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ORIGINAL ARTICLE

**Katsuo Fujiwara · Kenji Kunita · Hiroshi Toyama**

# Changes in saccadic reaction time while maintaining neck flexion in men and women

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**Abstract** We investigated changes in saccadic reaction time in relation to the degree of increase in activity of neck extensor muscles when neck flexion occurred, and assessed the reliability of the measurements. Saccadic reaction time was measured firstly, during neck flexion angles set at 5° increments from 0° (resting position) to 25°, with the chin either resting on a stand or not, and secondly, during shoulder girdle elevator muscles providing a relative muscle force of 30%, with the neck flexion angle maintained at 0° by having the subjects rest their chins on a stand. Saccadic reaction time was evaluated by the latency to the beginning of eye movement toward the lateral target, which was moved at random intervals in 20° amplitude jumps. Muscle activity in the trapezius muscle was evaluated using the mean amplitude of electromyogram recordings. Very high coefficients of reliability in muscle activity and saccadic reaction time were observed between the two sets of tests at 1-h intervals and also among the three trials with a 1-min rest. When their necks were flexed and the subjects rested their chins on a stand, muscle activity increased slightly in accordance with the enlargement of this angle, with no significant change in saccadic reaction time. With the chin not resting on the stand, muscle activity increased gradually, while the saccadic reaction time decreased to that obtained at an average neck flexion angle of 20°. However, the angle where the shortest reaction time was obtained showed considerable individual variation (5–25°). Activity in the trapezius muscle at a 20° neck flexion angle, with the chin not resting on the stand, was far less than that for 30% maximal voluntary contraction in shoulder girdle elevator muscles. Nevertheless, the saccadic reaction times were roughly equivalent under the two different sets of conditions. No sex differences were observed in terms of saccadic reaction time under any set of conditions.

**Key words** Saccadic reaction time · Arousal · Neck flexion · Reliability · Sex difference

## Introduction

Human beings can perform a range of motions while maintaining a standing posture. Howorth (1946) has surveyed various exercise postures using motion pictures and has observed that a basic dynamic posture in which the foot, hip, knee and neck joints, and the trunk were lightly flexed was consistently shown throughout a variety of different exercises. He suggested from a biomechanics point of view that muscle tension, balance and co-ordination of motion were optimized by maintaining this posture. However, no subsequent studies have confirmed these phenomena.

On the other hand, Fukuda (1961) has reported that the neck reflex caused by a change in neck position relative to the trunk resulted in an increase in muscle force in limbs. Hinoki et al. (1975) have reported that maintaining the neck posture to elicit a tonic neck reflex influenced the optokinetic nystagmus. The eye movement increased in speed in the gaze phase of nystagmus rather than in the tracking phase. In addition, body reaction time has been reported to be shortened by maintaining a basic dynamic posture (Kinugasa et al. 1985) and flexion reaction time in the index finger (Fujiwara 1994) to be shortened in response to neck flexion. Studies investigating the physiological mechanisms underlying the shortening of reaction time in response to postural changes have suggested an activation of the central nervous system as the triggering mechanism (Taniguchi et al. 1980; Nara and Kasai 1991; Fujiwara 1994; Kunita and Fujiwara 1996b).

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K. Fujiwara (✉) · H. Toyama
Faculty of Medicine, Kanazawa University,
13-1 Takara-machi, Kanazawa, 920-8640 Japan
e-mail: fujikatu@med.kanazawa-u.ac.jp
Fax: 81 762 34 4219

K. Kunita
Institute of Health Science and Physical Education,
Osaka City University, 3-3-138 Sugimoto,
Sumiyosi-ku, Osaka, 558-8585 Japan

Changing the position of the upper limbs is one of the commonly used proprioceptive neuromuscular facilitation techniques. This technique has been shown to a shortening of limb reaction time (Taniguchi et al. 1980; Nara and Kasai 1991), an enhancement of spinal motor neuron excitation (Delwaide et al. 1977), an increase in the amplitude spectrum on the α band of electroencephalograms (Hosokawa et al. 1985), and an increase in blood flow volume in the cerebral cortex (Kosaka and Nakamura 1993). These phenomena are believed to have been due to an enhancement of the level of arousal, in tandem with an increase in afferent information, via an activation system primarily present in the brainstem, and/or efferent signals from the cerebral cortex and other structures.

Similar effects may be present for the angle of neck flexion. Maintaining such a neck posture during exercise would effectively enhance the activation level within the central nervous system, increase muscle tension in the limbs and speed up information processing in the sensori motor system. Furthermore, as the neck does not directly participate in limb movement, postural changes in the neck may not disturb the control of limb movement. Thus, it may be of great significance to investigate the activation of the central nervous system in response to neck flexion.

