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Respiratory and head position influences on late stretch reflexes

KEY WORDS
Elbow
Positioning, head
Reflex primitive, ATNR
Reflex, stretch

ABSTRACT The purpose of this study was to determine the relative effects of the asymmetric tonic neck reflex (ATNR) and of respiration on the upper limb, as measured by their influence on the stretch reflexes.

Long latency stretch reflexes (M2 and M3) were induced in elbow muscles of human subjects. The subject's right forearm was strapped into a manipulandum. The forearm was perturbed with a torque test pulse at a fixed interval prior to an intended forearm movement. It was found that both the M2 and M3 reflexes, in triceps or brachialis muscles were significantly increased when perturbations were delivered during inspiration as compared to expiration. Rotated head positions to the right or left could also significantly alter reflex magnitude but there was no consistent pattern among subjects.

The clinical implications of these findings are discussed.

RÉSUMÉ Cette étude veut préciser les effets relatifs du réflexe tonique assymétrique du cou et de la respiration sur le membre supérieur, tels que mesurés par leur influence sur les réflexes d'étirement.

Les réflexes d'étirement à longue latence (M2 et M3) ont été provoqués dans les muscles du coude. L'avant-bras droit a été immobilisé par courroies dans un manipulandum. Préalablement à un mouvement intentionnel, l'avant-bras a été déplacé par une impulsion de force passive appliquée à intervalles fixes. On a observé que les réflexes M2 et M3 au niveau du triceps ont augmenté de façon appréciable quand les stimulations ont été administrées au moment de l'inspiration en comparaison de l'expiration. On a observé que les rotations droite et gauche de la tête pouvaient aussi modifier de façon significative l'ampleur des réflexes sans toutefois noter de conformité parmi les sujets.

Les implications cliniques de ces résultats sont discutées.

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Occupational therapists and physiotherapists have sought to understand normal motor control in order to develop appropriate assessment and treatment strategies for the rehabilitation of the neurologically impaired. For example, in rehabilitation of adults following stroke, differences in the understanding of what is normal in the reflexive basis of movement has led to the opposing treatment approaches of Bobath, (1978) Eggers (1983) and Brunnstrom (1970). As a result, in clinical practice the treatment techniques are often applied in a pragmatic heuristic approach.

The asymmetric tonic neck reflex (ATNR) is one reflex which is considered in the Bobath approach (1978) to be abnormal in human adults and is therefore avoided in movement therapy following a stroke. However this physiological premise, which still forms a basis of treatment, was based on uncontrolled studies and anecdotal descriptions. According to the Brunnstrom (1970) approach, the ATNR might be used to help initiate voluntary movement. A review of the literature revealed a number of studies of ATNR in normal adults with varying degrees of objective control and varying results. It has been seen experientially that normal adults often match their movement to their respiratory pattern or modify their respiratory pattern (e.g. inspiring or holding of one's breath when doing activities which require a sudden physical effort). However the potential influence of respiration on movement is not generally considered in neurological rehabilitation.

