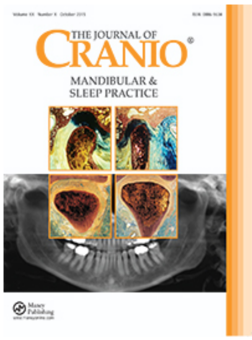

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ISSN: 0886-9634 (Print) 2151-0903 (Online) Journal homepage: http://www.tandfonline.com/loi/ycra20

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To cite this article: Simona Tecco, Christian Colucci, Auro Caraffa, Vincenzo Salini & Felice Festa (2007) Cervical Lordosis in Patients Who Underwent Anterior Cruciate Ligament Injury: A Cross-Sectional Study, CRANIO®, 25:1, 42-49

To link to this article: http://dx.doi.org/10.1179/crn.2007.008

Published online: 31 Jan 2014.

Cervical Lordosis in Patients Who Underwent Anterior Cruciate Ligament Injury: A Cross-Sectional Study

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ABSTRACT: It has been proposed that intraoral devices can influence cervical posture. Cervical posture might also be influenced by stimuli from the lower limbs, such as injury of the knee. The hypothesis to be tested is that intraoral devices are useful during the rehabilitation of orthopedic patients to accelerate the restoration of postural control. This study evaluates cervical posture on lateral skull radiographs in subjects who suffered anterior cruciate ligament (ACL) injury of the left knee. Twenty adult Caucasian males (mean age 30.6±9.2 yrs.) with ACL injury of the left knee were compared with 40 control subjects (mean age 27.9±7.2) who did not show any ACL injury. Lateral skull radiographs, made in natural head position (mirror position), were obtained for all subiects. Various postural and morphological variables were individualized on each radiograph. To assess errors due to landmark identification, duplicate measurements were made of 15 radiographs and compared using the Dahlberg formula. The method error from both sources was less than 0.5° for all angular measurements and less than 0.5 mm for all linear measurements. No difference was observed between the two groups in any of the morphological variables of face or in the cervical lordosis angle (CVT/EVT). However, subjects in the study group showed significantly higher craniocervical angulations (SN/OPT, SN/CVT, SN/EVT, pns-ans/OPT, pns-ans/CVT, pns-ans/EVT, GoGn/OPT, GoGn/CVT, GoGn/EVT) compared with the control subjects (p<0.001). The subjects with ACL injury had significant head extension compared with the control subjects.

0886-9634/2501-042$05.00/0, THE JOURNAL OF CRANIOMANDIBULAR PRACTICE,

Manuscript received July 18, 2005; revised manuscript received March 26, 2006; accepted March 29, 2006

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The existence of connections between the masticatory system and body posture has been discussed previously.[1-11] To date, the dental literature includes several articles about the influence of head and body posture on the mandibular rest position,[4] the range of functional mandibular movements,[2,9] and facial morphology.[6-7] Mintz[10] also observed that temporomandibular joint (TMJ) syndromes can develop based on an orthopedic postural problem. He found that a severe back injury or chronic lower back problems may alter the position of the cranium and finally result in a mandible malposture, which can affect the muscles of mastication and cause chronic irritation or spasm. Here, a TMJ problem might also be caused by repetitive maintenance of an unorthodox position in work or exercise that may tend to overstimulate any of the muscles in the previously described chain reaction.[10] Other authors[9,11] have suggested that body postural control is more difficult to maintain in subiects with occlusal problems because the range of body postural control seems to be generally greater in subiects without occlusal problems than in patients who have them.

