The influence of head-neck position on wrist flexor strength

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Abstract: Evaluation of muscle strength is important for human factors engineers, ergonomists, and healthcare practitioners to formulate successful ergonomic interventions, prescribe exercise regimens, and model credible rehabilitation programmes. Although previous studies have identified the influence of different head-neck (H-N) positions on joint strength production, none have assessed the influence of H-N position on wrist strength. The objective of this study was to compare wrist flexor strength in different head-neck (H-N) positions, including a neutral neck position and eight non-neutral positions involving single or combined rotations in the sagittal and horizontal planes. Isometric flexor strength of the left wrist was measured from 30 right-handed healthy female volunteers, using an isokinetic dynamometer, in each of the nine H-N positions in a random order. Among the nine H-N positions, significant differences in wrist flexor strength were observed only between neck rotation to the right and the remaining positions. These results suggest that H-N positions should be considered while assessing or predicting wrist strength. And, more generally, the results support that strength at a given joint can in some cases be substantially influenced by the postures of others joints, even those rather separated from the joint in question.

Keywords: isometric; isokinetic dynamometer; wrist flexor torque; asymmetric tonic neck reflex.
1 Introduction

Muscle strength testing is often employed to assess the integrity and functioning of the musculoskeletal system. Muscle strength forms an integral component of most rehabilitation or conditioning programmes for individuals of diverse ages and ability levels (Kitai and Sale, 1989). Evaluating the strength of a joint is important for human factors engineers, ergonomists, and healthcare practitioners, as it gives fundamental and valuable information about athletic and human performance (Brown, 2001). It can also be an important clinical consideration for patients who may have a neurological, muscular, and/or skeletal illness (Stark et al., 2011), and can, help to model rehabilitation strategies (King, 1986).

Human movement, performed with its usual gracefulness, demands the coordination of many muscle groups. The classic ‘two-joint effect’ is well established. This occurs when a biarticular muscle spans two or more joints, and results in the strength at one joint being affected by the angle of another joint that shares the muscle (Zajac, 1993). Some studies, though, have indicated that muscles not shared by joints can still affect joint strength. For example, the influence of head and neck (H-N) position on the behaviour of limb muscles was first reported over 75 years ago (Richard et al., 1989). Studies since have been conducted that assessed the influence of different H-N positions and its effect on joint strength production, including the elbow joint (Deutsch et al., 1987; Richard et al., 1989; Pelllec and Maton, 1993) and the distal muscles of prehension (Berntson and Torello, 1977). The present authors found that studies relevant to the influence of H-N position on wrist joint strength were lacking. Hence, it raised a need to evaluate wrist
strength, to determine if there is an influence of different H-N position, and which might further help to model and implement ergonomic or rehabilitation strategies for the upper extremity. The specific objective of the present study was to compare isometric wrist flexor strength in different H-N positions (neutral position, rotations in the sagittal and, horizontal planes, and combinations of both sagittal and horizontal planes) in healthy young females.

2 Methodology

2.1 Participants

A total of thirty right-handed, healthy female participants with mean (SD) age of 21.9(2.0) years, stature of 155.2(4.0) cm, and body mass of 51.7(5.3) kg, were randomly selected from an educational institution in India. The exclusion criteria included the left as the dominant hand, a history of fracture of upper extremity, a history of neurological disorders affecting cervical spine or upper extremity, a history of instability of wrist joint, deformity of upper extremity, muscle strain of upper extremity or cervical spine, and musculoskeletal complaints. The local institutional ethics committee approved the conduct of the study.

2.2 Procedures

Joint strength or peak torque production can be measured by isokinetic dynamometers with good reliability (King, 1986; Sapega, 1990; Zuluaga, 1995). Here, the entire sets of procedures were explained initially to the participants, who then signed an informed consent form. Following this, each participant’s height, body mass, and age were recorded. Testing was conducted using a HUMAC®/NORM™ (CSMi, USA) Isokinetic Rehabilitation System (Model-770), specifically to measure the maximal isometric torques during wrist flexion, and with the participants in different H-N positions. The order of testing in the different H-N positions was randomised to minimise potential confounding effects, such as due to fatigue.