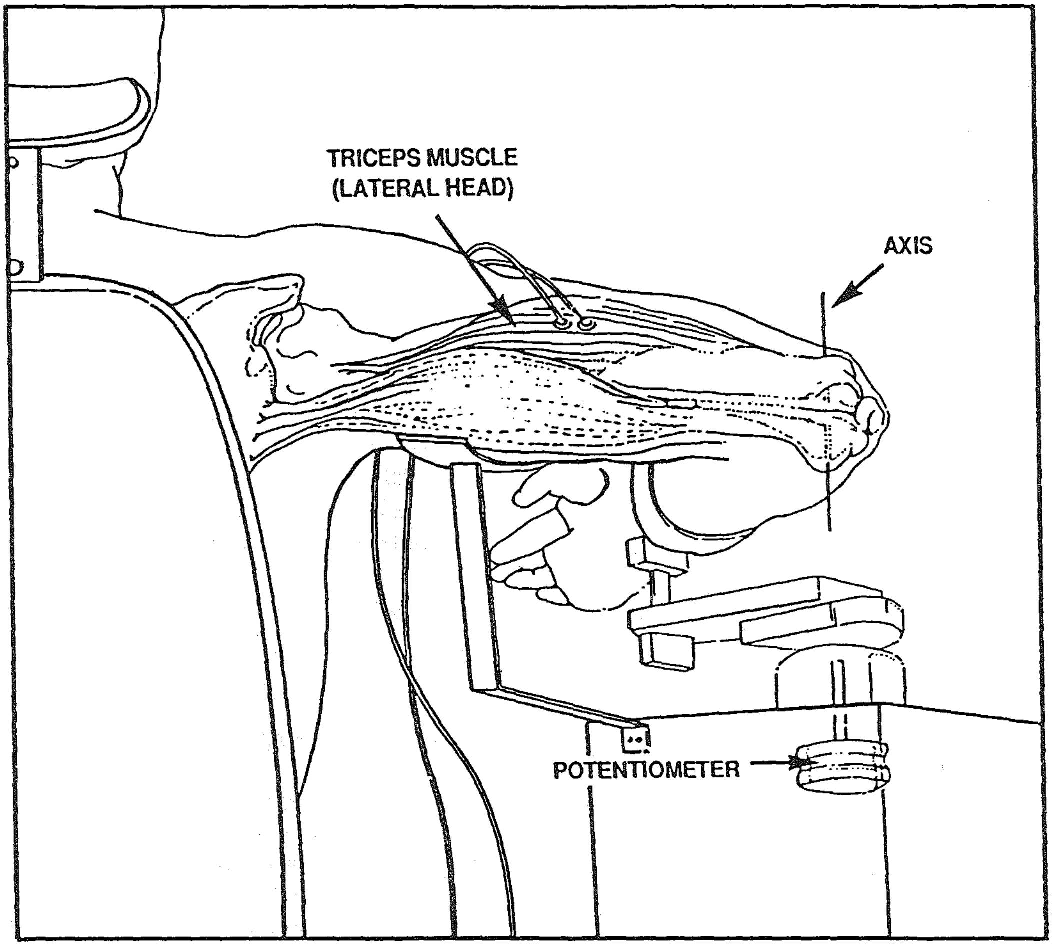
With a greater understanding of the reflex mechanisms that influence normal movement, therapists will be able to further select and develop sound intervention strategies.

LITERATURE REVIEW

The ATNR, described by Magnus (1926), has been examined in a number of ways in an attempt to identify the nature and degree of its influence in normal human adults. ATNR is expressed in normal infants, and in some adults with neurological pathology, such as following cerebral vascular accident (Bobath, 1978; Brunnstrom, 1970). In the ATNR when the head is turned to one side, the jaw limbs extend and the skull limbs flex. Magnus (1926) noted that attitudinal reflex postures such as ATNR were not striking in normal adult humans. Others, using various methods of eliciting and measuring its effects on limb muscle tone, have found varying degrees of influence by ATNR. Tokizane, Murao, Ogata and Kondo (1951) visually evaluated EMG records during passive movements of the head in 5 normal subjects, and found effects generally as ATNR would predict. Warren (1984) averaged the EMG response for 10s in each head position and found effects in biceps and triceps according to ATNR. This measurement method was only sensitive enough to demonstrate effects when the subjects forcefully squeezed a rubber pad with the other hand at the same time . Fukuda (1961), who examined photographs of adults doing various physical activities, claimed that ATNR was a basic constituent of normal movement patterns. However, Geddes and O'Grady (1979) reviewed video records of adults doing activities and found that head rotation affected limb positions in only a few instances. Ikai (1950) developed a device for measuring the intensity of the tonic neck reflex. Subjects sat in a chair and grasped a vertical bar placed in front of the chair. When the investigator passively rotated the subject's head, any resulting movement of the vertical bar, pulled on a thread which was attached to the recording lever of a kymograph. Ikai reported that the arm moved as expected by the ATNR. Hellebrandt, Houtz, Partridge and Walters (1956), Hayes and Sullivan (1976) and Traccis et al. (1987) have confirmed that head rotation can influence limb muscle activity. However, Stejskal (1979) showed that the effects of head posture were dependent on the degree of head rotation. Extreme head turns were usually accompanied by limb reactions opposite to those accompanying modest turns. Deutsch, Kelani, Moustafa, Hamilton and Hebert (1987) used a Cybex isokinetic dynamometer to measure isometric and isotonic elbow flexion force, in relation to head rotation to the right or left. In females they found no significant difference for isometric elbow flexion force, but found a significant difference for isotonic elbow flexion force in accordance with ATNR. In males, the effect of head rotation on isometric force was opposite that predicted by ATNR whereas there was no significant difference in isotonic force. Anderson and Bohannon (1991) used a hand-held dynamometer held against the distal forearm to measure the effect of head and neck position on maximum static elbow extension force. No significant difference was found due to head position. As the subjects were tested lying prone, vestibular righting reflexes might have masked any subtle effects of ATNR. Furthermore, the use of a hand held dynamometer further introduced the potential for human error in the measurement.