In the present study, we measured saccadic reaction time in response to a visual stimulus for three reasons. Firstly, it has been found that limb reaction time to various stimuli shows a circadian rhythm that closely corresponds to fluctuations in arousal level (Aschoff 1984; Lavie et al. 1987). Secondly, it has been shown that quick perception of a moving visual target is important for many kinds of sport or in work situations (Fujiwara 1994). Thirdly, the neural pathway of saccadic eye movement has been reported and is well understood (Nieuwenhuy et al. 1988; Pierrot-Deseilligny et al. 1995).

In our previous study, saccadic reaction time has been seen to be shortened with contraction of the shoulder girdle elevator muscles and reached a minimal value at 30% maximal voluntary contraction (MVC; Kunita and Fujiwara 1996b). It has been concluded that activation of the visual information processing system and/or the control system of saccadic eye movement is closely related to an increase in muscle activity in shoulder girdle elevator muscles. In a position of neck flexion, it has been found that deep muscles in the neck are activated excessively as is the trapezius muscle, which has been found to be one of the main shoulder girdle elevator muscles (Basmajian 1978). The muscle spindles in the deep muscles in the neck have been shown to occur more densely than do the spindles of the trapezius muscle (Cooper and Daniel 1963). If the muscle afferent information causes an activation of the nervous system associated with saccadic eye movement, the saccadic reaction time must in turn change according to the degree of neck flexion. We have previously reported on the changes in saccadic reaction time in response to neck flexion (Kunita and Fujiwara 1995). However, the report was inadequate, in that the number of subjects was small at seven and only men were studied. Furthermore, no assessment of the reliability of the measured values was undertaken.

In the present study, we studied 30 subjects (15 men and 15 women) in terms of the following four points.

1. The reliability of the measurement of saccadic reaction time
2. The relationship between saccadic reaction time and any increase in muscle activity of the trapezius muscle during neck flexion
3. The comparison of saccadic reaction time during neck flexion and contraction of shoulder girdle elevators
4. The sex difference relative to saccadic reaction time.

## Methods

### Protocol

This study consisted of two experiments. Experiment I examined the test-retest reliability of the activity of the trapezius muscle and the saccadic reaction time measured at 1-h intervals. Experiment II examined the changes in saccadic reaction time relative to neck flexion and tested the reliability of the measurements among the three trials separated by a 1-min rest. These experiments were carried out at a fixed time during the day.

### Subjects

The subjects were 10 men, aged 19–36 (mean age 20.7 years) in experiment I, and 15 men, aged 19–44 (mean age 23.7 years) and 15 women, aged 18–33 (mean age 19.3 years) in experiment II. All the subjects appeared to be free of any neurological or orthopaedic impairment and gave informed consent to the experiment protocol.

### Apparatus and data recording

An identical apparatus was used for the two experiments. The subjects sat on a steel-frame chair, with their backs resting against a vertical wall and the trunk held in place with two acrylic belts, one around the chest and the other around the hips (Fig. 1). The subjects kept their knees flexed at an approximate 90° angle and rested their feet on a low table.

Neck flexion angle was defined as the rotational angle of tragus around the shoulder (acromion) in the sagittal plane, with the starting position (0°) being a quiet sitting posture. The flexion angle was strictly determined using an angular detector of our own design. In all trials, the angle between auriculoinfraorbital line and the gravitational line was kept constant. The angle here was the same as that during the quiet sitting posture, the purpose being to maintain the constancy of the sensory stimulus from the vestibular organ. A protractor with a weight hanging from a thread was placed on the temple and was used to determine this angle. In addition, the head was supported on a stand to relax the neck extensor muscles as much as possible. Isometric contraction strength of the shoulder girdle elevator muscles was measured using a strain-gauge transducer (KYOWA, LU-SB34) placed on a steel frame, which was then connected to leather pads on the shoulders by a leather belt. The two leather pads were connected by a leather belt which prevented them from sliding laterally. The strain-gauge transducer was located under the axillary cavity at the height of the anterior superior iliac spine. Calibration of the electrical signals from the transducer was set at $0.196\ \mathrm{N} \cdot \mathrm{mV}^{-1}$.

