A dedicated device for isokinetic and isometric measurements of neck strength

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Abstract. In many sports activities, the neck is highly stressed and therefore painful syndromes can develop after long periods of repetitive, intense exercise. Quite a number of studies have looked into the isometric strength of the cervical spine but only a few explored the dynamic profile of these muscles. While commercial devices are available for assessing isokinetic movements of the knee, ankle and trunk none exist for the neck. In this paper we describe an attachment to a commercially available isokinetic dynamometer that is meant for static and dynamic testing of cervical muscles strength in the frontal and sagittal planes.

Keywords: Biomechanics, muscles, ergometer

1. Introduction

Neck pain is a common problem worldwide\cite{4}. Cervical spine degeneration involving the joints or discs can affect fighter pilots\cite{6}; participants in various sports, including football, wrestling\cite{26}, ice hockey\cite{21}, judo, sumo wrestling\cite{22}, rugby\cite{14}, and car racing. For example, car racing is a sport in which side accelerations can reach 4 g in bends and longitudinal accelerations can reach 5 g under sharp braking, causing severe constraints to the neck in particular\cite{17}. The development of muscular assessment devices for the neck would allow muscular assessment for people whose necks are at risk of injury. In addition, it could help physicians in recommending exercises in order to reduce the risk of injury or to establish a diagnosis when injury has already occurred. Such a measurement, training and reinforcement protocol could be tailored to individual behavioral patterns in real conditions\cite{17}. For example, it has been shown that, concentric conditioning can produce an increase in eccentric strength of about 20\%\cite{16}.

White and Panjabi\cite{24} describe three planes of reference and corresponding axes for the neck: the frontal plane and roll axis, the sagittal plane and pitch axis, and the horizontal plane and yaw axis. Isometric evaluation of the cervical spine has been widely studied\cite{1,9,12,23} but isokinetic assessment has been investigated only in the frontal plane\cite{17} or in the frontal and sagittal planes\cite{14}. Laboratory studies in the field of motor sports currently include work on the design of a driving simulator\cite{3}. Our experience indicates that the strength of the cervical spine is an essential element of driver performance.

To assess the capabilities of neck muscle groups, we propose a mechanical approach based on isokinetic and isometric measurements. To our knowledge there exists no specific commercial device for cervical spine testing that can be connected to an isokinetic dynamometer. A cervical unit has been previously constructed for a Biodex dynamometer\cite{20} while a multi-cervical rehabilitation unit (Hanoun Medical Inc., Ontario) is available for measuring active range of neck motion as well as the isometric strength of neck muscles\cite{2}.

Ideally, such a device should allow muscular evaluation of all kinds of head movements, but the apparatus described in this study is restricted to frontal and sagit-
2. Methods

2.1. Subjects

For the isometric component, nine volunteers aged 22 to 30 and with a mean height and weight of 174 ± 6 cm and 69.7 ± 3.8 kgf, respectively, participated in the study. The volunteers were in good health, were not highly-trained sports people and had not been involved in any special neck muscular reinforcement program.

For the isometric component only five of the nine volunteers were available. The mean height and weight was very similar to that of the whole group.

2.2. Mechanical design

Cervical muscles testing was carried out using a devise that hooked onto a single-arm Biodex dynamometer. This device consists of two sub-units:

i) A frame, connects the motor with the subject’s head using a full-face motorcycle helmet. As shown in Figs 1 and 2, the arm between the apparatus and the dynamometer axis is adjustable to fit the subject’s neck length.

ii) An integral seat whose height is adjustable to align the midpoint between the spinous processes of C7 and T1 with the dynamometer’s motor axis [14,17,23]. This reference point is commonly chosen probably because of ease of location and palpation. The apparatus can be set at this position with a laser pointer. However, 4 different geometric points can serve as reference using this design: 1. the articulation point of C4-C5 [1,12]; 2. the thyroid cartilage [11]; 3. C4 [23]; and 4. the mastoid point [8,23].