The effect of the respiratory cycle on the strength of segmental stretch reflexes in limb muscles not directly involved in breathing has been demonstrated in humans. King, Blair, and Garrey (1931) showed that the patellar and Achilles tendon reflexes, measured by surface EMG, were usually augmented during normal inspiration. In one case forced expiration was found to augment these reflexes. Similarly, Schmidt-Vanderheyden, Heinich and Koepchen (1970) noted an increase in the amplitude of the patellar tendon

Figure 1
Diagrammatic view of a subject positioned in the manipulandum. The support for the arm has been cut down in this diagram to allow a full view of the limb.



reflex (again measured by surface EMG) during inspiration in 50% of trials in which subjects were breathing spontaneously. During controlled respiratory periods of 2.5 to 12 s, these same subjects also showed reflex increases during inspiration (Schmidt-Vanderheyden & Koepchen, 1970).

The stretch reflexes provide rapid and automatic responses to limb perturbation. They are readily influenced by neural input from higher centres (Rosenbaum, 1991), which makes these reflexes potentially useful as a measure of descending influences on limb musculature. The long latency stretch reflexes in particular, because they traverse higher centres such as the motor cortex (Matthews, 1991), could be especially sensitive to supraspinal signals.

The long latency stretch reflexes (Lee & Tatton, 1975) are known to be modulated by a number of factors including motor preparation (Bonnet & Requin, 1982; Hammond, 1956) and phase of movement (Dufresne, Soechting & Terzuolo, 1980; MacKay, Kwan, Murphy & Wong, 1983). A review of the literature revealed no investigations of late reflex modulation which considered the influences of respiration or of head position.

The long latency stretch reflexes can be readily elicited in relaxed muscles by a torque perturbation delivered to the relevant limb immediately prior to an intended movement (MacKay, et al. 1983). If delivered at the right time, the adequate stimulus to elicit the late reflexes is much milder than that necessary to elicit a monosynaptic reflex in the same muscle. Facilitation or inhibition of any part of the reflex pathways by neuronal signals arising from head posture or the respiratory pattern generator would be reflected by an alteration of the reflex response.

The purpose of the present experiments was to evaluate the relative effects of head rotation and of respiration on upper limb musculature of normal human adults using an objective and sensitive outcome measure, i.e. the stretch reflex. The questions were 1) whether head rotation and respiration affect the upper extremity musculature of normal adults, as measured by the stretch reflexes and 2) whether these influences are important to control in studies of late reflex modulation. Since therapists are particularly concerned with movement as opposed to static posture alone, an experimental paradigm in which the effects of respiration and ATNR in relation to movement was chosen.

MATERIALS AND METHODS

Subjects

The six subjects who volunteered for this study were university graduate students or faculty and were fully aware of the procedures to be undertaken. None of the subjects had any known orthopaedic or neurological problems.