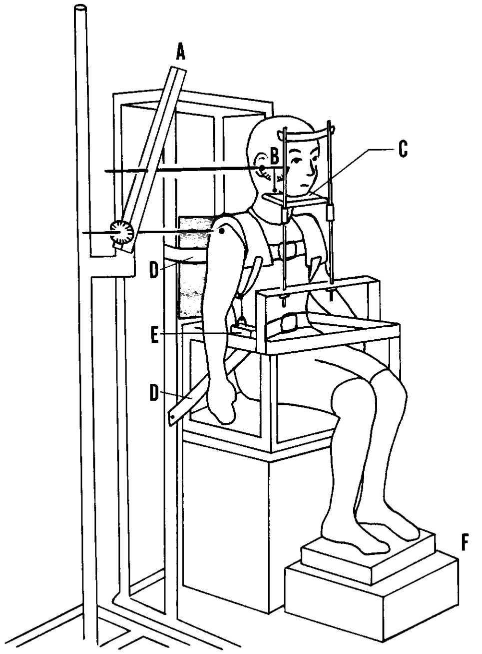

**Fig. 1** Experimental setup. *A* Angle detector, *B* protractor, *C* stand, *D* acrylic belt, *E* strain-gauge transducer, *F* foot table

Electromyograms (EMG) were recorded using bipolar surface electrodes (spaced 2 cm apart) placed over the motor point of the upper trapezius muscle. The position of the motor point was determined according to the method described by Warfel (1993). An earthed electrode was placed over the right lateral malleolus. The electrode-input impedance was reduced to less than 10 kΩ. Signals from the electrodes were amplified (×1000–×2000) and band-pass filtered (0.5 Hz–1.5 kHz) with an EMG amplifier (NEC-Sanei, BIOTOP-6R12). To monitor EMG of the trapezius muscle and the contraction strength of the shoulder girdle elevator muscles during the trial, the signals from the electrode and the strain-gauge transducer were directed to a digital oscilloscope (Iwatsu, DS-6612).

A visual stimulator (NIHON KOHDEN, SLE-5100) was used to elicit saccadic eye movement. A visual stimulus from left and right luminous emission diodes (LED) were alternately lit for random durations of 2–4 s using a personal computer (NEC, PC9801CV21) with a D-A converter (I/O-DATA, PIO9035). Two LED were set as high as the nose root, and the distance between the central point of the two LED and the nose root was set at 50 cm. The visual angle was set at 20° and thus LED were located 10° left and right from the central point. Horizontal eye movements were measured using the electro-oculogram (EOG) technique. Surface electrodes were placed at the outer canthus of each eye with a reference electrode at the centre of the forehead. The electrode input impedance was reduced to less than 10 kΩ. The signal from the electrodes was amplified (×2000) using a DC amplifier (NIHON KOHDEN, AN-601G). To obtain a steady EOG, the time interval from the securing of the electrodes to the data recording was set at over 20 min.

For subsequent analyses, the signals from the strain-gauge transducer, the electrodes and D-A converter were stored in a digital tape recorder (TEAC, RD-130TE).

## Procedure

### *Experiment I*

Prior to the start of data recording, to relax the trapezius muscle, contraction and relaxation of the shoulder girdle elevator muscles were alternately repeated several times and a deep breath was taken following the procedures of Basmajian (1981) and Shirley et al. (1982). Furthermore, a trial series of following the alternately lit LED was carried out for 20 s. Next, right and left isometric maximal force of the shoulder girdle elevator muscles were separately measured under conditions whereby the neck flexion angle was 0° with the chin not resting on a stand (chin-off). The measurement was carried out twice with a 3-min rest between measurements.

Thereafter, the saccadic reaction time was measured for 20 s under conditions whereby

1. The neck flexion angle was 0° or 20°, in the chin-off posture, and
2. The shoulder girdle elevator muscles were providing a relative muscle force of 30% MVC, with the neck flexion angle maintained at 0°, and the chin resting on a stand (chin-on).

In condition 1., three trials were undertaken at each neck flexion angle with a 1-min rest during each trial. In condition 2., three trials were undertaken with a 3-min rest during each trial. A 15-min rest was taken between measurements in both conditions. The first experiment was carried out twice separated by 1 h.

### *Experiment II*

First, as in experiment I, the subjects practised relaxing the trapezius muscle and following LED, and the maximal force of the shoulder girdle elevator muscles was measured. In addition, the maximal angle of neck flexion was measured using the angular detector. The lowest value of the neck flexion angles among all the subjects was 25°. The upper limit of neck flexion angle was thus set at 25°. Thereafter, saccadic reaction time was measured for 20 s under conditions whereby

1. Six angles of neck flexion were randomly set at 5° increments from 0° to 25°, in either the chin-on or chin-off postures, and
2. The shoulder girdle elevators were providing a relative muscle force of 30%, in the chin-on posture with the neck flexion angle maintained at 0°.

