

Effect of cervical headgear wear on dynamic measurement of head position

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SUMMARY The aim of this study was to identify the effect of cervical headgear (CHG) wear on dynamic measurement of head posture during walking.

Six male and 10 female patients (mean age, 11.9 ± 1.9 years) who were receiving CHG therapy for correction of a Class II molar relationship as part of their orthodontic treatment were included in this study. Dynamic head posture measurements were recorded using an inclinometer and data logger apparatus during a walking session of 5 minutes. This procedure was repeated before (T1) and after (T2) insertion of CHG. The T1 and T2 measurements were repeated twice at 30-minute intervals. The mean dynamic head posture was calculated for each subject using the collected data. The means of these measurements were statistically compared using a paired *t*-test.

Of the 16 subjects, 14 showed a cranial flexion with CHG wear in relation to T1 (1.4 to 8.9 degrees). The other two subjects showed a cranial extension of -1.6 and -3.8 degrees. The mean values at T1, T2 and T1–T2 were 1.4, -1.8 , and 3.1 degrees, respectively, which indicated a mean cranial flexion at T2 in relation to T1. According to the paired sample *t*-test, there were statistically significant differences between the two measurements of dynamic head posture recorded before and after CHG insertion ($P < 0.001$).

CHG wear causes a significant cranial flexion which may be responsible for its effects on the mandible.

Introduction

The effect of cervical headgear (CHG) wear on craniofacial growth has been examined in numerous cephalometric studies over recent decades, and inhibition of maxillary growth has been commonly described as an important effect (Meach, 1966; Jakobsson, 1967; Wieslander, 1974; Mills *et al.*, 1978; Sauer and Kuftinec, 1981; Baumrind *et al.*, 1983; Tulloch *et al.*, 1997; Keeling *et al.*, 1998). However, there is no consensus on the effect of CHG on mandibular growth. Jakobsson (1967), Wieslander (1974) and Tulloch *et al.* (1997) reported that CHG had no influence on mandibular growth, while Meach (1966) and Mills *et al.* (1978) showed that it inhibited forward growth of the mandible. In contrast, Sauer and Kuftinec (1981), Baumrind and Korn (1981), Baumrind *et al.* (1981, 1983) and Keeling *et al.* (1998) demonstrated that CHG facilitated mandibular growth. Thus, the previous findings diverge, and a common understanding has not yet been reached. Considering that CHG does not exert orthopaedic forces directly on the mandible, its effects on mandibular growth are interesting. Graber (1972) mentioned that reflective forward mandibular thrust was associated with CHG therapy and that such ‘activator-like’ movement could be beneficial to mandibular growth. It has also been reported that the resting mandibular position moved anteriorly when awake subjects wore CHG (Hiyama *et al.*, 1999).

The mandibular rest position was originally believed to be established at birth (Thompson, 1949) and maintained throughout life (Thompson, 1946, 1949). More recently, it has been suggested that the rest position is altered by occlusal interferences, temporomandibular dysfunction, psychosocial stress, diurnal variation, nasal obstruction, and head position (Thörne, 1953; Graber, 1963; Pae *et al.*, 1994; Gonzalez and Manns, 1996; Özbek *et al.*, 1998; Minagi *et al.*, 2000). For example, extension of the head reduces the interocclusal distance and retrudes the mandible, while head flexion increases the freeway space (Cohen, 1957). A forward head posture has also been associated with a decreased interocclusal dimension (Darling *et al.*, 1984; Gonzalez and Manns, 1996). Changes in body posture have been shown to elicit activity from muscles that could affect mandibular rest position (Lund *et al.*, 1970; Liistro *et al.*, 1988; Pae *et al.*, 1994; Odeh *et al.*, 1995). The effects of head posture may be especially important when the established relationship between craniocervical posture and craniofacial morphology is taken into account (Solow and Tallgren, 1971, 1976; Solow *et al.*, 1984; Solow and Siersbæk-Nielsen, 1992). This posture was previously shown to be relevant to craniofacial morphology (Solow and Tallgren, 1971, 1977), future growth pattern (Solow and Siersbæk-Nielsen, 1992), and mode of respiration (Woodside and Linder-Aronson, 1979; Solow *et al.*, 1984).

