Gait & Posture 38 (2013) 951–955

Contents lists available at SciVerse ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Influence of an eccentric load added at the back of the head on head-neck posture

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ARTICLE INFO

Article history:
Received 16 May 2012
Received in revised form 22 March 2013
Accepted 29 April 2013

Keywords:
Head-neck
Functional assessment
Posture
Motor control
Neck pain

ABSTRACT

A biomechanical study of the head-neck complex in seated subjects was conducted to verify whether a slight load, applied at the back of the head, could beneficially affect the head-neck posture, one of the factors of postural neck pain. An eccentric load of 0.5 kg was applied to the subjects' head by means of a special cap. A group of asymptomatic subjects ($n = 10$, 28.9 ± 12.1 yrs), and a group of subjects that had experienced mild, occasional neck pain ($n = 10$, 39.6 ± 18.4 yrs) were compared. They were analyzed while maintaining a still posture that was periodically perturbed to avoid habituation. A 3D motion analyzer and reflective markers placed over the head, the neck and the trunk, were used to compute head inclination and translation and head/neck flexion angle in different conditions: before, during and after having had the load applied for 15 min. Although the moment induced by the load was extensor, a forward-oriented movement of the head was observed in both groups. However, the forward displacement, in relation to the initial position, was smaller in the mild neck pain group than in the asymptomatic group (5.7 ± 4.7 mm vs. 8.9 ± 5.5 mm, $P < 0.05$ and 2.6 ± 5.9 mm vs. 11.0 ± 9.0 mm after 15 min, $P < 0.05$). After removing the load, the mild neck pain subjects assumed a retracted position (-3.8 ± 2.7 mm) while the asymptomatic subjects stayed protracted ($+3.5 \pm 5.1$ mm, $P < 0.01$). These unexpected findings suggest that a slight load added to the head can influence the postural control mechanisms and, in symptomatic subjects, lead to a new strategy aimed at a reduction of the neck extensor muscle contraction.

1. Introduction

Functional assessment of cervical spine is of great interest because of the high occurrence of neck pain and injury [1,2]. Range of motion in maximum voluntary neck flexion and extension is one of the most common measurements, sometimes obtained from radiographs [3]. However, critical studies [4–6] have revealed that such a static measurement can be inconsistent in time as it depends on the direction of motion, the initial head position, the sequence of movement of individual vertebrae while the cervical spine flexes or extends. The head repositioning test is another way to perform a functional assessment of the head-neck complex [7,8]. During this assessment, the subjects are asked to reproduce either the natural head posture or a predetermined target position of the head. In asymptomatic subjects, it has been demonstrated that the neutral head position could be reproduced with an absolute difference of $2.7 \pm 2.1^\circ$ in the sagittal plane, and less than 1° in the other planes [7]. The subjects affected by neck pain instead may have limitations in the ability of repositioning the head accurately, hence the head repositioning errors could be a meaningful measure of the cervical spine function [8], although several factors, including vision and memory, might influence the results [9]. All these tests are performed on natural, unloaded conditions. Other studies are aimed at understanding the effects of loads applied to the head-neck complex. In some cases the loading conditions considered are higher than natural since they are aimed at analyzing the effects of whiplash and other traumatic events [10]. In other cases, external perturbations [11] are applied to analyze the neural control system. Loads in this case are slight but applied in dynamic condition. Further studies refer to the problem of the relationship between posture and neck pain [2]. Actually the head weight in itself (the head mass can be estimated to be about 5 kg [12]) can constitute a considerable load for the cervical spine in particular if the head center of mass is advanced as a result of an incorrect posture. An electromyographic study has revealed, indeed, that a mass added to the front of the head can increase the myoelectric activity of neck and shoulder muscles [13].

Recently, a special cap which included a thin padding mass of 0.3/0.5 kg over the occipital region has been proposed under the assumption that a slight load applied to the back of the head could

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http://dx.doi.org/10.1016/j.gaitpost.2013.04.025

beneficially affect the head posture by reducing the tension of the neck extensor muscles with no need of increasing the flexor muscles activity [14]. A preliminary study on the effect of such a slight load, placed at the back of the head [15], has shown that it has an influence on head repositioning in seated subjects.

The aim of the present study was to experimentally investigate the short-term response of the head-neck posture control system to the application of this slight but constant load, added posterior to the head. The analysis was conducted on healthy subjects, in seated posture, and also extended to subjects that in the past had reported mild neck pain. The aim was to assess the presence of differences in the adaptive mechanisms or in the postural control strategies adopted that could help understanding whether the hypothetical beneficial effect of counterbalancing the head weight could be supported by biomechanical assumptions.

2. Methods

2.1. Subjects

Twenty subjects, students and members of the faculty, ranging in age from 22 to 68 years, of both genders, voluntarily participated to the study. The experimental protocol was approved by the Ethics Committee of the National Health Service (Italy). The informed consent was obtained from all subjects prior to participation in the study. Two groups of participants were recruited on the basis of an anamnesis questionnaire, according to whether or not they had previously reported occasional mild neck pain. One group of asymptomatic subjects ($n = 10$, three women, seven males, age 28.9 ± 12.1 yrs) was composed of subjects who had never reported a history of neck pain, the other one ($n = 10$, four females, six males, age 39.6 ± 18.4 yrs, no significant difference between group ages) was formed of subjects who had suffered from mild, non-specific neck/cervical pain, mainly after prolonged sitting, but neither had reported neck pain episodes in the past six month nor they were undergoing any treatment.