Previous investigations showed a strong correlation between TMD and cervical posture in Caucasian adult

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females[12] because subjects with TMD showed a lower cervical lordosis angle compared with subjects with no TMD. In a related investigation,[13] it was shown that cervical posture and cervical lordosis angle were also related to mandibular size and position in adult Caucasian females. The longer the mandible was, the straighter the cervical column. Another investigation[14] showed the possibility to influence the cervical lordosis angle in female children with class II malocclusion using an orthodontic device which causes an anterior repositioning of the mandible and, consequently, an increase of the cervical lordosis angle. Evidence for a functional and anatomic correlation between the stomatognathic system and the postural regulation system in cats[3] has also been demonstrated in rats.[8]

Somatosensory information from the lower limbs has been found to strongly contribute to postural control of the body.[15] Anterior cruciate ligament (ACL) injury has repeatedly been reported to compromise knee proprioception, presumably because of disruption of mechanoreceptors within the ligament,[15-19] and this observation has prompted researchers to study the effects of ACL injury on measures of balance during standing.[20-23]

There is still a lack of evidence that an alteration in postural control of subjects with ACL injury influences cervical posture. There is also no evidence that indicates how such an alteration could exert influence. Research into this question may be of some clinical importance in that improvement in postural control under conditions that involve an alteration of stomatognathic inputs could indicate the underlying cause. Identification of a mechanism could indicate how the potential benefits of intraoral devices (projected, theoretically, to improve the cervical posture of the subiect), arise during the period of functional rehabilitation in patients with ACL iniury. The period of functional rehabilitation includes complex and functionally relevant exercises that often are reported to be problematic for individuals with ACL injury. Given the importance that the orthodontist gives to cervical posture today and the possibility of influencing it by using intraoral devices, which, from a theoretical point of view, could improve the cervical posture of the subiects, preliminary investigations comparing the cervical posture in patients with ACL injury versus control subjects are necessary. Future investigations could be aimed to evaluate the influence of intraoral devices, used during the rehabilitation period in patients with ACL injury, on postural control. The aim of this study was to investigate and quantify the cervical posture in adult patients who underwent ACL injury, with particular care to use records that are usually studied by the orthodontist, i.e., a lateral skull radiograph.

Material and Methods

Twenty (20) adult Caucasian males with ACL injuries to the left knee made up the study group (mean age 30.6±9.2 yrs.).

An ACL injury is characterized by extreme stretching or tearing of the ligament in the knee (**Figure 1**). The tear may be partial or complete. In general, the ligament is injured through twisting the knee or through an impact to the side of the knee—often the outside (**Figure 1**). ACL tears may be due to contact or noncontact injuries. A blow to the side of the knee, such as may occur during a football tackle, may result in an ACL tear. Alternatively, coming to a quick stop, combined with a direction change while running, pivoting, landing from a jump, or overextending the knee joint, can cause injury to the ACL. Basketball, football, soccer, and skiing are common causes of ACL tears. In this study, all the patients were selected as having various causes of ACL tears (mostly sports related). Early symptoms of ACL injury are: 1. a *popping* sound at the time of injury; 2. severe pain; and 3. swelling of the knee within six hours of injury. Late ACL tear symptoms are knee joint instability and arthritis.

An ACL injury should be treated with a splint, ice, elevation of the joint (above the level of the heart), and pain relievers such as nonsteroidal anti-inflammatory drugs (NSAIDS, i.e., ibuprofen). The patient should not continue sports activities until evaluation and treatment has taken place. Some people may need crutches to walk until the swelling and pain has improved. Physical therapy may help regain joint motion and leg strength.

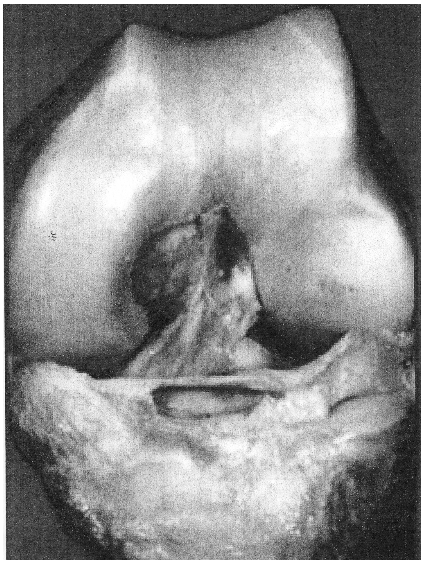

Figure 1
Anterior cruciate ligament.