Apparatus

Subjects were seated with the right arm fitted snugly into a manipulandum as shown in Fig. 1. The manipulandum has been described previously (MacKay, et al. 1983).

Procedure

The subjects performed a rhythmic flexion-hold-extension-hold movement of the forearm in the horizontal plane, paced by a metronome. The period of the movement cycle was 4 s, and the amplitude was 15^0, about a mid-point elbow angle of about 90^0.

A torque motor coupled to the manipulandum delivered trapezoidal test pulses of 3 N-m to the forearm, about 100 ms (± 20 ms SD) before the start of voluntary EMG. The test pulse ramp and plateau had durations of 70 and 80 ms, respectively. Test pulses were given in either the flexion or extension direction to stretch the elbow extensor or flexor muscles. Subjects were instructed to ignore the test pulses and continue with the movement cycle in as strict a rhythm as possible.

Brachialis and triceps EMG signals were recorded with Beckman 4mm diameter surface silver-silver chloride disc electrodes placed over the distal belly of the brachialis and the lateral head of triceps. In trial experiments the optimal recording of the flexor stretch reflex was found when the electrode was placed over the distal brachialis muscle rather than biceps, in which the response was very weak in this paradigm. In order to ensure that there was no cross talk of the EMG signals between brachialis and triceps, when the electrodes were placed on the subjects, they were asked to vigorously contract the elbow flexor muscles isometrically and then the extensors. The EMG signals through both electrodes were examined to make sure that the activity from the flexors was not picked up by the electrode over the extensor muscle and vice versa. The EMG signals were fullwave rectified and partially integrated (time constant of 20 ms). Elbow torque was monitored by means of strain gauges on the forearm support of the manipulandum, and angular displacement by means of a potentiometer mounted on the torque motor. Integrated EMG signals were digitized at a sampling rate of 1 kHz. Two separate experiments were conducted, one of the effects of head rotation and the other of the effects of respiration. For each test condition (i.e. with the head facing straight ahead, right or left in the first experiment, and with inspiration or expiration in the second experiment), mean records of a set of 10 consecutive trials were computed. Each set was repeated at least 3 times during an experimental session, randomly interspersed with others.