In each condition, three trials were undertaken with 3-min rests per trial. The rest time between measurements in both conditions was 15 min. All measurements in experiment II were finished within 1 h.

## Data analysis

The electrical signal from the strain-gauge transducer in the measurement of maximal muscle force was recorded using a digital oscilloscope with a resolution of 0.784 N. The larger of two measurement values was used for analysis.

The data from EMG, EOG and the visual stimulus were sent to a computer (NEC, PC-9821V233) via and A-D converter (Canopus, ADJ-98) at 1000 Hz with a 12-bit resolution. In order to estimate the relative activity of the trapezius muscle during neck flexion and 30% MVC, EMG mean amplitude in each condition was calculated after the EMG data was high-pass filtered (20 Hz) and full-wave rectified. Relative muscle activity was calculated using the following equation:

$$\text{Relative muscle activity (\%)} = (\mathrm{EMG_x} - \mathrm{EMG_{min}})/(\mathrm{EMG_{max}} - \mathrm{EMG_{min}}) \times 100$$

where $\mathrm{EMG_x}$ is the EMG mean amplitude of the trapezius muscle in each condition, $\mathrm{EMG_{min}}$ is the smallest value in EMG mean amplitudes of the neck flexion angles in the chin-on posture, and $\mathrm{EMG_{max}}$ is the EMG mean amplitude in the maximal force of the shoulder girdle elevator muscles.

Saccadic reaction time was defined as the latency to the beginning of eye movement following the onset of lateral target movement. Processing of the EMG amplitude of the trapezius muscle and the saccadic reaction time was performed using BIMUTAS-E version E2.20 (Kissei Comtec Co., Ltd).

### Statistical analysis

As the data for maximal muscle force and EMG mean amplitude of the right and left sides were similar, the data from the two sides were combined. The mean values and standard deviations in saccadic reaction time and relative muscle activity were calculated for every set in experiment I and in every trial of experiment II. To examine the temporal stability of saccadic reaction time and the relative muscle activity of experiment I, reliability coefficients were calculated using the test-retest method. The relationship among the three trials between saccadic reaction time and the relative muscle activity in experiment II was examined in terms of the reliability coefficient by an analysis of variance. In addition, in experiment II, a two-way analysis of variance was made to study the effect of neck flexion angle and any individual differences among subjects. A multiple comparison analysis using Fisher's protected least significant difference was made to examine any differences suggested by the analysis of variance. To test the significance of any difference in terms of the reliability coefficient, a $\chi^2$ test was conducted after Fisher's $Z$ transformation. To examine the relationship between the relative muscle activity and the saccadic reaction time, $T$-score of each datum (x) was calculated using mean and standard deviation (SD) for each subject by the following equation: $T\text{-score} = 10(\mathrm{x} - \mathrm{mean})/\mathrm{SD} + 50$. Significance was accepted at the $P < 0.05$ level. All statistics were calculated using Excel Version 5.0 (Microsoft Corp.).

## Results

### Reliability of measurements of muscle activity of trapezius muscle and saccadic reaction time

Under all conditions, high reliability coefficients were shown in the relative muscle activity of the trapezius muscle and the saccadic reaction time. In experiment I, the reliability coefficients in the relative muscle activity were consistently 0.919 at the neck flexion angles of 0° and 20°, and 0.909 at 30% MVC. The concurrent reliability coefficients of saccadic reaction time were 0.937, 0.885, and 0.913, respectively. In experiment II, the reliability coefficients of measurements at each angle of neck flexion varied from 0.782 to 0.974 in relative muscle activity, and from 0.872 to 0.952 in saccadic reaction time (Table 1). No significant effect of neck flexion angle was found for the reliability coefficients in the two measurements.

### Muscle activity of trapezius muscle and saccadic reaction time following changes in neck flexion angle

A significant sex difference was observed in the maximal force of shoulder girdle elevator muscles [men 602.7 (SD 198.94) N, women 275.38 (SD 87.22) N; $F_{1,28} = 34.15$, $P < 0.001$]. The angle between the auriculoinfraorbital line and the gravitational line while a quiet sitting posture was maintained failed to show any significant sex difference, and the mean value for all the subjects was 14.4° (SD 3.5).