However, if instability continues even after leg strength and knee motion are regained, most orthopedists recommend a surgical reconstruction of the ACL. ACL surgical repair involves reconstructing the ligament from a tendon elsewhere in the body or simply repairing the damaged ligament. The simple repair of the damaged ligament is only possible if the ACL is of good quality and if the ligament can be passed posterior to the posterior cruciate ligament, both of which are determined in surgery. If the old ligament cannot be repaired, a new one needs to be constructed. Usually a piece of the patellar tendon (the tendon connecting the kneecap to the tibia) is used, although the hamstrings can also be effective. Cadaveric grafts may also be used to reconstruct the ACL. Acutely (recently) torn ligaments are typically of better quality and therefore have a greater chance of being repaired as opposed to chronically torn ligaments.

All of the pathological knees in this investigation had acute tears of the ACL defined as less than eight weeks from injury to surgery, and the patients were selected for ACL reconstruction.

The 20 study subjects were selected from an initial group of 55 patients with ACL injury from the Unit of Orthopedic, University G. D'Annunzio, Chieti, based on the following inclusion criteria, which were also used to select the voluntary control subjects: 1. absence of any previous orthodontic treatment; 2. presence of natural dentition and bilateral molar support with molar and cuspid Angle class I; 3. absence of crossbite; 4. absence of chronic muscle pain according to the history of signs and symptoms elicited during palpation of the muscles of the trunk, neck, and stomatognathic region; 5. absence of referred pain due to myofascial trigger points; 6. absence of whiplash, neurological, vestibular, oculomotor disorders and/or hip asymmetry; 7. absence of any particular episode of psychosocial or psychological stress in the last six months, except for the injury to the knee for the study subjects. Moreover, any subjects positive for the diagnosis of pure articular pathology of the knee were not included in the study or in the control population.

The 40 control subjects, aged 23-39 years, average 27.9 (SD=7.2) were from a group of orthodontic patients from the Department of Oral Science, University of Chieti, selected according to the previously stated criteria except for having had an ACL injury. Each subject of the control group signed a consent form permitting investigation and underwent standardized TMJ clinical examination. Subjects in the control group also consented to undergo a free lateral skull radiograph, because they were interested in an orthodontic evaluation and because in exchange, they received panoramic radiographs at no cost. The Institutional Review Board approved the research with the understanding that control subjects would undergo lateral skull radiographs for reasons independent of the research. Ethics approval was obtained by the University's Review Board for Health Sciences Research Involving Human Subjects, and all subjects provided written informed consent prior to testing.

Cervical Pain Assessment

All of the subjects in the sample were screened for normal, pain free, cervical range of motion according to the detailed procedure reported by Visscher, et al.[24] (dynamic/static test). The evaluation revealed no pain in the neck and shoulder areas in any of the subjects.

TMJ Disk Displacement Assessment

All of the subjects in the sample were screened for the presence of TMD signs and symptoms.[25-26] Those who had signs and symptoms were excluded from the investigation. Each subject from the two groups signed a consent form permitting lateral skull radiographs.

Lateral skull radiographs were taken using Orthoceph 10E (Siemens AG, Germany), which has vertical adjustability that allows the recording of standing subjects. The x-ray source had a focus of 0.6 mm. Exposure data were 80-86 KV and 32 mAs. The equipment used a fixed film to focus plane distance of 190 cm and a fixed film to midsagittal plane distance of ten cm resulting in a final enlargement of 10%. For all subjects, 18x24 cm films were used. The head was oriented using a fiber-optic light beam to maintain the midsagittal line in a vertical plane at ten cm from the cassette and 180 cm from the focus median plane of the x-ray source. The examiner (blind to group classification) stood behind the subject and corrected any deviation of the head and neck relative to the alignment of the light beam. This procedure allowed the examiner to maintain a fixed distance of the midsagittal plane of the head to the x-ray source and cassette. This ensured a constant enlargement of 10% of the midsagittal plane and permitted precise analysis of linear and angular dimensions. A 0.5 mm lead wire suspended using a weight was mounted in front of the cassette in order to indicate the true vertical on the film. A 20 by 100 cm mirror was placed on the wall, 150 cm in front of the ear rods, to allow recording of the natural head posture with external reference.[27] The radiographs taken with the subjects standing in orthoposition[28] (the most reproducible natural standing body position), defined as the intentional position from standing to walking. In order to minimize external influence, no ear rods were used in the cephalostat. The mirror position was carried out only after the head was placed in the self-balance position.[29]