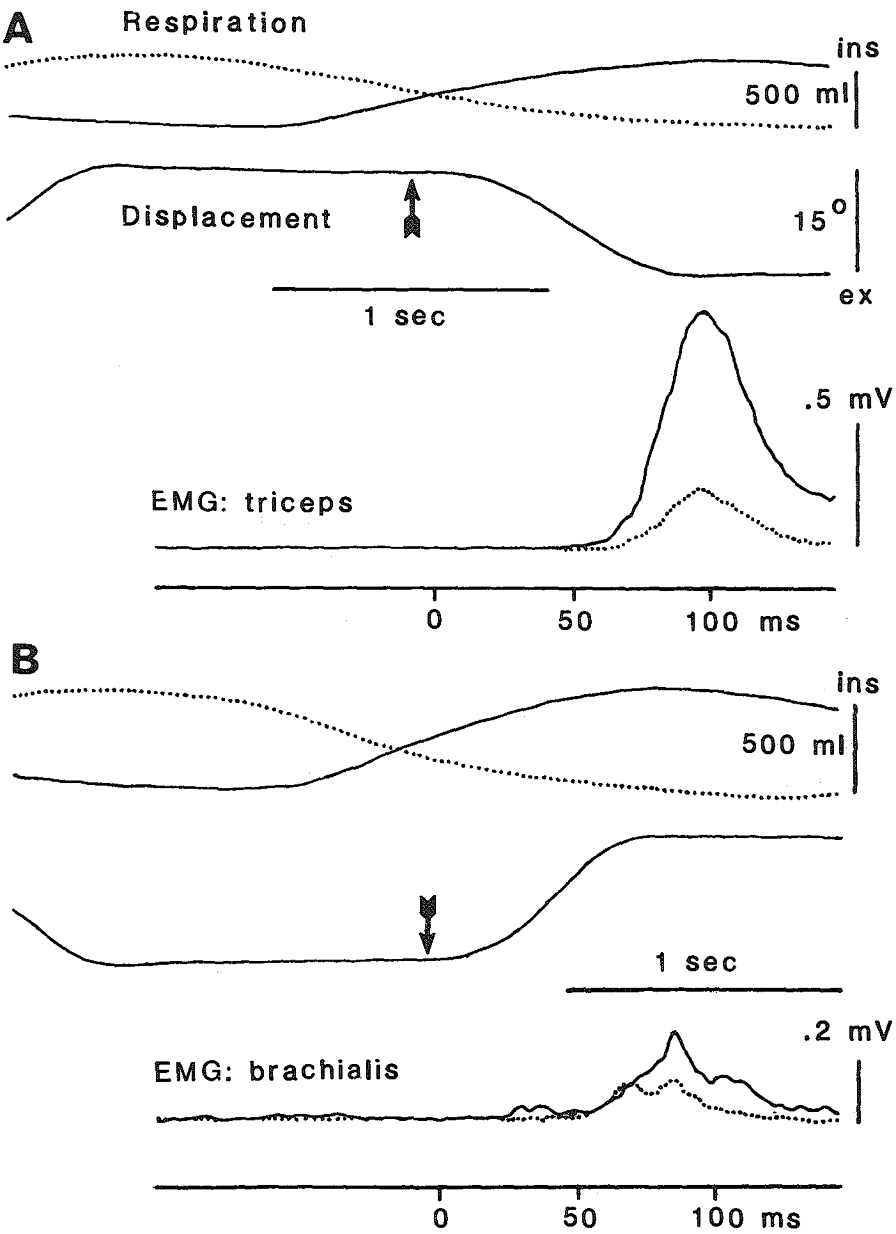
Effects of respiration were tested on 5 normal adults (3 male, 2 female). Three of the subjects were retested following an interval of greater than one month. The subjects were instructed to initiate inspiration on one metronome beat, begin movement (while still inspiring) on the next, initiate expiration on the third beat, and begin the opposite movement on the fourth beat. All subjects found this to be a comfortable and easily maintainable pattern. Respiration was monitored using a pneumatic transducer strapped around the chest, and calibrated against a respirometer.

To test the effects of head position, subjects (2 male, 1 female) were instructed to face straight ahead, to the left, or to the right during a series of movement cycles. The head rested against a support but remained vertical. The angular displacement from the midline was approximately 70^0. For each condition, test pulses were delivered in the extension and flexion directions. Breathing was spontaneous.

DATA ANALYSIS

The mean EMG for each test condition was divided into 3 intervals for analysis: a baseline period before initiation of the reflex, M2 reflex interval 50-80 ms after perturbation onset, and M3 response interval of 80-105 ms (cf. Lee & Tatton, 1975). The mean background was subtracted from each data point in the M2 and M3 intervals and then the means of these groups were compared for each subject between different conditions. For testing the influence of respiration, the M2 and M3 reflexes (brachialis or triceps) during inspiration were compared with the M2 and M3 reflexes during expiration using the Student's T-test. For testing head position effects, the same reflex responses were compared. A one-way analysis of variance (ANOVA)

Figure 2
Effect of respiratory phase on late stretch reflexes. A: Forearm extension is synchronized to either inspiration (solid line) or expiration (dotted line). The arrow on the displacement trace marks the time when the test pulse was given. The triceps EMG response was much larger during inspiration than expiration.
Subject II. B: Same as A but respiratory phases are synchronized to forearm flexion and brachialis reflexes are tested. Subject III. Each trace is a mean of 10 trials. Abbreviations: ex, extension; ins, inspiration.



was initially used for the comparison of different head position effects. This was followed by a post hoc Tukey analysis on the data where a significant F was found using the ANOVA. The Tukey analysis determined which head postitions significantly affected the reflex response and whether the effects were as predicted by ATNR or opposite. Although several subjects were used in both parts of the study, data for respiration and head position effects were collected in different experimental sessions on different occasions.

