Cervical range of motion and strength in 4,293 young male adults with chronic neck pain

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Abstract

Purpose The correlation of cervical biomechanics and neck pain in young patients has, to date, only been described in terms of small cohorts. This study focuses on the correlation of chronic neck pain and cervical biomechanics.

Methods Neck pain, cervical range of motion (CROM) and maximal cervical torque were recorded in 746 patients with conservatively treated chronic neck pain and 3,547 participants of physiotherapy training without chronic neck pain aged 16–32 years.

Results The “neck pain” group had a highly significant ($s < 0.001$) higher neck disability index (44.7 vs. 10.4 %), longer history of neck pain (3.47 vs. 0.59 years), higher pain intensity (VAS 5.93 vs. 0.93), higher pain frequency (VAS 6.98 vs. 1.09). No differences of CROM and maximal torque in the sagittal, frontal and transverse plane were found.

Conclusion This study describes the largest cohort of biomechanical data of the cervical spine in young adult recorded to date. The findings demonstrate that no correlation was found between neck pain, CROM and maximal torque in the study cohort. On this basis, we conclude that the CROM and maximal cervical torque should not be used as indicators to measure the progress of chronic neck pain in physiotherapy training and sports medicine for the young adult.

Keywords CROM · Neck pain · Biomechanics · Adaptation · Cervical Torque

Introduction

The correlation of cervical biomechanics and neck pain in young patients has, to date, only been described in terms of small cohorts. In Germany, Bellach et al. [1] found cervical neck pain in 13.9 % of young 30-year-old male patients and up to 27 % in young 30-year-old female patients. The incidence of neck disorders is becoming severe in industrial nations especially in young and middle aged humans [2]. In Norway, Makela et al. observed incidences of chronic neck pain in 13.8 % of a random sample of 10,000 persons aged 18–67 [3]. In Finland, 9.5 % of males and 13.5 % of females complain about pain of the cervical spine [4]. The economic impact through days absent, medical health care, diagnostic imaging and physiotherapeutical treatment is increasing [5]. The most significant contributing factor in chronic neck pain is fatigue caused by the sustaining neck muscle, which is essential to hold the head in various positions [4].

While neck pain is a widespread disease, the cervical range of motion (CROM), isometric strength and torque forces of the cervical spine in asymptomatic patients have only been analyzed in detail in various small cohorts [6–9].

Bogduk and Mercer [6] highlighted the biomechanics of the cervical spine and its normal kinematics. In addition, he described comprehensively how the cervical spine behaves under adverse conditions, as well as how it might be injured. Lansade et al. [7] identified a significant correlation between aging and a decrease in CROM and proprioceptive abilities in 140 healthy volunteers. Coupled movements of the cervical spine did not vary with degree

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of movement and age. Reynolds et al. [8] demonstrated in 100 subjects aged between 20 and 40 years that neck anatomy, especially the circumference, should be incorporated into a functional cervical outcome assessment. Salo et al. [9] showed that their collective of 220 healthy women aged from 20 to 59 years had similar absolute neck muscle strength irrespective of their age. Jordan et al. identified an impressive level of muscular strength of the cervical spine in 100 human beings aged between 70 and 79 years [10].

While clinical research into the characteristics of the cervical spine in asymptomatic patients has been scarce to date, there has been even less clinical research into the biomechanics of the cervical spine in patients with neck pain [5, 11–13]. Häkkinen identified lower maximal neck strength relative to the healthy control in his cohort of 46 patients who were treated with botulinum toxin for cervical dystonia [14]. Cagnie et al. [11] proposed to take neck strength into account in her study of 96 patients with chronic neck pain, and demonstrated that women with chronic neck pain exhibited lower neck muscle strength during neck extension. Ang et al. [12] proposed treatment in the form of neck exercises to reduce neck pain and to improve neck flexor function in 68 helicopter pilots.

While the studies noted above provide some insight into the research on chronic neck pain performed to date, a study of a large cohort with measurements of CROM, isometric neck strength and torque forces combined with a history of neck pain has not yet been published. In response, we have undertaken research that seeks to test these concepts, which until now have only been applied to small subject groups, on a significantly larger cohort. In this regard, we set out the hypothesis that young male adults with chronic neck pain do not have any reduction in CROM and maximal neck torque forces. Our hypothesis is supported by Ylinen's theory that neck functions can be improved by effective exercises and low intensity neck muscle therapy to gain a successful rehabilitation of the cervical musculature [13]. Therefore, the primary goal in this study was to investigate a possible correlation between cervical biomechanics and the level of pain, and to propose an effective treatment.