The radiologist was asked to register all the neck and the sixth cervical vertebra on the lateral skull radiographs.

The reference points, reported in **Table 1**, were marked directly on each film using a soft cephalometric tracing sharp pencil (Propelling Pencil 0.5, Everflow Pen. Co., Langport, Somerset, TA 10 9RB). Four points were marked in the cervical column area. The references lines, described in **Table 2**, were considered. The variables studied are listed in **Table 3** and illustrated in **Figure 2**. CVT/EVT angle and postural variables were traced according to Hellsing, et al.[35]

Method Error

In order to assess errors due to landmark identification, duplicate measurements were made of 15 radiographs as described by Hellsing, et al.,[36] illustrated in **Figure 2** and listed in **Tables 1**, **2**, and **3**. Variables were compared for each registration and the error variance calculated using Dahlberg's,[37] formula:

$$\sigma = \sqrt{(\Sigma d^2/2N)}$$

where *d* is the difference between the first and the second measurement and *N* the number of double registrations.

Statistical Analysis

The Excel 2000 software (Microsoft,Inc., Redman, WA) and the Statistical Analysis System (SAS) package (SAS Institute, Cary, NC)[38] were used to perform data analysis. Descriptive statistics, including means, standard deviations (SD), medians, 25th and 75th percentiles and range, were computed for each morphological variable.

Between the study and control groups, differences in central tendency of angular and linear measurements were tested using the Mann-Whitney rank sum test, corrected for large samples with Z_t for normally distributed values of *t* coefficient and corrected for ties.[39] The *p* values were calculated for each of the variables with a level of significance for each test established at 0.05.

Table 1
Reference Points*

S	Sella point
A	A point
B	B point
N	Nasion point
Gn	Gnation point
cv2tg	Tangent point of the superior-posterior extremity of odontoid process of the second cervical vertebra
cv2ip	Most infero-posterior point on the body of the second cervical vertebra
cv4ip	Most infero-posterior point on the body of the fourth cervical vertebra
cv6ip	Most infero-posterior point on the body of the sixth cervical vertebra
Go	Point of intersection between RL (ramus line) and ML (mandibular line)
snp	Posterior spinal point
sna	Anterior spinal point

*Table lists reference points on lateral skull radiographs

Table 2
Reference Lines*

SN	Sella-Nasion line (line through S and N)
NA	Nasion to A point (line through N and A)
NB	Nasion to B point (line through N and B)
sna-snp	Palatal plane (PP) (line through sna and snp)
GoGn	Line through Go and Gn (anatomical points)
CVT	Upper part of cervical spine (line through cv2+g and cv4ip)
EVT	Lower part of cervical spine (line through cv4ip and cv6ip)
OPT	Odontoid line (line through cv2tg and cv2ip)

*Table lists reference lines on lateral skull radiographs

Results

The minimum age was 23 years and the maximum age was 39 years for both groups. The mean age for the experimental group was 30.6 years (SD=9.2). The control group mean was 27.9 (SD=7.2) years. Both groups had a combined mean age of 28.2 years (SD=9.9).

Descriptive statistics including mean value, SD, 25th and 75th percentiles, and range were performed for the study group (**Table 4**) and for the control group (**Table 5**).