RESULTS

Respiration

As summarized in Table 1, reflexes in both brachialis and triceps were significantly larger, more often during inspiration than during expiration. In some instances the difference was very striking (Fig. 2A) and in the majority of cases it was present, especially in the brachialis, where the M3 component of the long latency stretch reflex showed a consistent increase during inspiration. The example illustrated in Fig. 2B is noteworthy, because it was the only case in which the inspiratory phase facilitated the early segmental reflex (latency 25 ms). The M2 reflex was not significantly changed but the M3 response was considerably increased.

More variability was seen in the triceps responses. For two subjects inspiration gave a significantly larger reflex than expiration. For two subjects, no significant difference occurred between inspiration and expiration and, in one subject, expiration gave a larger reflex than did inspiration. When the experiment was repeated on the same subject, the results were usually well reproduced.

Table 1
Respiratory Phase in which Relatively Larger Late Stretch Reflexes Occurred

Subject	Brachialis M2	Brachialis M3	Triceps M2	Triceps M3
Ia	O	O	I	O
Ib	I	I	I	O
IIa	O	I	I	I
IIb	I	I	I	I
IIIa	O	I	O	O
IIIb	O	I	O	O
IV	O	I	O	O
V	I	I	E	E

E: Expiration I: Inspiration O: No statistically significant difference between E or I phase

Roman numerals are used to identify each subject. a and b represent two separate testing sessions for a given subject.

Head position

No condition appeared to be more effective and no consistent trends were evident among the subjects (Table 2). In most cases there was no significant difference between head positions. Where a significant difference was encountered, it was as often contrary to the classical ATNR pattern as in accord with it (Table 2A). An example is shown in Figure 3 where in one set of ten trials head turns to the right were associated with larger brachialis responses (right side) than head turns to the left (when all the sets of trials were considered in the statistical analysis, there was no significant difference in this subject). There was no correspondence between effects on the triceps and brachialis. They could be either the same or opposed. When an experiment was repeated on the same subject, the results were not reproduced. Spontaneous breathing was not phase-linked to the time of reflex testing and thus did not appear to bias the neck position results.

