involving in the Caucasian, Japanese and Chinese. Since SSEPs are compound sensory action potentials propagated via proprioceptive nerve fibres, it is conceivable that the latencies vary directly with nerve-spinal cord length, which in turn are in direct proportion to the body height (Halliday 1978; Shearer & Dustman 1980; Allison et al., 1983; Chu & Hong, 1985; Chu, 1986; Kakigi, 1987). Data in the present study showed good correlation between height and absolute latencies of every component of SSEPs. It should be pointed out that subjects in the previous studies (Allison, 1983; Chu 1985; Kakigi, 1989) were higher than the Thai subjects. This would account for the longer latencies reported in the previous studies.

From the previous studies (Cracco & Cracco, 1976; Halliday, 1978; Kimura & Yamada, 1982; Allison et al., 1983; Chu & Hong, 1985; Chu, 1986) and ours, it is clear that the absolute latencies of SSEPs should be corrected for height before being considered abnormal. The correction factors obtained in this study are comparable to the previous reports. At present, the only reliable criteria of SSEPs' abnormality are : (1) absence of N9, N13, N19, P22, N27, P32 and N45; and (2) exceedingly delayed latencies, i.e., greater than 2SD from mean after correction for height.

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บทคัดย่อ

คณะวิจัยได้ทำการหาค่าปกติของคลื่นไฟฟ้าช่วงสั้นของระบบประสาทสัมผัส ในคนไทย 112 ราย อายุ 18-74 ปี เป็นชาย 58 อายุเฉลี่ย 41.7 ปี ความสูงเฉลี่ย 164.3 ซม. และหญิง 54 ราย อายุเฉลี่ย 32.6 ปี ความสูงเฉลี่ย 158.9 ซม. พบว่าระยะเวลาที่แฝงของประสาทแขน, ไขสันหลังปล้องที่ 7 และสมองในกลุ่มอายุ 18-40 ปี เท่ากับ 8.05±0.097 มิลลิวินาที, 11.64±0.635 มิลลิวินาที, 16.683±1.017 มิลลิวินาที และ 22.089±2.314 มิลลิวินาที ตามลำดับ เมื่อกระตุ้นประสาทมีเดียนข้างขวา ส่วนการกระตุ้นประสาทอัลนาร์ข้างขวาได้ผลระยะเวลาแฝงตามลำดับดังนี้ 8.357±0.521 มิลลิวินาที, 12.077±0.720 มิลลิวินาที, 17.055±1.224 มิลลิวินาที และ 21.683±2.091 มิลลิวินาที. เมื่อกระตุ้นประสาททิเบียลข้างขวาได้ค่าระยะเวลาแฝงที่สมองเท่ากับ 28.104±4.4 มิลลิวินาที, 37.746±2.347 มิลลิวินาที และ 44.522±4.368 มิลลิวินาทีตามลำดับ ผลที่ได้จากการกระตุ้นประสาทมีเดียน, อัลนาร์, ทิเบียล ทั้งซ้ายขวาไม่แตกต่างกันอย่างมีนัยสำคัญทางสถิติ แต่การกระตุ้นประสาทอัลนาร์ได้ค่าระยะเวลาแฝงยาวกว่าการกระตุ้นประสาทมีเดียน ($P<0.05$) ความสูงของอาสาสมัครที่รับการตรวจมีความสัมพันธ์กับค่าระยะเวลาแฝงไม่ว่าจะกระตุ้นด้วยประสาทเส้นใด ($r = 0.3-0.6$, $P<0.05$) ในอาสาสมัครกลุ่มสูงอายุคือ 41-60 ปี และ 61-74 ปีมีค่าระยะเวลาแฝงยาวกว่ากลุ่มหนุ่มสาว