Nine H-N positions were used, including the neutral position (NP), where the participants was asked to look straight forward at a point marked on the wall; rotation in the sagittal plane, where the participants adopted either flexion (SPF) or extension (SPE) positions; rotation in the horizontal plane, where the participants adopted either rotation left (HPRL) or rotation right (HPRR); and combinations of rotations in both the sagittal and horizontal planes, specifically rotation right with flexion (CRRF), rotation right with extension (CRRE), rotation left with flexion (CRLF), and rotation left with extension (CRLE). Other than the NP, H-N positions adopted were at the voluntary range-of-motion limit. To avoid confounding effects (Marsh et al., 1981; Cunningham et al., 1987; Magnusson et al., 1993; Keating and Matyas, 1996; Hulens et al., 2002) and to enhance the precision of measurements, positions of participants were carefully controlled and standardised as described subsequently (Figure 1).
Participants were comfortably positioned in a seated posture in the dynamometer chair, with hips and knees at 90° flexion. The hips, shoulders and forearm were firmly secured by Velcro™ straps for stabilisation. Stabilisation was used to prevent substitution or force augmentation by muscle groups other than those that are the focus of measurement (Guenzkofer et al., 2012). The dynamometer height was then adjusted, so that the participants could position their arm comfortably with the shoulder in 10 to 15 degree of flexion (Vanswearingen, 1983) and 15° of abduction. The elbow was at 90° flexion and the forearm in supination (Ng and Chan, 2004; Ellenbecker et al., 2006). The forearm, rested in a V-shaped stabilising platform, and was secured to the dynamometer with straps to prevent it from rising out of the platform (Stonecipher and Catlin, 1984). The dynamometer attachment length was adjusted and the axis of the dynamometer centred at the wrist joint (Deutsch et al., 1987; Stonecipher and Catlin, 1984). The functioning of the dynamometer was explained to the participants prior to testing, and the required limb action was also demonstrated. During the isometric flexion strength test, the wrist was aligned in a neutral position in flexion/extension plane with 0° in radio-ulnar deviation, and 90° in supination.

During isometric tests, the participants generated maximum efforts for six seconds (Brown, 2001). Verbal encouragement was given, with the intent of helping the participants achieve near their true maximum torque (Thomas, 1984). Each participant performed three repetitions in each H-N position (Anderson and Rutt, 1992; Brown, 2001) with a minimum of one minute of rest between repetitions (Deutsch et al., 1987; Brown, 2001; Parcell et al., 2002). Wrist flexion strength was extracted from each repetition and the maximum value across the three repetitions was used in subsequent data analysis. The peak torque was defined as the peak value obtained across the three trials measured (Fratocchi et al., 2013).

2.3 Statistical analysis

Statistical analysis was done using SPSS Statistics 20 software. Repeated measures ANOVA was used to assess the effect of H-N posture on wrist flexor strength, followed by Bonferroni post hoc comparisons. The level of significance was set at 0.05.
3 Results

Summary data on wrist flexor torques in the different H-N positions are shown in Table 1. Repeated measures ANOVA demonstrated a significant H-N position effect \( [F(8,29)=14.6; \ p < 0.0001, \ \text{partial } \eta^2 = .335] \). Pair-wise comparison between the nine H-N positions indicated only that strength with horizontal plane rotation right (HPRR) was significantly greater than all other H-N positions (\( p < 0.01 \)).

<table>
<thead>
<tr>
<th>H-N position</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
<td>7.2</td>
<td>2.6</td>
</tr>
<tr>
<td>SPF</td>
<td>7.9</td>
<td>2.5</td>
</tr>
<tr>
<td>SPE</td>
<td>7.5</td>
<td>2.1</td>
</tr>
<tr>
<td>HPRR</td>
<td>11.2</td>
<td>2.4</td>
</tr>
<tr>
<td>HPRL</td>
<td>7.9</td>
<td>2.4</td>
</tr>
<tr>
<td>CRRF</td>
<td>8.0</td>
<td>2.9</td>
</tr>
<tr>
<td>CRRE</td>
<td>7.3</td>
<td>2.6</td>
</tr>
<tr>
<td>CRLF</td>
<td>7.4</td>
<td>2.7</td>
</tr>
<tr>
<td>CRLE</td>
<td>7.0</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Notes: NP – neutral position; SPF – sagittal plane flexion; SPE – sagittal plane extension; HPRR – horizontal plane rotation right; HPRL – horizontal plane rotation left; CRRF – combined rotation right flexion; CRRE – combined rotation right extension; CRLF – combined rotation left flexion; CRLE – combined rotation left extension.