DISCUSSION

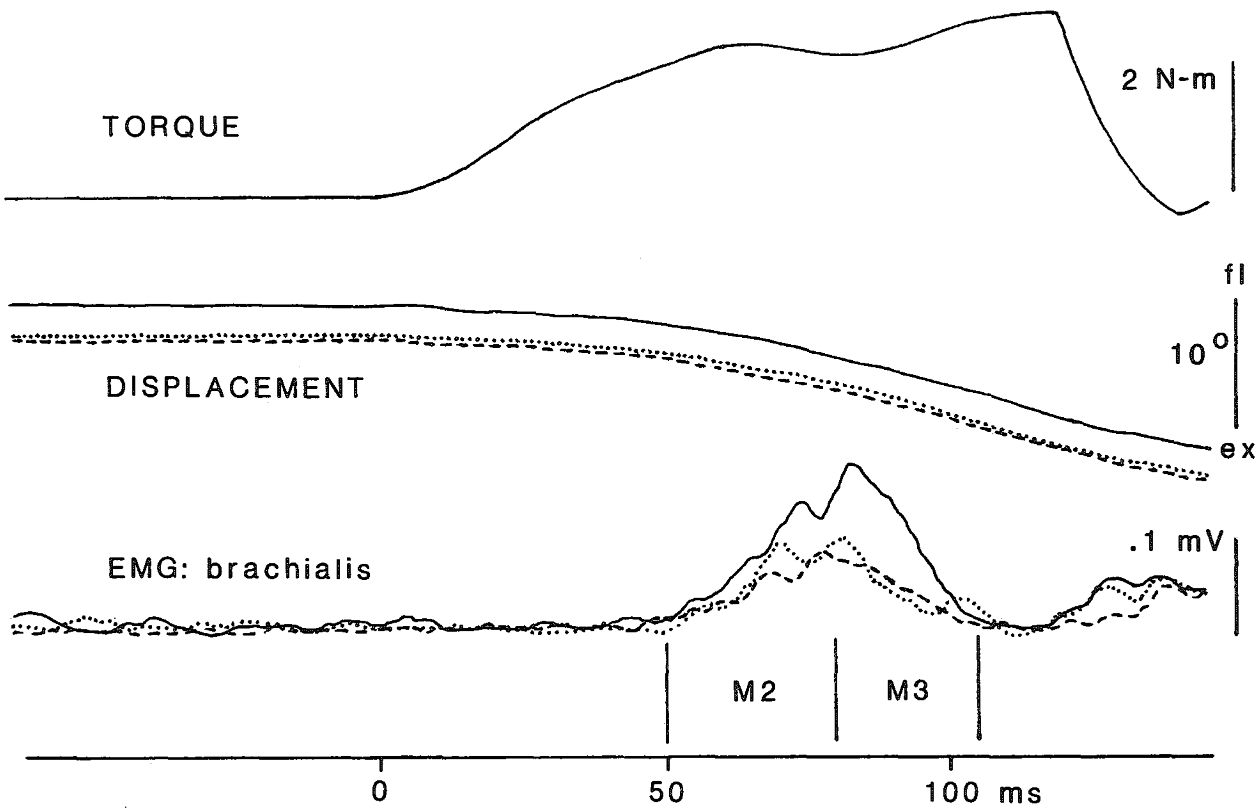
Of the two investigated factors, only respiration had a consistent and potentially strong effect on reflex responsiveness in the elbow muscles. Our results for late reflexes in arm muscles fully corroborate those reported for ankle and patellar tendon jerk (King, et al. 1931; Schmidt-Vanderheyden, et al. 1970). It may therefore be concluded that the inspiratory phase of respiration has a facilitatory effect on limb proprioceptive reflexes, at least in normal adults. This facilitation is presumably mediated within the spinal cord. Inspiratory cell groups of the medulla and upper cervical cord have extensive projections within the spinal cord (Long & Duffin, 1984) which could influence the excitability of reflex pathways. Although the long-latency reflexes are mainly transcortical (Matthews, 1991), there is currently no evidence that respiration affects single unit responses to torque perturbations in motor or somatosensory cortex.

In contrast to the results in normal humans, Meyer-Lohmann (1974) reported that the expiratory phase enhanced the tonic stretch reflex responsiveness of triceps surae motoneurons in decerebrate cats. Possibly the excessive extensor tone released by decerebration changed the normal influence of the medullary respiratory centers on limb motor nuclei.

If there is a distinct ATNR pattern in the elbow musculature of normal human adults, it was not evident in our results. Significant differences did occur in reflex magnitude due to head position, but they were small and did not repeat when the same subject was retested on another occasion. The experimental evidence in the literature does not unequivocally establish, in adult arm musculature, an ATNR pattern as defined by Magnus (1926). Hellebrandt et al. (1956) showed that rotation of the head towards the exercising side had a facilitatory effect on the work output of wrist extension against heavy resistance. Contralateral head turns were said to facilitate wrist flexion at maximal exertion, but the illustrations of "contralateral" head turns displayed pronounced ipsilateral turns combined with ventroflexion (ibid. Fig. 10). It should also be noted that Hellebrandt et al. (1956) were able to clearly distinguish head position effects on flexion and extension only under conditions of extreme muscle fatigue. Warren (1984) used a Jendrassik-type facilitation to get a measurable response. The situation is clearer for ankle extensors. Hayes and Sullivan (1976) found that the Achilles tendon reflex amplitude was influenced by head position as would be predicted by ATNR. Moreover, the H-reflex was proportional to the angle of head rotation (Traccis, et al. 1987). In neither study, however, was the effect on the tibialis anterior determined (tibialis anterior is the antagonist to the triceps surae used to measure the H-reflex).