Materials and methods

Study population

Four thousand two hundred and ninety three consecutive males of a cooperating physiotherapy studio (NOVOT-ERGUM AG, Muelheim, Germany) at the age of 16–32 years were included in the study. The “neck pain” group consisted of 746 patients with conservatively treated radiating neck pain. The “control” group consisted of 3,547

participants who started with supervised physiotherapy fitness training for reasons other than neck pain. The collectives were matched by age, height, weight, BMI and subjective fitness. Only patients that had spine surgery in the past were excluded from the study. The data gained from these patient groups were assessed following approval by the University ethics committee according to the official guidelines of the Declaration of Helsinki 1996, as amended.

Study design

All participants were interviewed by specially trained physiotherapists and physicians concerning medical history, pain intensity (visual analog scale, range 0–10), pain regularity (visual analog scale, range 0–10), pain duration (visual analog scale, range 0–10), pain radiation, subjective well-being (ranging from 1 to 5 with one being the highest well-being), subjective fitness (ranging from 1 to 5 with one being the highest fitness) and the subjective correlation of back pain and work. We used a standardized interview form for all patients. The 3-month prevalence of patient consultations with a physician (days), in-patient treatment (days) and painkiller intake due to back pain (ranging from 0 to 3 with one being monthly, two being weekly, and three being daily) were assessed using a standardized self-administered questionnaire under the supervision of a specially trained physiotherapist or physician. The answers were developed quantitatively to allow statistical processing. The body size was measured with a measuring tape (Seca, model 206). The body weight was collected with a calibrated scale (Seca, model 877). The body mass index was calculated by the formula $\text{bodyweight/bodyheight}^2$ (kg/m^2).

Neck disability index (NDI)

The validated NDI was used to assess self-rated disability caused by neck pain [15]. The limitations range from 0 to 20 % (minimal restrictions) to 80–100 % (maximum limits). The questionnaires were filled out individually by the participants, while therapists were made available to respond to questions.

Mobility of the cervical spine

The mobility of the cervical spine was measured in the sagittal, frontal and transverse plane. The maximum mobility of the cervical spine was defined as the maximum amplitude which the patient achieved actively in an upright sitting standardized position using an individually applied head goniometer “Cervical Measurement System” (CMS). The CMS system is equipped with two inclinometers and a

compass on the top. The accuracy (measurement error $<1^\circ$) meets scientific criteria [16]. The mobility of the cervical spine was documented by the neutral zero method.

Torque of the cervical spine

The maximal torque of the cervical spine was measured with equipment from *SCHNELL training System GmbH* (Type DIAHR, FPZHR and FPZHE), Peutenhausen, Germany, and is specifically designed for biomechanical testing of the spine. The devices are equipped with sensors for angle, force and torque with a measurement error of $<1^\circ$ or <1 N and were calibrated in the legally prescribed intervals. The software *Diagnos 2000* (SCHNELL) was used to document the strength and mobility of the cervical spine. The maximum isometric torque of the neck muscles was generated against an immovable resistance in a neutral standardized position of trunk, head and cervical spine. C7 and TH1 were palpated and the transition between C7 and TH1 was adjusted as a virtual axis of rotation for the maximum isometric torque measurement. The fixation of the trunk guaranteed a standardized condition for the torques of the cervical muscles analog to Rezasoltani et al. [17]. The patient had to incline and recline the cervical spine against an immovable resistance with maximum isometric torque. This was followed by measurements of the maximum torque that can be generated by backward bending, lateral bending and rotations to the left and right. All measurements were performed twice using the higher values for statistical analysis.

Statistical analysis

Analysis was performed using SPSS statistical software. The data are reported as mean $\pm$ standard deviations (SDs). The normality of variables was evaluated by the Kolmogorov–Smirnov test. Statistical comparison between the “neck pain” and “normal” group was performed using an independent samples *t* test. The correlation between cervical spine biomechanics and individual characteristics, such as pain intensity and pain frequency, were obtained with the Pearson test. We applied a significant level α of 5 % (two-sided). A significance level α of 0.1 % was considered highly significant.