Analysis of variance of the relative muscle activity indicated a significant effect of sex for both the chin-on and chin-off posture (Fig. 2; chin-on, $F_{1,179} = 14.36$, $P < 0.001$; chin-off, $F_{1,179} = 10.17$, $P < 0.003$). Post hoc analysis indicated that the relative muscle activities for all angles of neck flexion were significantly greater in the men than in the women (chin-on $F_{1,28} > 7.34$, $P < 0.001$, chin-off $F_{1,28} > 6.43$, $P < 0.002$).

In the chin-on posture, the relative muscle activities of both sexes increased as the neck flexion angle increased (men $F_{5,89} = 3.59$, $P = 0.006$, women $F_{5,89} = 3.32$, $P = 0.009$) but the maximal values here were very small [0.2 (SD 0.1)% MVC in the men; 0.6 (SD 0.2)% MVC in the women). The relative muscle activities while maintaining each neck flexion angle in the chin-off posture were significantly greater than those in the chin-on posture (men $F_{1,14} > 6.50$, $P < 0.023$, women $F_{1,14} > 17.06$, $P < 0.001$). A significant effect of neck flexion angle was observed for the relative muscle activity in the chin-off posture (men $F_{5,89} = 11.11$, $P < 0.001$, women $F_{5,89} = 28.90$, $P < 0.001$).

The men and women showed essentially similar patterns of change in the relative muscle activity according to the neck flexion in the chin-off posture. When the neck was flexed from 0° to 20°, the relative muscle activities gradually increased from 0.2 (SD 0.1)% MVC to 1.3 (SD 1.0)% MVC in the men and from 0.8 (SD 0.6)% MVC to 2.4 (SD 1.1)% MVC in the women. In contrast, this value at 25° increased little when compared to that at 20° [1.3 (SD 1.3)% MVC in the men; 2.6 (SD 1.4)% MVC in the women]. Post hoc analysis indicated that the relative muscle activities at the neck flexion angles of 10–25° for the men ($P < 0.001$) and 5–25° for the women ($P < 0.028$) were significantly greater than their respective muscle activities at the neck flexion angle of 0°.

Analysis of variance of saccadic reaction time indicated no significant effect of sex in either in chin-on or chin-off posture (Fig. 3). Although the average saccadic reaction time for all subjects varied from 201.1 to 204.2 ms in the chin-on posture, no significant effect of neck flexion angle was detected. Saccadic reaction time

**Table 1** Reliability coefficients in relative activity of trapezius muscle and saccadic reaction time among three trials in the chin-on and the chin-off posture for 30 subjects. *MVC* Maximal voluntary contraction

| | Angle of neck flexion | | | | | | 0°–30% MVC |
|---|---|---|---|---|---|---|---|
| | 0° | 5° | 10° | 15° | 20° | 25° | |
| Chin-on | | | | | | | |
| Relative muscle activity | 0.889 | 0.803 | 0.787 | 0.782 | 0.869 | 0.850 | |
| Saccadic reaction time | 0.872 | 0.918 | 0.915 | 0.892 | 0.943 | 0.910 | |
| Chin-off | | | | | | | |
| Relative muscle activity | 0.943 | 0.938 | 0.974 | 0.957 | 0.930 | 0.970 | 0.926 |
| Saccadic reaction time | 0.894 | 0.952 | 0.932 | 0.924 | 0.902 | 0.893 | 0.946 |

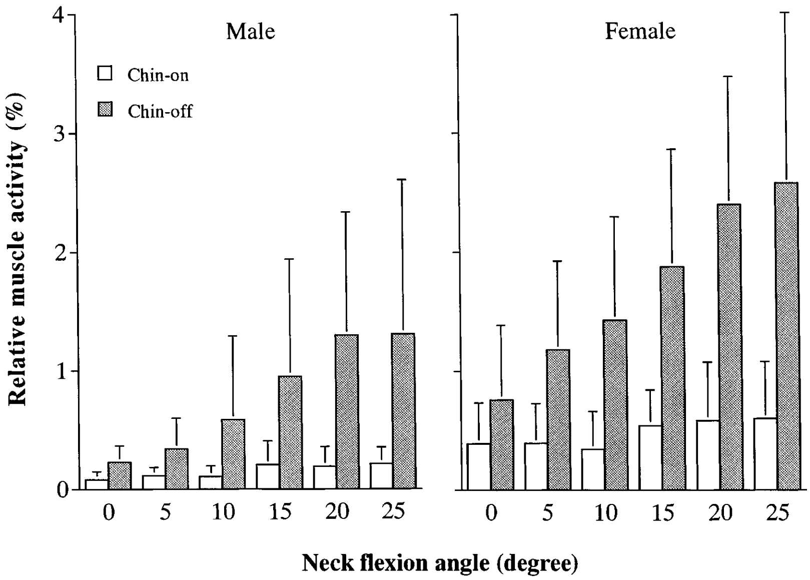

**Fig. 2** Relative activity of the trapezius muscle as a function of neck flexion angle in the chin-on and the chin-off posture. Values are mean and SD for 15 men (*left figure*) and 15 women (*right figure*)

