Introduction

Cervical spondylosis (CS) refers to the progressive degeneration of the intervertebral discs, leading to changes in the surrounding structures such as the bones and meninges [1,2]. Its signs and symptoms emanate from root compression (cervical radiculopathy) or cord compression (cervical myelopathy) [1,3] and may include pain, paresis, dysaesthesia, numbness, fasciculation, and atrophy of the upper limbs [3]. Because of these observed effects of impaired cervical neuromusculoskeletal systems on hand function, parameters such as manual dexterity and grip have been measured clinically as part of the means of ascertaining the functional status of CS patients [3,4]. However, the exact changes in hand grip parameters associated with CS are only partially understood.

Current physiological findings indicate that grip may be influenced by motor control. This has been explained in the reach-to-grip model of motor control by van Vliet and Heneghan [5]. This model proposed two mechanisms for this function: feedback and feedforward. The feedforward mechanism, which is responsible for online movement adjustment, has been shown to be compromised in the neck muscles in the presence of neck pain and isometric muscle fatigue, which may affect grip. Also, the feedforward mechanism was found to be absent during rapid upper limb activity, such as gripping, in patients with chronic recurrent back pain but not in healthy individuals. However, the effect of handedness and stage of spinal neuromusculoskeletal dysfunction at which these mechanisms begin to affect the grip of CS patients remains speculative.

Furthermore, some distortions in human biopsychosocial balance are also known to affect grip [6,7]. Previous studies indicate that grip decreases in patients with tennis elbow or muscle disuse, after tendon repair or wrist tapping, and in cerebral lesions. Gripping is also affected by music, with grip increasing after listening to stimulating

Research Report

ISOMETRIC GRIP STRENGTH AND ENDURANCE OF PATIENTS WITH CERVICAL SPONDYLOSIS AND HEALTHY CONTROLS: A COMPARATIVE STUDY

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Abstract: This study compared the grip strength (GS) and grip endurance (GE) of patients with cervical spondylosis (CS) with those of healthy controls and determined the effect of hand dominance on these variables. Forty subjects (20 with CS and 20 controls; age range, 27–70 years; mean age, 47.5 ± 13.9 years) participated in this study. Sitting on an armless chair of standard height, the subject's test arm was held at 90° elbow flexed with the forearm in neutral position; subjects squeezed a dynamometer maximally (GS) and held it until the contact force output could not be maintained (GE) while being timed with a stop watch. Patients with CS had significantly lower GS (p < 0.05) and GE (p < 0.001) than the controls in both dominant and non-dominant hands. There was no significant difference (p > 0.05) between the GS and GE of the dominant and non-dominant hands in patients with CS and controls. GS and GE are lower in CS patients than in controls but are similar in the dominant and non-dominant hands in both groups, suggesting that limb dominance does not affect GS and GE.

Key words: cervical spondylosis, degenerative changes, grip endurance, grip strength, hand dominance
music compared with sedative music. Occupation may also be an important factor affecting grip, because it has been observed that heavy manual workers have a stronger grip than office workers and light manual workers [6]. Finally, age, sex, life stresses, emotional status, and culture are known to affect pain coping strategy and muscle contraction [8,9]. These factors may affect grip in healthy individuals and in the presence of CS.

In physiotherapy departments, physiotherapists commonly measure isometric hand grip strength (GS; degree to which one can hold very tightly) and grip endurance (GE; duration for which one can hold very tightly) as diagnostic evidence of loss of hand power prior to rehabilitation and as a therapeutic outcome measure after rehabilitation [7,9]. During this procedure, hand dominance is often identified by determining which hand is used preferentially for activities of daily living. But information concerning the relationship between dominance and activities of daily living is scant.

The purpose of this study was to compare the GS and GE of CS patients with those of healthy controls and determine the effect of hand dominance on these variables. The working hypothesis was that there would be no significant difference between GS and GE of patients with CS and healthy individuals in the dominant and non-dominant hands.