4 Discussion

Muscle strength testing is a common physical examination and an integral part of an ergonomic assessment to provide information usually not obtained by other procedures. It is useful in differential diagnosis, prognosis of neuromuscular disorders, prescribing exercises and modelling ergonomic interventions or rehabilitation strategies. In this study, wrist flexor strength on the non-dominant side (i.e., left wrist) was obtained from right-handed female participants. The major finding was that, even though no muscle is shared between the neck and the wrist, right H-N rotation in the horizontal plane (i.e., away from the left wrist) produced a greater influence on wrist flexor muscle torque production all other neck positions, including the neutral position.

The underlying mechanism for this effect may be attributed, at least in part, to the tonic neck reflex. The tonic neck reflex has a symmetrical and an asymmetrical component. The asymmetrical tonic neck reflex (ATNR) pattern involves elbow extension and shoulder abduction on the chin side and elbow flexion with shoulder adduction on the back of the head side when the head and neck are rotated (Lee et al., 2010). ATNR is normally present during infancy (Capute et al., 1982a, 1982b) and becomes integrated by the central nervous system at an early age (Sullivan and Schmitz, 2006). Once integrated, these reflexes are not generally recognised in adults in their pure form. They continue, however, as adaptive fragments of behaviour, underlying normal
motor control (Hellebrandt and Waterland, 1962; Sullivan and Schmitz, 2006). The ATNR can be elicited in normal healthy adults (Berntson and Torello, 1977; Deutsch et al., 1987; Pellec and Maton, 1993; Lee et al., 2010) along with infants (Capute et al., 1982; Lee et al., 2010) and neurologically impaired persons (Sullivan and Schmitz, 2006). In the present study, head rotation away (i.e., toward the right) from the testing/active hand (i.e., left side) resulted in a significant increment in wrist flexor strength. The finding is in accordance with the observations made by Berntson and Torello (1977), Deutsch et al. (1987), Pellec and Maton (1993) and Lee et al. (2010) and appears to support the involvement of the ATNR.

The current study was conducted with only female volunteers, as previous studies have demonstrated that the influence of the tonic neck reflex may be elicited more easily in female volunteers than in males, primarily due to the reduced limb strength in females (Deutsch et al., 1987). Additionally, only the non-dominant side was tested, with the intent to minimise the influence of bilateral differences on strength. Therefore, further study should be repeated on males or on the dominant side to understand if there is any differentiation from the present results. It is also important to understand the effect of H-N positions on isotonic wrist flexor strength.

It can be postulated that the positioning of the head neck is impressed by the proprioceptive input of the testing joint (wrist joint) which is modulated by the influx of sensory stimuli from the muscle group of the isometric testing limb (wrist flexors). These cascades of impulses then stimulate the motor neurons to evoke selective activation of neck musculature, sufficient to modify the position of the head autonomously and to stimulate the receptive field (first three cervical joints) activating asymmetrical tonic neck reflexes (Hellebrandt et al., 1956, 1962). The recruitment of reserve motor units augments the sensory input via synaptic arrangement and operates in the absence of cortical interference (Hellebrandt et al., 1956, 1962; Hellebrandt and Waterland, 1962). Further, the effects of ATNR are facilitated when the influence of gravity is eliminated (Hellebrandt et al., 1956, 1962); therefore HPRR demonstrated the significant difference, as there was no influence of gravity in HPRR unlike the positions of SPF or CRRF, which had highest values when compared in their respective planes. We conclude from the current results, that the activated ATNR, influences the H-N position to affect the wrist flexor torque.

5 Ergonomic implications and conclusions

The results of this study illustrate that, although muscles at the neck and those at the wrist joint are different, the position of the H-N does still have a significant effect on the strength of the wrist joint. Additionally H-N rotation in the horizontal plane and away from the active side has a greater influence on wrist flexor muscle torque production than the neutral H-N position, H-N rotation in the horizontal plane and towards the active wrist side, movements in the sagittal plane, or a combination of both sagittal and horizontal planes. Hence, it may be advised that human factors engineers, ergonomists and healthcare practitioners consider the above result when evaluating isometric muscle strength of the wrist flexors.
Conflict of interest

There is no conflict of interest.

Acknowledgements

The study was self-funded; however authors would like to gratefully acknowledge the support of DIBNS, Dehradun, India for allowing access to the isokinetic device. We would also like to thank all the volunteers who participated in the project. A special thanks to the editorial team and anonymous reviewers of this journal for their consistent support through suggestions.

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