When errors in landmark localization during retracing and re-digitization were evaluated, the difference in the means revealed that the error from both sources was less than 0.5° for all angular measurements and less than 0.5 mm for all linear measurements.

Between group differences are reported in **Table 6**. No difference was observed between the two groups in any of the morphological variables of face. Additionally, no difference was observed in the cervical lordosis angle (CVT/EVT) between the study and the control groups. However, subjects in the study group showed significantly higher cranio-cervical angulations (SN/OPT, SN/CVT, SN/EVT, pns-ans/OPT, pns-ans/CVT, pns-

Table 3
Variables Studied*

SNA	Angle between S, N, and A points
SNB	Angle between S, N, and B points
ANB	Angle between NA and NB lines
CVT-EVT	Cervical lordosis angle (downward opening angle between CVT and EVT lines)
SN/OPT	Cranio-cervical angle (downward opening angle between OPT and SN lines)
SN/CVT	Cranio-cervical angle (downward opening angle between CVT and SN lines)
SN/EVT	Cranio-cervical angle (downward opening angle between EVT and SN lines)
Pns-ans/OPT	Cranio-cervical angle (downward opening angle between OPT and pns-ans lines
Pns-ans/CVT	Cranio-cervical angle (downward opening angle between CVT and pns-ans lines
Pns-ans/EVT	Cranio-cervical angle (downward opening angle between EVT and pns-ans lines
GoGn/OPT	Cranio-cervical angle (downward opening angle between OPT and GoGn lines
GoGn/CVT	Cranio-cervical angle (downward opening angle between CVT and GoGn lines
GoGn/EVT	Cranio-cervical angle (downward opening angle between EVT and GoGn lines
GoGn/SN	Cranio-mandibular angle (angle between GoGn and SN lines
MM	Maxillary-mandibular angle (angle between GoGn and pns-ans lines

*Table lists morphological and postural variables traced on lateral skull radiographs

ans/EVT, GoGn/OPT, GoGn/CVT, and GoGn/EVT) compared with the control subjects (p<0.001) (**Table 6**).

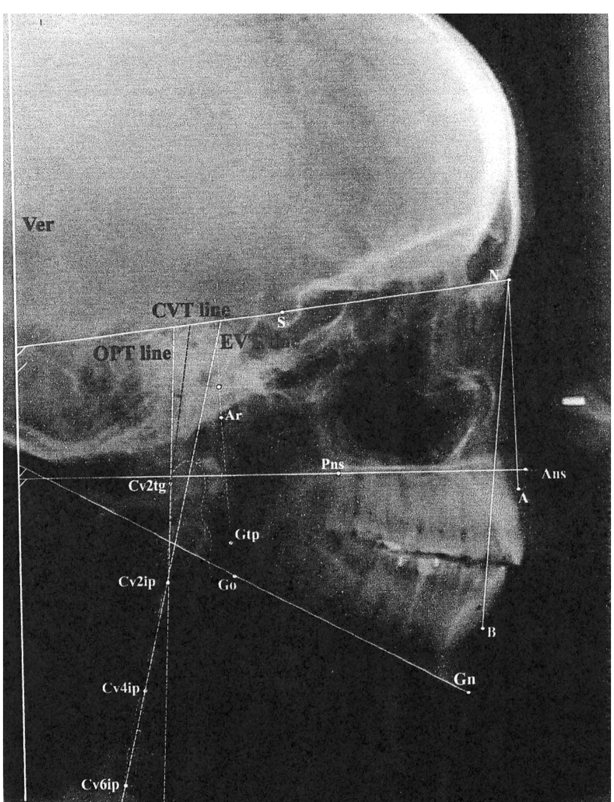

Figure 2
Cephalometric tracing.

Discussion

In this study, a homogeneous group was selected for the following factors: race, sex, age, mandibular inclination, previous orthodontic treatment, and airway adequacy problems which, according to previous observations by several authors, could influence cervical posture.[12-14,24,27,29,32-36] Based on those findings, the population was selected carefully based on the selection criteria.