Two orthogonal arrangements were needed for testing in the frontal plane and the sagittal plane (Fig. 1). Details of helmet clamping are shown in Fig. 3. Clamping can be adjusted to any helmet.
2.3. Data recording and calibration

We have used a Biodex dynamometer which is equipped with a built-in torque measurement unit. However in order to monitor data acquisition and precision, a torque sensor was fitted to the lever arm. The sensor is based on a full bridge, temperature independent, strain gauge design (Vishay micro-measurements & SR-4) which was glued close to the dynamometer’s axis (Fig. 2). Data were obtained using an extensometer bridge and an ADC 16 acquisition card (Pico Technology) with an RS 232 connection to the PC. The voltage-to-torque ratio was 0.2319 Nm.mV$^{-1}$ with a sampling frequency of 12.8 Hz. It is important to note the special shape of the ergometer shoulder (Fig. 2), with two securing stops at 60°. The sensor accuracy was checked using the following configuration: a 5 kgf weight exerts a 49.05 N gravity force with a lever arm of 25.3 mm leading to a 12.4 Nm torque with anticlockwise or clockwise rotation. Experimentally, the maximum mean torque was found to be 12.05 Nm with a standard deviation of 1.05 Nm. These operations were also carried out with 10 kgf and 15 kgf weights. The rotation velocity during the trials was verified by a chronometer, and we obtained a deviation of 0.3°/s on a target velocity of 30°/s.

2.4. Protocol

The research protocol was based on previous studies [8,9,17,23]. The measurements were recorded as follows:

1. For isokinetic side flexion (frontal plane) the head moved ± 30° relative to the neutral vertical position, at a speed of 30°/s
2. For isokinetic flexion-extension, the head moved in a similar way but along the sagittal plane.
3. For isometric assessments, these evaluations were restricted to neutral positions.

The subject’s shoulders were fastened to the side bars of the seat and a belt was tightened to the abdomen in order to hold the subject firmly in the seat. A recent study showed that the location of the thoracic strapping could influence results [19]. Consequently, our subjects were fastened onto the seat at shoulder level and blocked sideways, thus minimizing the influence of the trunk muscles.

Subjects were familiarized with the system. Several forward and backward movements were made to accurately adjust the lever arm length. A preliminary warm-up consisted of 15 forward and backward movements of increasing intensity. Subjects were given verbal encouragement but were not allowed any visual feedback.

For the isokinetic evaluation, the test consisted of five forward and backward movements. For the isometric evaluation, the test consisted of two maximal contractions in the neutral position, an approach that has been widely used in the literature.

3. Results

3.1. Isokinetics results

Even with only five backward and forward movements, the measured torque decreased. This was ascribed to subject fatigue and not to sensor drift because the decrease was not observed during the calibration check. The mean value and the standard deviation were calculated using the maximum torques recorded for each volunteer and for all the volunteers. Table 1 shows results of previous studies along with those obtained in the present study. Using the C7-T1 reference, a muscular capacity of 25.6 ± 7.6 Nm was obtained for the frontal plane. This represents the average between right and left movement torque, because no significant difference was observed between the two sides. With the same reference point (C7-T1), the flexion and extension strengths were 25.5 ± 3.9 and 42 ± 4.4 Nm, respectively.

3.2. Isometrics results

The mean value was calculated using the two maximum torques recorded for each volunteer. Table 2 shows all the results in the frontal and sagittal plane with an imposed rotation axis at C7-T1. A muscular capacity of 31 Nm, in the frontal plane, 28 Nm in flexion, and 38 Nm in extension was obtained.

4. Discussion

It is difficult to compare the present findings with those of previous studies because of a lack of information on details such as lever arm length, level of sporting ability or test protocol. The present torque values
were slightly lower, but this may be attributable to absence of an adaptation time and specific preliminary test training [13]. The lack of visual feedback may be important [10] and the amount of encouragement may have had an effect [25]. Torque values also vary with strapping conditions (proximal stabilization).

This is a preliminary study relating to 9 subjects for the isokinetic and 5 for the isometrics tests. As such the findings may be cautiously considered. However, the diversity of findings derived from this and previous studies only serve to reinforce the recognition that there is an acute need for a standard apparatus. We are presently assessing the influence of gender, age, and participation in sports on neck strength and hope to come forward with a more coherent picture in the near future.

References