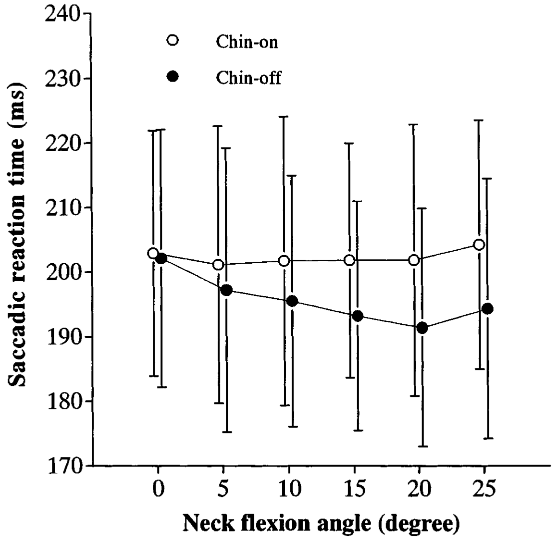

**Fig. 3** Saccadic reaction time as a function of neck flexion angle in the chin-on and the chin-off posture. Values are mean and SD for 30 subjects

in the chin-off posture was significantly shorter than that in the chin-on posture at all neck flexion angles except for 0° ($F_{1,29} > 5.97$, $P < 0.02$). Analysis of variance of saccadic reaction time in the chin-off posture indicated a significant effect of neck flexion angle ($F_{5,179} = 9.59$, $P < 0.001$).

The longest reaction time in the chin-off posture was obtained at a neck flexion angle of 0° [202.1 (SD 19.9) ms], and this duration gradually shortened to the time recorded for the neck flexion angle of 20° [191.4 (SD 18.4) ms]. However, the reaction time was slightly increased at a neck flexion angle of 25° [194.3 (SD 20.1) ms]. Post-hoc analysis indicated that the reaction time at neck flexion angles from 5° to 25° was significantly shorter than that at 0° ($P < 0.005$). The neck flexion angle where the shortest saccadic reaction time was obtained varied from 5° to 25°, and the shortest reaction time occurred most frequently at a neck flexion angle of 20° (10 to 30 subjects). This angle was not significantly correlated with either the maximal neck flexion angle or the maximal force of the shoulder girdle elevator muscles.

As stated previously, the relative muscle activity of the trapezius muscle increased according to the neck flexion angles up to 20° in the chin-off posture. Thus, relative muscle activity and saccadic reaction time at the neck flexion angles from 0° to 20° were normalized using a *T*-score transformation. There was a relatively high degree of negative correlation between the *T*-scores of two items (Fig. 4), and the coefficient here was significant ($r = -0.437$, $P < 0.001$).

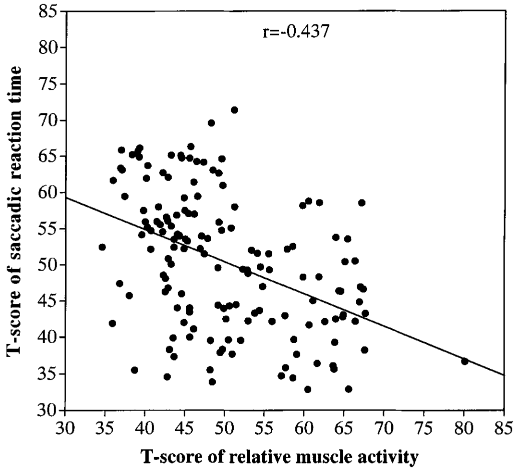

**Fig. 4** Correlation between *T*-scores for relative activity of trapezius muscle and the saccadic reaction time in the chin-off posture for 30 subjects

### Relative activity of trapezius muscle and saccadic reaction time at 30% MVC and at neck flexion angle of 20° in the chin-off posture

The relative muscle activity of trapezius muscle at 30% MVC was 29.8 (SD 8.3)% MVC for the men and 30.6 (SD 10.9)% MVC for the women, with no significant sex difference. For both sexes, the muscle activities were dramatically greater than those at a neck flexion angle of 20° in the chin-of posture [men 1.3 (SD 1.0)% MVC, $F_{1,29} = 194.9$, $P < 0.001$; women 2.4 (SD 1.1)% MVC, $F_{1,29} = 94.5$, $P < 0.001$].