The cranio-cervical angles (SN/OPT, SN/CVT, SN/EVT, pns-ans/OPT, pns-ans/CVT, pns-ans/EVT, GoGn/OPT, GoGn/CVT, GoGn/EVT), and the cervical lordosis angle (CVT/EVT) were chosen because they have often been employed in previous studies from the same researchers[12-14] to define the cervical posture.

The SN plane represents the anterior cranial base and describes the position of the head with respect to the cervical segment when considered in the SN/OPT, SN/CVT and SN/EVT angles. The pns-ans and GoGn planes represent the position of the two maxillary bases with respect to the cervical segment when considered in the pns-ans/OPT, pns-ans/CVT, and pns-ans/EVT angles.

For the cervical region, the OPT line represents the upper segment of the cervical tract, including the first and second vertebrae; the CVT line represents the middle segment of the cervical tract, including the second to the fourth vertebrae; and finally, the EVT line represents the lower segment of the cervical tract, including the fourth to the sixth vertebrae.

The most important finding in this investigation was

Table 4
Descriptive Statistics in the Study Group*
(n=20)

Degree	Mean	SD	25th p.le	Median	75th p.le	Minimum	Maximum
SNA	78.90	3.45	76.75	80.0	81.25	72	83
SNB	75.40	1.85	74.00	76.0	77.00	72	78
ANB	3.55	2.67	2.50	4.0	5.25	-3	7
GoGn/SN	32.20	4.10	30.00	31.0	35.00	25	40
MM	24.90	7.51	17.75	28.0	30.00	16	38
CVT/EVT	9.70	4.68	6.00	8.5	14.25	2	16
SN/OPT	98.50	13.10	93.25	98.5	110.00	73	115
SN/CVT	115.90	9.91	107.75	116.0	122.25	102	134
SN/EVT	125.95	10.72	116.50	124.0	135.25	111	147
Pns-ans/OPT	100.45	9.56	96.25	103.5	108.00	79	110
Pns-ans/CVT	106.85	10.76	99.00	104.5	116.25	92	123
Pns-ans/EVT	116.70	11.61	108.75	111.0	129.00	98	132
GoGn/OPT	69.45	4.93	65.00	69.0	72.25	63	80
GoGn/CVT	82.45	8.06	75.75	82.0	86.75	71	100
GoGn/EVT	92.55	10.16	86.50	90.5	98.25	74	114

*Table lists descriptive statistics for morphological and postural variables in the study group

between group differences with regard to the existence of statistically significant differences in postural variables between the two groups.

Mean value of all the considered cranio-cervical angules was higher in the study group than in the control group ($p<0.001$), (**Table 6**). This finding seems to suggest that the ACL injury could influence the cranio-cervical angles (SN/OPT, SN/CVT, SN/EVT, pns-ans/OPT,

Table 5
Descriptive Statistics in the Control Group*
(n=40)

Degree	Mean	SD	25th p.le	Median	75th p.le	Minimum	Maximum
SNA	79.98	3.35	78.00	80.5	82.25	73	85
SNB	75.10	3.71	73.00	76.0	77.00	69	82
ANB	4.88	1.52	4.00	5.0	6.00	3	8
GoGn/SN	33.93	4.05	31.75	33.0	36.25	27	43
MM	28.53	3.84	25.75	28.0	30.00	22	39
CVT/EVT	9.85	5.17	5.50	9.0	14.25	1	21.5
SN/OPT	82.30	4.72	78.75	82.0	86.00	73	93
SN/CVT	87.43	4.59	85.00	88.0	91.00	78	98
SN/EVT	97.28	6.95	92.00	97.5	101.62	82	112.5
Pns-ans/OPT	75.28	4.21	72.75	75.0	78.00	68	84
Pns-ans/CVT	78.60	4.30	76.00	78.5	82.00	70	88
Pns-ans/EVT	88.45	6.81	82.87	89.0	92.62	76	102.5
GoGn/OPT	55.80	3.86	54.00	55.5	57.25	48	65
GoGn/CVT	58.78	3.77	56.75	58.0	61.00	52	68
GoGn/EVT	68.63	6.16	62.87	68.8	72.25	56	82.5