Thus there is no decisive evidence that lateral head turns produce a consistent differential influence on flexor and extensor muscle groups according to a definable ATNR pattern in normal adults. Any responses to head turns per se may be based on a broader body schema such that the motor output is not a simple function of head input. For example, it has been demonstrated that the direction of body sway

Figure 3
Effect of head position on brachialis reflexes (right arm). When the head was turned to the right (solid line) the brachialis response to the test pulse was greater than when the head was centred (dotted line) or turned left (broken line). The stimulus torque was exactly the same in each condition. Each trace is a mean of 10 trials. Subject Ib.



induced by galvanic vestibular stimulation shifts according to the direction of head rotation relative to the feet (Lund & Broberg, 1983).

The essential afferent input to elicit ATNR in cats originates most probably in the tiny intervertebral muscles which are very densely supplied with muscle spindles (Richmond & Abrahams, 1979). Head position effects in humans may be dependent on the same afferent source: twisting of the vertebral column at the cervical level gives similar effects (Lund & Broberg, 1983).

This study shows that the influence of respiration on long-latency elbow muscle reflex responsiveness is more consistent and significant than that of head position. All studies of reflex modifiability should control for the phase of breathing, or ensure that it is not biasing the results. Clinical assessments of upper extremity movement and strength should take into consideration the potential effect of respiration on the results. Although the effects are weak and unpredictable, head position should not be allowed to change while collecting reflex data from a research subject or from a client during assessment. In some cases head position can have a significant influence and ATNR may be seen in some normal adults. The premise that ATNR is a pathological sign in adults is not supported by this study. It is possible that following a stroke, some individuals may exhibit ATNR which may be normal. Furthermore, there may be instances when head position influences movement in a manner opposite ATNR, which may also be normal. The premise that ATNR should be totally inhibited by therapeutic

Table 2
Effect of head position on the late stretch reflexes.

2a

ANOVA

Subject	Brachialis M2	Brachialis M3	Triceps M2	Triceps M3
Ia	F(2,382) < 1	F(2,271) = 8.01***	F(2,207) = 74.61***	F(2,147) = 44.66***
Ib	F(2,207) = 2.98	F(2,147) = 1.92	F(2,312) < 1	F(2,222) < 1
IIa	F(2,312) = 4.67*	F(2,222) = 6.43**	F(2,312) = 1.85	F(2,222) < 1
IIb	F(2,207) = 2.04	F(2,147) = 6.13**	F(2,207) < 1	F(2,147) = 87.16***
VI	F(2,312) = 4.26*	F(2,222) = 19.63***	F(2,312) = 2.46	F(2,222) < 1

* p < .05   ** p < .01   *** p < .001

2b

Tukey

Subject	Brachialis M2 R/C	C/L	R/L	Brachialis M3 R/C	C/L	R/L	Triceps M2 R/C	C/L	R/L	Triceps M3 R/C	C/L	R/L
Ia				+	O	+	+	O	O	+	O	O
Ib												
IIa	O	+	+	−	+	−						
IIb				+	−	O				−	+	−
VI	+	−	O	+	−	O						

R/C: Head right vs. head center
C/L: Head center vs. head left
R/L: Head right vs. head left

O No significant difference
\+ Significant difference as predicted by ATNR (p < .05)
− Significant difference opposite ATNR (p < .05)

techniques in rehabilitation following stroke, is not supported by this study.

The effects of head position and respiration should be considered for each client and the potential for the effects to change from one treatment session to the next should be recognized. The therapist may choose not to inhibit ATNR and respiratory effects especially when they do not hinder movement (or indeed when they facilitate desired movement).

Further studies of the effects of respiration and head position in people with stroke would determine if there are some systematic effects which occur in that population that are not evident in normal adults. In particular, future studies are needed to elucidate the potential facilitatory effect and use, particularly of inspiration, on upper extremity movement during treatment.

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