Methods

Forty subjects (age range, 27–70 years; mean age, 47.5 ± 13.9 years) participated in this study. These included 20 patients (female: n = 13; age range, 30–63 years; mean, 43.4 ± 12.2 years; male: n = 7; age range, 27–68 years; mean, 47.5 ± 13.9 years) with the diagnosis of CS referred for therapy to the Physiotherapy Department, Obafemi Awolowo University, Nigeria. The total number represented the patients referred for treatment that gave their consent to participate in the study. A brief examination was conducted for each fresh referral with a diagnosis of CS to ensure that they met the following inclusion criteria:

1. All had severe neck pain (7–10 in Borg 10-point ratio scale) as scored by the patients [8].
2. Skin rolling test was positive.
3. Digital pressure over the fifth (C5) and sixth (C6) cervical vertebrae elicited bilateral pain associated with brachial symptoms. C5/C6 levels were selected, because it is the most frequently injured region with neck pathologies affecting upper limb muscle strength [3,4].
4. None of the patients had received therapy for neck pain.
5. The onset of pain in all the cases was within 12 weeks of entry into this study.
6. Despite physician diagnosis, patients that presented with signs and symptoms of systemic ailment (e.g. fever or high blood pressure) or motor/sensory deficit (e.g. stroke survivors or brachial plexus injury) were excluded from the study.

The patients were selected prospectively, and only those who demonstrated the above characteristics were included in the study. Another 20 (female: n = 12; age range, 30–63 years; mean, 43.4 ± 12.2 years; male: n = 8; age range, 29–70 years; mean, 47.5 ± 13.9 years) apparently healthy age- and sex-matched adults with no reported symptoms of CS or any other systemic or mechanical musculoskeletal disorder were recruited as controls.

Informed consent was obtained from each participant after explaining the test procedure. Weight and height were measured. Hand dominance was established by asking the subject to write on a sheet of paper and to drink a glass of water. The hand that was used in writing and was also used in drinking water was considered to be the dominant hand. These criteria were chosen, because physiotherapists commonly choose the hand preferentially used for activity of daily living as the dominant hand.

The patients used a straight-back and armless chair of standard height as described by Fess and Moran [10]. The subject’s test arm was held at a 90° elbow flexed position with the forearm in neutral position (Figure). The hand was parallel to the forearm holding the dynamometer (Takei Kiki Kogyo, Tokyo, Japan). Subjects were instructed to squeeze maximally and hold until the contact force output could not be maintained while being timed with a stop watch to ascertain endurance. Three measurements were taken for both upper extremities with a 2-minute rest interval, and the average was recorded as the GS and GE values. This study was approved by the ethics and research committee of the Obafemi Awolowo University Teaching Hospital Complex, Ile-Ife, Nigeria.

Data analysis

Descriptive statistics of mean and standard deviation were used to describe the participants’ profile, GS, and GE.

Figure. Measurement of hand grip strength and endurance.
Student’s t test was used to compare the ages of the CS and healthy subjects. A two-way mixed factorial analysis of variance was used to examine whether there was a significant difference in GS and GE between CS patients and healthy controls between the dominant and non-dominant limb, and whether there were interactions between group and dominance [11]. If the F ratio was significant, Bonferroni-Dunn post hoc analysis was used to ascertain which mean differences were significant. Level of significance was set at 0.05. Data were analysed using the Statistical Package for the Social Sciences version 11.

Results

Out of the 44 initial volunteer participants, four were excluded during data analysis because two of the CS patients were found to be stroke survivors and another two (one CS and one control subject) were on anti-hypertension drugs. Therefore, this report is based on the data of 40 valid subjects who were all right-hand dominant.

The physical characteristics of the patients and controls were similar (Table 1). Patients with CS had a significantly lower GS (dominant: p < 0.005; non-dominant: p < 0.004); and GE (dominant, p < 0.001; non-dominant, p < 0.001) than the controls (Table 2). There was no significant difference (p > 0.05) between the GS and GE of the dominant and non-dominant arm of both patients with CS and healthy individuals (Table 3).