*Table lists descriptive statistics for morphological and postural variables in the control group

Table 6
Between Group Differences

Variable (degree)	Mann Whitney U test	Z	Significance
SNA	323.50	-1.206	0.228 (NS)
SNB	388.00	-0.190	0.850 (NS)
ANB	297.50	-1.635	0.102 (NS)
GoGn/SN	285.50	-1.806	0.071 (NS)
MM	323.50	-1.205	0.228 (NS)
CVT/EVT	399.50	-0.008	0.994 (NS)
SN/OPT	131.50	-4.215	p<0.001*
SN/CVT	0	-6.281	p<0.001*
SN/EVT	1.00	-6.259	p<0.001*
Pns-ans/OPT	9.50	-6.831	p<0.001*
Pns-ans/CVT	0	-6.279	p<0.001*
Pns-ans/EVT	3.00	-6.228	p<0.001*
GoGn/OPT	7.00	-6.176	p<0.001*
GoGn/CVT	0	-6.296	p<0.001*
GoGn/EVT	8.00	-6.149	p<0.001*

* p<0.01;
U: Mann-Whitney rank sum test;
Z: Mann-Whitney rank sum coefficient for large samples

pns-ans/CVT, pns-ans/EVT, GoGn/OPT, GoGn/CVT, GoGn/EVT).

However, this assumption cannot be deduced by using only cephalometric relations and cross-sectional observations, because the values of the cranio-cervical angles were not known before the appearance of the ACL injury in the study group. In a previous study, Kantor and Norton[40] observed that the normal lordotic curve becomes straight as a result of cervical muscle spasm that causes the patient to posture the head in an effort to reduce pain and discomfort. The reason may be found in the neurophysiological principles of convergence and sensitization.[41-42] A constant nociceptive input on second-order neurons may increase the sensitivity of these neurons. Then, non-nociceptive neural impulses from other areas within the same segment, which converge with these neurons, may give rise to nociceptive sensations. For the craniocervical region, constant nociceptive input from, for example, the upper part of the trapezious muscle or a lower limb, can lead to an increased sensitivity of the spinal trigeminal nucleus. Non-nociceptive stimuli from the cranio-cervical areas would then lead to painful sensations from the trigeminal region.[41] In these cases, the patient could experience craniomandibular and cervical spinal pain, and the pain could induce the patient into a new head posture in order to decrease pain.

A possible hypothesis for the mechanism at work may concern the fact that the effects on muscular tensions, produced by the postural pathology of the knee, can also extend to some of the neck muscles, according to the principle of neurological association,[41,42] suggesting a functional physiological interdependence between total body posture and head posture.

A possible clinical correlation between the head posture and the rest of the body may be based on the body muscle chains of the neuromuscular system.[5] In fact, it is suggested that when a muscle is in spasm or has a myofascial trigger point, this situation might lead to a modification in postural position.[5]

However, it must be noted that this hypothesis cannot be confirmed by data from a cross-sectional investigation. No conclusion is possible regarding the "mechanism at work," since the cross-sectional construction of the study did not find statistically significant differences. The results obtained in this study warrant further longitudinal investigation in order to clarify the mechanism of the observed significant associations.

Conclusions

This study showed that a postural problem due to an ACL iniury of the knee could be associated with a significant change in cranio-cervical angles (SN/OPT, SN/CVT, SN/CVT, pns-ans/OPT, pns-ans/CVT, pns-ans/EVT, GoGn/OPT, GoGn/CVT, and GoGn/EVT). Further studies should aim to evaluate cervical posture in patients having had an ACL injury before and after ACL reconstruction, and to evaluate the role of intraoral splints in the acceleration of postural rehabilitation.

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