It is clear from previous findings that there is a relationship between headgear wear/mandibular position and head position/mandibular position. The missing link however is the effect of CHG wear on dynamic measurement of head posture. Therefore this study aimed to identify the effect of CHG wear on dynamic head posture in order to elucidate one of the possible mechanisms that enables CHG to act on the position of the mandible.

Subjects and methods

Six male and 10 female patients (mean age 11.9 ± 1.9 years) who were receiving CHG therapy as a part of their orthodontic treatment were included in this investigation. All had a Class II occlusal relationship and were confirmed by their parents to have no medical history of temporomandibular disorders or sleep disordered breathing (such as snoring or apnoea), head or neck injury, and none wore eyeglasses to correct vision. All subjects gave their informed consent to participate after receiving a full explanation of the aim and design of the study.

CHG was applied to each patient and the outer bows of the facebows were bent 25 degrees upwards in relation to the occlusal plane. The force application point on the outer bow was located approximately on the tri-furcation of the roots of the first permanent molars to which a standard cervical traction of 300 g per side was applied.

Dynamic measurement and data logging procedure

An inclinometer device and a portable data logger were used to collect the dynamic head posture data as described previously (Usumez and Orhan, 2001, 2003; Usumez *et al.*, 2003) with and without the CHG (Figure 1).

The dynamic measurement of natural head posture required several instruments to be linked (Figure 1). First, a device to measure the pitch and roll of the head was required. An inclinometer (linear tilt sensor, SX-070D-LIN; Advanced Orientation Systems, Linden, New Jersey, USA) that measured single-axis angles was selected, and two were incorporated into the experimental device. The inclinometer had a ceramic cavity lined with electrodes and filled with an electrolytic liquid. Excitations caused by shock and vibration were filtered digitally in the conversion module (Figure 1, B). This inclinometer could measure a total span of 160 degrees around the true vertical. It weighed 3 g and measured $19 \times 19 \times 5$ mm. One inclinometer was attached to each arm of a pair of eyeglasses, out of the subject's visual range and not touching the temple (Figure 2). The right sensor was placed parallel to the sagittal plane to measure changes in pitch, and the left sensor perpendicular to the sagittal plane to measure changes in inclination. The total weight of the apparatus, including the two inclinometers and the eyeglasses, was 21.67 g.

Electronic cables originating from the inclinometers were directed from the back of the neck into the conversion module

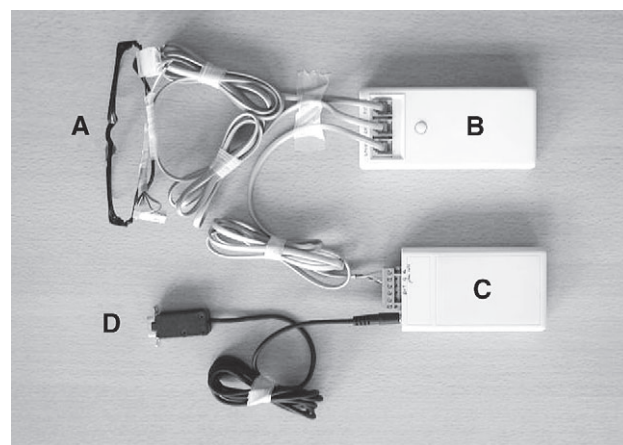


Figure 1 Instruments used in the study: (A) Eyeglass frame with inclinometers; (B) conversion module; (C) data logger; (D) PC connection cable. A, B, and C were worn, and D was unplugged from the logger during walking. (Reprinted from the Journal of Prosthetic Dentistry, 90(4) 394–400. Usumez A. *et al.* Effect of complete dentures on dynamic measurement of changing head position: a pilot study. Copyright (2004), with permission from The Editorial Council of the Journal of Prosthetic Dentistry.)



Figure 2 Cranial portion of the device. Note the placement of inclinometers on opposite sides.