No significant sex difference in the saccadic reaction time was observed at 30% MVC, with the value for all subjects being 190.4 (SD 19.8) ms. The above reaction time did not differ significantly from that at a neck flexion angle of 20° in the chin-off posture [191.4 (SD 18.4) ms].

## Discussion

### Reliability of measurement of saccadic reaction time

Before discussing the effect of neck flexion on saccadic reaction time, we need to confirm that certain experimental conditions were satisfied and that all factors that might have caused saccadic reaction time to fluctuate were excluded. Neck flexion angle, contraction strength of the shoulder girdle elevator muscles, and the movement interval for the target light were important conditions in our experiment. In terms of potential factors for fluctuation, fatigue and biorhythm should be considered.

As neck flexion began from a quiet sitting position, it was important for the neck angle to be maintained throughout the experiment in this position. If the neck flexion angle had been allowed to fluctuate between trials, the activity of the neck extensor muscles would have varied accordingly. In experiment II, high reliability coefficients were observed in relative muscle activity. This confirms that the target angles of neck flexion were maintained consistently at a quiet sitting position.

The problem of contraction strength was also solved, judging from the small amount of variation observed in relative muscle activity among the three trials. As to the movement interval of the target light, we reasoned from the simple reaction time that has been found by Klemmer (1956) that even if it is randomly changed, the saccadic reaction time must be influenced by the mean value of the movement intervals of the target light. For each angle of neck flexion, a muscle force of 30% MVC and the chin-on or -off posture, we obtained high reliability coefficients in saccadic reaction time in experiment II. Thus, it follows from these results that our experimental conditions were fairly well met.

It has been established that when a muscle is fatigued, the amplitude of EMG increases even if the same force is developed (Edwards and Lippold 1956), and that when the attention level goes down in response to fatigue of the central nervous system, the reaction time is lengthened (Singleton 1953; Bertelson and Joffe 1963). Judging from the reliability coefficients of the relative muscle activity and the saccadic reaction time in experiment II, the problem concerning fatigue can be excluded. The arousal level of the brain has been demonstrated to show a circadian rhythm having a period of approximately 24 h and an ultradian rhythm having a period of approximately 2 h (Lavie et al. 1987). We have previously reported that the saccadic reaction time is longer in both the morning and at night than it is during the day (Kunita and Fujiwara 1996a). Hence, our experiments were carried out at a fixed time of day, and experiment II was finished within 1 h. Very high reliability coefficients in muscle activity and saccadic reaction time were obtained between the two sets of tests at 1-h intervals. Therefore, the problem concerning differences in biorhythm can also be excluded.

Thus, we can now discuss with extreme precision how the saccadic reaction time changed according to neck flexion positions.

### Relationship between the saccadic reaction time and the muscle activity of trapezius muscle during neck flexion

When the neck flexion angle was increased in the chin-on posture, the activity in the trapezius muscle increased slightly (maximum: 0.2% MVC in the men, 0.6% MVC in the women). This increase in muscle activity is considered to have been the body's response to maintaining a regular position of the head and neck, the latter having a multi-joint structure. However, the activity was markedly less than that in the chin-off posture and a flexion angle of 0°. Meanwhile, the saccadic reaction time under the same condition did not change according to neck flexion, and showed no significant difference from that in the chin-off posture and a neck flexion of 0°. The above results would indicate that the change in saccadic reaction time under conditions with so little muscle activity is negligible.

When the neck flexion angle was increased in the chin-off posture, the activity in the trapezius muscle increased considerably, and the saccadic reaction time was shortened up to a certain angle (mean 20°), and then the reaction time became lengthened. A relatively high degree of correlation was found between the two $T$-scores for relative activity of trapezius muscle and saccadic reaction time, which were measured at neck flexion angles from 0° to 20°. The results indicated that the decrease in saccadic reaction time up to a certain angle of neck flexion corresponded to the activity of the neck extensor muscle.

It has been reported that information in muscle afferent nerves increases together with the increase in muscle activity (Edin and Vallbo 1990; Wilson et al. 1997). It has been suggested therefore that an increase in information in muscle afferent nerves from the neck extensor muscles should cause an enhancement of the level of arousal, via an activation system that exists primarily in the brainstem (Klemm 1990; Roll et al. 1991; Taylor and McCloskey 1991; Vallar et al. 1995). As noted above in the Introduction, it has been considered that a facilitating effect of efferent signals from the cerebral cortex and other structures, which are needed to maintain the neck flexion position, might also be playing a role (Uchida et al. 1980; Gratyn and Berthoz 1987; Hikosaka et al. 1993).