Results

Study population

The average age of the study population was 27.08 years (16–34 years), with an average height of 181.18 cm (9.59), weight of 82.57 kg (14.99) and body mass index of 25.16 kg/m² (6.65). The subjective fitness was 2.56 (0.94) and the subjective well-being was 2.61 (0.86). 1,177 (27.41 %) of the study participants reported complaints of the cervical spine with a history of 1.08 (2.73) years, an intensity of 1.78 (2.93) and frequency of 2.06 (3.38) days. A 3-month prevalence of 3.58 (5.04) consultations of a doctor, 0.34 (2.48) days of in-house treatment and 0.81(1.06) intake of pain killers due to back pain were

Table 1 Differences of anthropometry and pain history in the study population

	“Neck pain” [mean (SD)]	“Control” [mean (SD)]
Age (years)	28.14 (18–31)	26.85 (18–31)
Height (cm)	180.62 (8.57)	181.3 (9.77)
Weight (kg)	81.69 (14.88)	82.75 (14.99)
Body mass index (m/kg ²)	24.86 (2.98)	25.04 (3.42)
Subjective fitness (range 1–5)	3.02 (0.93)	2.94 (0.95)
Subjective well-being (range 1–5)	2.77 (0.86)	2.56 (0.85)
Complaints cervical spine (%)	100**	12.15
History of cervical pain (years)	3.47 (2.84)**	0.59 (2.14)
Pain intensity cervical spine (range 0–10)	5.93 (2.13)**	0.93 (2.26)
Pain frequency of cervical spine (range 0–10)	6.98 (2.40)**	1.09 (1.26)
Use of pain killers for spinal complaint in the last 3 months (see “Materials and methods”)	0.8 (1.03)	0.82 (1.64)
Visits to a doctor in the last 3 months for spinal complaint (days)	3.43 (4.8)	3.44 (5.09)
In-patient treatment in the last 3 months for spinal complaint (days)	0.17 (1.55)	0.38 (2.64)
Subjective correlation of back pain and work (%)	55.23	56.73
Neck disability index	44.67 (10.56)**	10.4 (6.94)

Significant differences between “headspin” versus “neck pain” and “headspin” versus “control” collectives are marked (* $p < 0.05$, ** $p < 0.001$)

found. In 56.12 % a subjective correlation of back pain and work was stated. The average NDI was 16.59. Differences of the “neck pain” and “control” groups are shown in Table 1.

Maximal CROM

The average maximal CROM for flexion was 55.53° (17.10), 48.59° (15.30) for extension, 34.74° (11.63) for lateral flexion to the right, 34.38° (11.73) for lateral flexion to the left, 64.52° (17.72) for rotation to the right, and 64.50° (17.63) for rotation to the left. We could not find any differences in CROM in these collectives between males and females ($p = 0.59$). Differences of the “neck pain” and “control” groups are shown in Table 2.

Maximal cervical torque

The maximal torque of the cervical spine was 4.19 N m/kg (2.17) of flexion, 6.62 N m/kg (2.81) of extension, 5.36 N m/kg (2.48) of lateral flexion to the right, 5.49 N m/kg (2.59) of lateral flexion to the left, 1.98 N m/kg (1.26) of rotation to the right, and 2.01 N m/kg (1.25) of rotation to the left. When comparing the isometric strength of the cervical spine between men and women, men illustrated 30 % stronger isometric strength in flexion and 33 % in extension compared to women ($p < 0.001$). No significant differences between men and women were found when comparing the extension and flexion ratios ($p = 0.652$). Differences between the “neck pain” and the “control” groups are shown in Table 3.

“Normal” versus “neck pain” cohorts

Significant differences ($p < 0.001$) of the “normal” and the “neck pain” cohorts were found for cervical complaints, pain intensity, pain frequency and NDI. No differences in either CROM or strength were found.

Table 2 Differences of the cervical range of motion in the study population

	“Neck pain” [mean (SD)]	“Control” [mean (SD)]
Maximal flexion (°)	49.52 (13.54)	47.57 (17.1)
Maximal extension (°)	55.46 (15.09)	55.36 (19.17)
Maximal lateral flexion right (°)	35.99 (9.4)	33.94 (13.58)
Maximal lateral flexion left (°)	35.49 (9.87)	32.94 (13.63)
Maximal rotation right (°)	65.26 (14.86)	63.49 (20.56)
Maximal rotation left (°)	65.38 (15.02)	63.31 (20.21)

Significant differences between “headspin” versus “neck pain” and “headspin” versus “control” collectives are marked (* $p < 0.05$, ** $p < 0.001$)

Table 3 Differences of the cervical torque in the study population

Differences of cervical strength	“Neck pain” [mean (SD)]	“Control” [mean (SD)]
Flexion torque (N m/kg)	4.19 (1.98)	4.18 (2.37)
Extension torque (N m/kg)	6.42 (2.69)	6.83 (2.96)
Lateral flexion right torque (N m/kg)	5.35 (2.39)	5.34 (2.70)
Lateral flexion left torque (N m/kg)	5.48 (2.41)	5.49 (2.82)
Rotation right torque (N m/kg)	1.89 (2.30)	2.07 (1.34)
Rotation left torque (N m/kg)	1.93 (1.26)	2.09 (1.31)