(CM, Digitech Ltd, Ankara, Turkey), which processed voltages from the inclinometers. The analogue output of the module could be used for dynamic data recording with a portable data logger (XR440, Pace Scientific Inc., Mooresville, North Carolina, USA). The analogue output was used to record the dynamic changes in head position, and data were stored in a portable data logger (Figure 1, C). The logger measured $120 \times 61 \times 24$ mm and weighed 156 g. The stored data was transferred to a computer via a RS232C port (Figure 1, D) using software provided by the data logger manufacturer. The inclinometer measured a positive angle relative to the true vertical (0 degrees) when the head was tipped forward in the sagittal plane. A negative angle indicated a backward tipping in the sagittal plane relative

to the true vertical (0 degrees). The inclinometers and the conversion module did not require calibration, while the data logger was calibrated against known angles to read the analogue signals correctly.

The sampling rate of the data logger was set to one sample every 2 seconds for a recording period of 5 minutes. The data logger and conversion module were attached to the belt of each subject in mobile telephone covers in an unobtrusive manner. The measurements of head posture were recorded and the data were subsequently transferred to a personal computer. The measurements could be displayed in both tabular and graphic form (Figure 3).

The continuous recording of head posture in walking subjects was conducted in a large room with bare walls, without direct vision to the outside, and good artificial lighting. Each subject in turn was fitted with the inclinometer system (Figure 4) and instructed to walk in a relaxed manner without special focus on any part of the room. Each subject was allowed to walk for some time to become conversant with the required protocol. Once the subject was comfortable with this routine, a 5-minute recording session of walking head posture was commenced. The software package of the data logger made it possible to transfer all the data recorded during the 5-minute recording session. This procedure was repeated before (time-point T1) and after (time-point T2) insertion of CHG. The T1 and T2 measurements were repeated twice with a 30-minute interval. An intraclass correlation coefficient was computed to determine the reliability of the measurement process (Table 1).

The mean dynamic head posture was calculated for each subject using the collected data. The means of these measurements were statistically compared with a paired *t*-test. For the purposes of this study, the null hypothesis assumed that the dynamic measurements of head posture with and without CHG were not statistically significantly different ($\alpha = 0.05$).

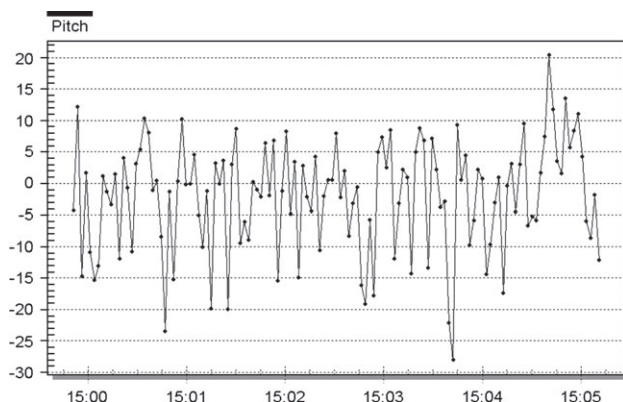


Figure 3 View from the graphic window of the pocket logger software showing the dynamic cranial posture of a patient over a period of 5 minutes.

Table 1 Mean dynamic head posture measurements (degrees) before (T1) and after (T2) insertion of the cervical headgear, and their differences.

Patient	T1	T2	T1-T2
1	-11.86	-18.46	6.60
2	-8.34	-11.92	3.58
3	-7.95	-11.92	3.97
4	-7.68	-13.07	5.39
5	-5.33	-9.36	4.03
6	-1.51	-5.37	3.86
7	-1.15	-10.05	8.90
8	-0.67	0.96	-1.63
9	1.00	4.84	-3.84
10	3.57	1.62	1.95
11	3.69	2.08	1.61
12	5.25	3.35	1.90
13	7.32	3.06	4.26
14	8.50	5.66	2.84
15	12.90	7.62	5.28
16	24.25	22.84	1.41
Intraclass correlation†	0.9419	0.9334	
Test			***
Mean	1.37	-1.76	3.13
SD	9.20	10.42	3.03
Range	-11.86 to 24.25	-18.46 to 22.84	-3.84 to 8.90

†Intraclass correlation coefficient of two repeated measurements at each time point.