2.2. Experimental set-up

The head/neck and trunk positions of seated subjects were measured through an optoelectronic motion capture system (Smart-E, BTS, Italy) composed of 8 infrared TV-cameras. Eleven reflective markers were placed in different positions over head, cap, shoulders, trunk and chair, as depicted in Fig. 1. The 3D coordinates of the markers were acquired at a sampling rate of 60 Hz. A proper calibration of the working volume, a cube of 0.6 m per side, allowed us to achieve an accuracy of less than 1 mm in the coordinates' measurement.

Fig. 1. The marker placement: passive reflective markers were placed over temple (right and left temporal fossa), frontal area (nasion), nasal supratip, acromion process (right and left), seventh cervical vertebra, sternum, and the chair where the subject was seated. When wearing the cap, markers were also placed over its vertex and over the mass added to the cap, posteriorly to the head.

2.3. Testing protocol

The subjects were asked to sit in a standard, armless chair with backrest, comfortably in a self selected position and with their trunk supported by the backrest slightly reclined at an angle of 15° (Fig. 2). Then, they were asked to attentively watch a documentary movie displayed on a 20 in. desktop monitor placed in front of them, with the line of sight downward inclined by approximately 10° and the head in a neutral position. Four acquisition trials, each lasting 5 min, were performed within one experimental session. The first acquisition (condition n.1, no load) started as soon as the subjects sat. After 5 min, the subjects wore the cap (strapped to the head to prevent it from slipping), and the second acquisition started (condition n.2, with load). Then, to avoid the manifestation of postural habituation, the subjects were asked to rise from the chair and walk, freely moving the head (always wearing the cap), and after 5 min to sit down again. Hence the third acquisition was performed (condition n.3, with the load still added, after walking). After that, the subjects undressed the cap and the fourth acquisition was done (condition n.4, no load, after cap removal). In this way, each subject had the load added for 15 min, and two trials were acquired in each condition (with and without load, respectively). During each 5 min lasting acquisition, at regular intervals of time (every 75 s), the subjects were asked to look at one of three target pictures that were located on the left and on the right of the subjects head and at the ceiling of the sitting place, respectively (Fig. 2), and to answer the question "what do you see on the right/left/over your head?" In this way they had to rotate the head or extend the neck. The goal of this task was to interrupt a possible habituation phenomenon and to allow the subject to reset his/her posture. In this case the variability related to head repositioning was not neglected. The target pictures, as well as the order of movements, were randomly changed during the acquisition session. The subjects were reminded to watch the video and to rotate the head only when asked, no encouragement was issued to them to immobilize the head during the trials, not even when wearing the cap.

2.4. Data analysis

A kinematic analysis was performed to quantify the time courses of head position and orientation, as well as of the head-neck flexion angle, in the different conditions considered. The midpoint between the two acromion processes was defined as the origin of a 3D reference frame, parallel to the laboratory reference axes. The coordinates of all markers were referred to this reference system. The midpoint between the markers over right and left temple was defined to be the origin of the local reference frame of the head. On the basis of this reference point and the marker over nasion, the absolute rotation of the head in the sagittal plane (head inclination) and its anterior–posterior horizontal translation (head protraction) as well as the head-neck flexion angle were computed. From each acquisition, the only data related to steady posture (i.e. the four intervals excluding the head perturbations) were considered.

The markers placed over the acromion processes and on the chair allowed us to verify whether trunk posture was steadily maintained during the whole acquisition. Since the back of the subjects was resting on the chair, only small oscillations due to breathing were expected.

For each condition considered, the time course of head/neck position and orientation obtained from each subject were averaged. The statistical analysis was performed using Matlab (The MathWorks, Natick, USA). A paired samples Student's t-test was performed to determine the significance of the differences both between groups and between conditions. The effects of the load were assessed by comparing the averaged values of position and orientation obtained from the conditions n.2 (with cap) and n.1 (no-cap). The ability of head repositioning was analyzed in both 'no-load' conditions, i.e. by comparing condition n.4 (after cap removal) to condition n.1 (initial posture before adding the load). The time effects were quantified by comparing the two 'with load' trials, i.e. condition n.2 (load just added) and condition n.3 (with load, after 15 min).

3. Results

During quiet sitting most subjects in both groups maintained the head in an almost stable position. However, slow trends towards neck flexion or head anterior translation (protraction) were sometimes observed during each steady period (see Fig. 3 concerning the head horizontal movement). Two additional types of movements were also observed: (a) a continuous head oscillation of small amplitude (less than 1 mm), synchronized with breathing, at a frequency of 0.3–0.35 Hz and (b) sporadic movements that could be associated to postural corrections or to deep breath. These were of small duration (0.5–2 s) and amplitude comparable to the differences between trials (6° flex-ext, 2–5 mm