Significant differences between “headspin” versus “neck pain” and “headspin” versus “control” collectives are marked (* $p < 0.05$, ** $p < 0.001$)

Discussion

Our cohorts of “normal” and “neck pain” patients are the largest cohorts analyzed for CROM and isometric maximal torque forces of the cervical spine in young adults to date. In contrast, the previous studies that examined cohorts of “normal” CROM ranged in number from 16 to 337 participants [5–7, 9–11, 18], and the cohorts that evaluated isometric neck torque in all three planes consisted of 220 “normal” female participants [9] and 30 “neck pain” patients [11].

In our study, the cohorts are comparable in age, height, weight and BMI. Accordingly, going forward, this cohort should become the baseline for future comparative studies when evaluating participants in the age range between 16 and 32 years. It should be noted that one limitation with respect to our “normal” cohort is that most of the participants started supervised physiotherapy training because of a medical reason, the most common of which was low back pain. In order to mitigate the impact of this factor, we sought to match the cohorts by age, as Lansade et al. showed a correlation between age, three dimensional CROM and cervical complaints. In our results, 12.1 % of the healthy persons periodically complained about cervical neck pain, which is comparable to recent investigations [6–8]. Furthermore, the CROM and maximal torque forces of our normal group are comparable to the collectives described by Klein and Sommerfeld [19]. In women the relative weak neck muscles cause muscular fatigue syndrome resulting in chronic neck pain [11]. Our investigation uses torque forces of the cervical spine instead of linear forces. We and other an author take the view that torque—rather than linear force—reflects the biomechanics of the cervical spine more accurately. Furthermore, Rezasoltani et al. [17] found a significant correlation between isometric linear force and isometric torque measurements of the neck extensor muscles at different levels.

Our cohorts show that the CROM and maximal isometric forces cannot be easily correlated with cervical pain as it has been described in the much smaller cohorts of Vogt et al. [18], Cagnie et al. [11] and Lecompte et al. [11, 18, 20]: Vogt et al. [18] stated that chronic neck pain had a significantly lower maximal CROM in the 18 patients that were observed; Cagnie et al. [11] found significantly lower flexion (29 %), extension (29 %), and rotation forces (23 %) in their chronic “neck pain” group (30 participants) compared to a control collective (96 participants of different age); and Lecompte et al. [20] reported that the nine fighter pilots with “neck pain” exhibited 17–19 % lower side-bending strength than the 10 asymptomatic fighter pilots.

Analogous to our own results, and in contrast to these other smaller cohort studies, De Loose et al. [21] found no significant differences in neck muscle strength between healthy pilots and those with neck pain; however, he did identify a limited CROM in the sagittal plane of pilots suffering from neck pain relative to healthy pilots. Further, Seng et al. [22] analyzed fighter pilots that were repeatedly exposed to +Gz forces and found that the overall muscular neck strength of the fighter pilots did not differ significantly from that of non-pilots.

Many studies show a positive influence of cervical strengthening on pain [12, 13, 22–24]. Ylinen et al. [5] found that a correlation of the change in neck pain and disability indices correlated with isometric neck strength. Sovellius et al. [24] reported of a reduction of cervical strains after cervical strengthening and trampoline training in 16 fighter pilots. Ang et al. [12] found that supervised neck/shoulder exercise regimen was effective in reducing neck pain cases in air force helicopter pilots. The comparable cervical biomechanics of the “neck pain” and “normal” collective show that the maximal isometric torque and the CROM cannot be easily used as diagnostic criteria to determine the extent of pain. Therefore, we believe that the low intensity strengthening and stretching training of the cervical muscle itself is far more important than the maximal isometric torque and maximal CROM. Training of the cervical surrounding muscles could be important to achieve good long-term results in chronic neck pain patients.

A limitation of the study is that further anatomical differences such as head and neck dimension of the collective were not recorded. The synovial folds of the atlanto-axial joints would further be interesting structures to study in our collective as they were recently described as possible reason for neck pain [25, 26].

In all, this study presents the largest cohorts of CROM and maximal isometric cervical torque in “neck pain” and “normal” young adults that have been investigated to date. Our results show that there is no correlation between

CROM, cervical torque and neck pain in the young adults that were studied. As our results offer conclusions with respect to young adults, further studies should consider focusing research on the correlation of cervical biomechanics and pain in different age ranges.

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Conflict of interest All authors state no conflict of interest.

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