*** $P < 0.001$.

SD, standard deviation.

Results

The intraclass correlation revealed a high positive correlation between the two different measurements of dynamic head position at the same time point (Table 1).

The mean values of the dynamic head posture measurements are shown in Table 1; T1-T2 represents time-point differences for each subject in the sample. A positive value indicates that the mean dynamic head posture was tipped forward, and a negative value that the mean walking head posture was tipped backward relative to the previous measurement of dynamic head posture.

Of the 16 subjects, 14 showed a cranial flexion with CHG wear in relation to T1 (1.4 to 8.9 degrees). The other two subjects showed a cranial extension of -1.6 and -3.8 degrees. The mean values at T1, T2 and T1-T2 were 1.4, -1.8, and 3.1 degrees, respectively, which indicated a mean cranial flexion (Figures 4 and 5).

According to the paired sample *t*-tests, there were statistically significant differences between the two measurements of dynamic head posture positions ($P < 0.001$). The null hypothesis was thus rejected.

Discussion

The method used in this investigation to record dynamic changes in natural head position (NHP) has been used



Figure 4 A subject wearing the cranial portion of the device.

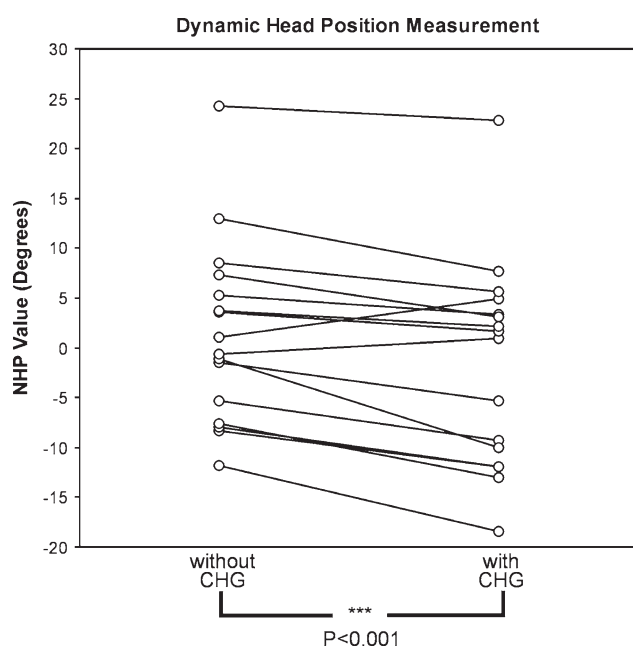


Figure 5 Ladder plot of the changes in dynamic measurement of head position with cervical headgear.

in previous studies (Murphy *et al.*, 1991; Usumeze *et al.*, 2003; 2005). It can be questioned whether the wearing of the inclinometer apparatus itself may have an effect on NHP. The head portion of the instrument used in this study was kept as light and as small as possible to avoid affecting NHP. The cranial portion of the device developed previously by Murphy *et al.* (1991) has been shown not to significantly affect NHP. The cranial portion of the instrument used in this study weighed only 21.6 g, less than one-fifth of the weight of the previous system. It was therefore assumed that it did not significantly change head position. The inclinometers and cables were placed out of the subject's visual range: the inclinometers on the arms of the eyeglasses without touching the temple,

and the cables directed from behind the neck without causing any discomfort. It has previously been shown that the eyeglasses could be placed in the same position consistently on separate occasions and demonstrated that reasonably exact positioning of the inclinometer was repeatable (Murphy *et al.*, 1991). Therefore, these parameters were not tested in this study, and the results of Murphy *et al.* (1991) were adopted.

Since Björk (1955) observed that subjects with an obtuse cranial base angle were more likely to exhibit facial retrognathism and elevated head posture, a number of cross-sectional studies have demonstrated a correlation between head posture and craniofacial morphology (Solow and Tallgren, 1976; Wenzel *et al.*, 1985; 1989; Solow and Siersbæk-Nielsen, 1986; Showfety *et al.*, 1987; Tallgren and Solow, 1987). There has been a pattern in the majority of these studies of higher correlations between variables representing posture and mandibular, rather than maxillary, morphology (Wenzel *et al.*, 1985).