Discussion

In this study, the GS and GE of patients with CS and apparently healthy age- and sex-matched controls were compared. The results indicated that patients with CS have significantly lower hand GS (dominant: p < 0.005; non-dominant: p < 0.004) and GE (dominant: p < 0.001; non-dominant: p < 0.001) than the controls, suggesting that reductions in GS and GE are clear changes in hand power associated with CS. The reason for the reduction in GS and GE among patients with CS is not clear. However, over the years, the pathogenesis of adult CS has been linked with degenerative changes associated with ageing [3,12,13]. At 29 years, growth stops while degeneration sets in at about 32 years and progresses thereafter [3,12]. Typically, when degeneration sets in, the intervertebral disc water content reduces, causing it to shrink, tear and sometimes prolapse. Thus, it becomes unable to correctly attach space, and restrain and position its vertebrae, and its function of absorbing shock and distributing pressure becomes impaired; the cartilaginous end-plate thins and cracks while the vertebrae experience osteoporosis and develop osteophytes; ligaments get lax, and facet joints develop arthritis [12,13]. Because none of the CS patients in this study had a history of trauma, it is believed that the spine of this cohort of CS patients shared this experience to a variable extent.

In addition, degenerative changes have been known to place motor, sensory and autonomic neurones in a hyperexcitable state, increase blood vessel tone, and render connective tissues more susceptible to injury without necessarily being painful [3,12]. It was when a motion segment was irritated or a nerve was sensitized that pain (which is the main symptom separating the two groups) was felt, compelling the patient to seek help in the hospital.

Therefore, feedforward motor control, endoneural hypoxia, and pain coping strategy may explain the decrease in GS and GE of CS patients. van Vliet and Heneghan [3] pointed out that gripping movements are planned and controlled in advance by the central nervous system through the feedforward mechanism. This ongoing effort by the central nervous system to control

### Table 1. Physical characteristics of subjects*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Cervical spondylosis (n = 20)</th>
<th>Healthy controls (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>50.6 ± 13.4</td>
<td>47.5 ± 13.9</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.70 ± 0.1</td>
<td>1.65 ± 0.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.3 ± 12.8</td>
<td>72.6 ± 11.1</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.6 ± 5.4</td>
<td>26.6 ± 4.7</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± standard deviation. BMI = body mass index.

### Table 2. Variations in grip strength and endurance in the dominant (Dm) and non-dominant (NDm) hands of patients with cervical spondylosis (CS) and healthy controls*

<table>
<thead>
<tr>
<th>Grip variables</th>
<th>CS</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dm</td>
<td>NDm</td>
</tr>
<tr>
<td>Strength</td>
<td>23.35 ± 8.5</td>
<td>22.3 ± 6.95</td>
</tr>
<tr>
<td>Endurance</td>
<td>21.8 ± 16.2</td>
<td>18.8 ± 13.3</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± standard deviation.
grasp has been found to be altered to a variable extent in patients with cervical spinal dysfunction to affect hand grip. GS and GE may be especially reduced (as may be the experience of CS patients in this study) if physiological (pain or weakness) or psychological (mood, anxiety, etc) conditions of the patient change after the onset of grip movement [5–7]. Similarly, it has been reported that increased tissue pressure arising from degenerative changes compromises myoneural conduction velocity and tissue blood flow and oxygenation when a particular threshold is exceeded [14]. These factors interfere with the ability of the nervous system to activate hand muscles through the motor units to cause a reduction in GS and GE.

A pain coping response of patients with neck pain may be in the form of confrontation or avoidance [9]. A fear avoidance response suggests that CS patients using this pain coping model avoid and reduce neck and hand movements for fear of (re)injury, leading to disuse, atrophy and reduction in the capacity to generate and retain force, as was found in this study [8,9].

The duration of cervical dysfunction prior to reporting to the hospital may also be an important factor affecting the grip of CS patients [2,4]. This may be so because a recent study observed that most back pain patients of low–medium socio-economic status have experienced more stressful life events, which influences their care-seeking behaviour and potentially leads to delays in reporting for treatment [8]. Besides, it is known that people with different tolerances seek help for a symptom for the first time, because they are unable to tolerate it any longer, suggesting that there is always a time lag between onset and reporting of pain [2,9,11]. An additional time lag is found in the hospital, because physicians investigate and initiate chemotherapy prior to referral for physiotherapy [6,9]. Therefore, most CS patients presenting to physiotherapy departments are chronic episodic pain sufferers experiencing a flare-up [8].