From the above data it seems that an inhibitory mechanism preventing a shortening of saccadic reaction time begins to come into play at the larger angles of neck flexion. In this study, the angle between the auriculoinfraorbital line and the gravitational line was kept constant at the same angle as in a quiet standing posture. Consequently, the backward flexion of the head became extreme at smaller angles than in maximal neck flexion. Because attention was distracted to maintain the angle of the auriculoinfraorbital line at larger neck flexion angles, concentration on the visual target may have been reduced.

A similar phenomenon has been reported, wherein the reaction time in a main task was lengthened when increased attention had to be paid to factors only indirectly concerning the task or to the control of other tasks (Cordo and Nashner 1982; Massion 1992). It has been generally accepted that inhibitory sensory information is accompanied by excessive extension of the neck extensor muscles (Schmidt 1985). We have previously reported that when a force of more than 30% MVC in the shoulder girdle elevator muscles was produced, the saccadic reaction time became markedly lengthened (Kunita and Fujiwara 1996b). This finding clearly supports the existence of an inhibitory mechanism as suggested by this study.

It was also remarkable that there were great individual differences in the neck flexion angle at which saccadic reaction time became minimal. This may have been due to individual differences in optimal activation of the saccadic reaction system and/or in the amount of facilitating sensory information induced by neck flexion.

## Comparison of saccadic reaction time during neck flexion and contraction of shoulder girdle elevator muscles

In our previous study, the shortest saccadic reaction time was obtained at 30% MVC when the shoulder girdle elevator muscles were contracted (Kunita and Fujiwara 1996b). In the present study, the shortest saccadic reaction time was shown at a neck flexion angle of 20°. Both times were approximately the same. On the other hand, the relative muscle activity of the trapezius muscle at 20° neck flexion angle was 1.3% MVC in the men and 2.4% MVC in the women, and these values were much lower than those at 30% MVC. In the neck flexion position, both superficial and deep neck extensor muscles must be activated, and in such a position it has been suggested that the deep neck extensor muscle may be activated excessively (Basmajian 1978; Schüldt et al. 1986).

In the present study, only the activity of the trapezius muscle, which has been shown to have a large volume, was investigated (Voss 1956). It is possible that the muscle activity of the deep neck extensor muscle markedly influenced saccadic reaction time. One reason for this is that the density of muscle spindles in deep muscles has been reported to be much higher than it is in superficial muscles (Cooper and Daniel 1963). Researchers must consider that the amount of muscle afferent information may be abruptly increased even during weak contraction of the neck extensor muscle during neck flexion. However, we were unfortunately unable to examine such an influence directly in this study.

## Sex difference in saccadic reaction time

No significant sex differences were seen in the saccadic reaction time in all conditions or in the degree of shortening in saccadic reaction time during neck flexion. Many previous studies have reported that the manual reaction time to a visual stimulus in young adults is significantly shorter in men than it is in women (Welford 1980; Nagel-Leiby et al. 1990), whereas saccadic reaction time does not show a sex difference, or, if present, the tendency is for it to be slightly shorter in women than in men (Nagel-Leiby et al. 1990; Wilson et al. 1993). However, no studies have yet examined the sex difference of activation in the neural pathway of saccadic eye movement.

Saccadic eye movement has been classified into the following types: reflexive visual-guided saccade, intentional visual-guided saccade, predictive saccade and memory-guided saccade (Pierrot-Deseilligny et al. 1995). The saccadic eye movement in the present study was visual-guided saccade, in which the neural pathway is composed of a lateral geniculate body, occipital cortex, posterior parietal cortex, parietal eye field, frontal eye field, superior colliculus and reticular formation.

According to Celesia et al. (1987), when neural transmission time from the retina to the visual cortex was measured using the latency of the visual evoked potential, it was shorter in women than in men. The pathway was contained within the neural pathway of saccadic eye movement. The sex difference has been reported to be caused potentially by head size and/or the neuroendocrine system (Celesia et al. 1987; Guthkelch et al. 1987). A sex difference in the transmission time in neural pathways following the visual cortex has yet to be examined. Future research, taking into consideration the neural pathway and type of eye movement, should attempt to determine if any sex difference exists in saccadic eye movement.

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