The results of the present study showed that CHG wear significantly changed the dynamic measurement of head posture and caused a statistically significant flexion of the head. The force vector of the headgear passes from under the centre of resistance of the cranium. Therefore this might be regarded as an expected finding as this force vector may easily tip the head forward or cause its flexion. The average change in the dynamic posture was 3.1 degrees of cranial flexion. The vast majority of the subjects (87%) followed this pattern; however, it should be borne in mind that the total number of subjects was only 16.

Solow and Kreiborg (1977) put forward the 'soft tissue stretching hypothesis' to elucidate the link between extended or flexed cranial posture and changes in craniofacial development. The idea was lacking in evidence, but some years later Hellsing and L'Estrange (1987) reported precisely such forces in a sample of dental students. A tiny pressure transducer was glued to the labial surface of an upper central incisor and the pressure recorded when the subjects tilted their head 5 degrees upwards from natural head posture, then 5 degrees down. The changes in head posture resulted in a difference of several grams being recorded on the pressure transducer when the head was tilted through 10 degrees. Such differences could easily influence dentofacial and skeletal development (Solow and Sandham, 2002). It has also been shown previously that when the head is in an erect and upright position, the postural position of the mandible is located 2 to 4 mm below the intercuspal position (Okeson, 1998). If the elevator muscles contract, the mandible is elevated directly into the intercuspal position. However, if the face is directed approximately 45 degrees upward, the postural position of the mandible is altered to a slightly retruded position. This change is related to the stretching and elongation of the various tissues that are attached to and support the jaw

(Okeson, 1998). Conversely, when the head is directed downwards 30 degrees, the path of closure is anterior to the upright postural position. Tooth contacts therefore occur anterior to the maximum intercuspal position (Okeson, 1998). In the present study, only seven subjects (43%) showed a change of 4 degrees or more with the insertion of the CHG appliance. However, a greater degree of change in posture may be expected when higher orthopaedic forces are exerted with CHG.

In a previous study of CHG wear on mandibular position and upper airway dimension (Hiyama *et al.*, 1999) it was found that significant forward displacement of the mandible was induced in awake subjects who wore CHG. However, a later study by the same group (Hiyama *et al.*, 2001) suggested that no antero-posterior mandibular displacement occurred when wearing CHG, and only counterclockwise rotation of the mandible was induced. The underlying mechanism of counterclockwise rotation of the mandible was unclear; however, a possible explanation was based on another study which evaluated neural and anatomic factors related to upper airway occlusion which had reported that jaw closing leads to an increase in the upper airway dimension, i.e. the subjects rotated their mandibles unconsciously to facilitate respiration (Kuna and Remmers, 1985). The decrease in the amount of jaw opening may be a protective response to upper airway narrowing that is induced by CHG (Okeson, 1998). Therefore, the CHG-induced change in mandibular position observed by Hiyama *et al.* (2001) was related to the mechanism that protects the upper airway. Those authors argued that the pressure on the back of the neck from the neck strap of the CHG would push the soft tissue surrounding the neck anteriorly, which should augment the soft tissue volume in the submental region and result in passive supero-anterior rotation of the mandible, regardless of the neuromuscular mechanism (Okeson, 1998). It is believed that the flexion effect of CHG on head posture may be the triggering factor that initiates a neuromuscular feedback mechanism to maintain the airway dimension which eventually leads to changes in mandibular position and/or growth direction if the effect persists. However, the present study did not evaluate long-term mandibular position or airway dimension changes in CHG wearing subjects and focused on the effect of CHG on head posture. Therefore, these assumptions should be considered with caution.

Conclusion

Within the limitations of this study, it was demonstrated that CHG wear caused a statistically significant average 3.1 degrees of flexion in head posture in a group of 16 patients, but not for all. This effect of CHG wear may be the initiating factor for forward mandibular positioning which has been reported as a result of CHG therapy in previous studies.

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