The current findings suggest that, due to the above factors, degenerative changes may have gone beyond the threshold of brachial neurapraxia prior to reporting for physiotherapy, thus affecting GS and GE. Further studies will be needed to ascertain how pain tolerances, socioeconomic status, life stresses, and time of reporting for treatment affect the GS and GE of CS patients.

Another finding in this study was that there was no significant difference between the GS and GE of the dominant and non-dominant arms of both patients with CS and healthy individuals. It is difficult to explain why there was no disparity between GS and GE of the dominant and non-dominant arms of CS patients and controls.

Nevertheless, Ganong [15] explains that cerebral hemispheric specialization is related to handedness, which is genetically primed. In humans, right-handed individuals with left hemispheric dominance constitute 91% of the population. In addition, 70% of left-handed people also have left hemispheric dominance, leaving only 30% with right hemispheric dominance [3,4]. This preponderance of left hemispheric control of both left- and right-handed individuals may constitute an initial GS and GE neutralizing factor under similar physiological (stage of degeneration) and environmental (job demand, fitness, and mood) conditions.

Furthermore, in many cultures in the world, especially in Africa, the right hand is considered synonymous with righteousness [6,7]. Children (even those who are known to be left-dominant) are often compelled to use the right hand for public functions such as handshaking, eating, drinking, and writing. A left-dominant adult who uses the right hand for socially acceptable functions but uses the left for activities requiring dexterity may develop equal strength in both limbs. This observation is further substantiated by the finding of Al-Dali et al [6] that professionals who use both hands equally in their work have similar arm strength and endurance.

Therefore, the dominant hand may not necessarily correspond to the hand preferentially used for activity of daily living, which is often used clinically to establish dominance. Efforts should, therefore, be made to develop more reliable means of establishing hand dominance of

**Table 3. Comparisons among means of repeated measures of grip strength and endurance in the dominant (Dm) and non-dominant (NDm) hands of patients with cervical spondylosis (CS) and healthy controls (CO)**

<table>
<thead>
<tr>
<th>Grip variables</th>
<th>Difference</th>
<th>Statistics</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS Dm vs. CS NDm</td>
<td>1.000</td>
<td>1.251</td>
<td>0.266</td>
</tr>
<tr>
<td>CS Dm vs. CO Dm</td>
<td>4.000</td>
<td>4.722</td>
<td>0.004</td>
</tr>
<tr>
<td>CS Dm vs. CO NDm</td>
<td>3.000</td>
<td>3.612</td>
<td>0.005</td>
</tr>
<tr>
<td>CO Dm vs. CO NDm</td>
<td>2.000</td>
<td>2.113</td>
<td>0.258</td>
</tr>
<tr>
<td>Endurance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS Dm vs. CS NDm</td>
<td>2.000</td>
<td>2.702</td>
<td>0.204</td>
</tr>
<tr>
<td>CS Dm vs. CO Dm</td>
<td>7.000</td>
<td>9.721</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CS Dm vs. CO NDm</td>
<td>6.000</td>
<td>8.222</td>
<td>0.001</td>
</tr>
<tr>
<td>CO Dm vs. CO NDm</td>
<td>1.000</td>
<td>1.386</td>
<td>0.258</td>
</tr>
</tbody>
</table>
patients during rehabilitation, especially in a mixed cultural environment.

Limitation
In this study, it was not possible to ascertain the effects of sex and occupation on strength and endurance.

Conclusion
GS and GE are lower in CS patients than in controls but are similar in the dominant and non-dominant hands in both groups, suggesting that limb dominance does not affect GS and GE. Therefore, the dominant hand may not necessarily be the hand preferentially used for activity of daily living, thus pointing to the need for a paradigm shift in the clinical determination of handedness.

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