Comparison and correlation of cervical proprioception and muscle endurance in general joint hypermobility participants with and without non-specific neck pain – a cross-sectional study

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Background: Cervical proprioception and muscle endurance are essential for maintaining cervical functional joint stability. Proprioception and muscle endurance may be impaired in those with general joint hypermobility (GJH). Examining these aspects is crucial. This study's aims are to 1) compare the cervical joint position error (JPE) and muscle endurance holding capacities in GJH individuals with and without non-specific neck pain (NSNP). 2) to assess the relationship between hypermobility Beighton scores, cervical JPE's, and muscle endurance in GJH individuals with and without NSNP. **Methods:** In this cross-sectional comparative study, 33 GJH participants with NSNP (mean age 21.7 ± 1.8 years) and 35 asymptomatic participants GJH (mean age 22.42 ± 1.7 years) participated. Beighton's score of ≥ 4 of 9 tests was used as criteria to diagnose GJH. Cervical JPE's are estimated in degrees using a cervical range of motion device, and muscle endurance (flexor and extensor) were estimated in seconds using a stopwatch. **Results** GJH participants with NSNP showed significantly larger cervical JPE's (p<0.001) and decreased muscle endurance holding times (p<0.001) compared to asymptomatic participants. Beighton hypermobility scores showed a significant moderate positive correlation with cervical JPE's (flexion: r=0.43, p=0.013), left rotation: r=0.47, p=0.005, right rotation: r=0.57, p=0.001) in NSNP individuals. Also, Beighton hypermobility scores showed a moderate negative correlation with muscle endurance in NSNP (flexor muscles: r= -0.40, p=0.020, extensor muscles: r= -0.41, p=0.020, and asymptomatic individuals (flexor muscles: -0.34, p=0.045, extensor muscles: r= -0.45, p=0.007). **Conclusion:** GJH individuals with NSNP showed increased cervical JPE's and reduced muscle endurance compared to asymptomatic. Individuals with GJH with higher Beighton scores demonstrated increased cervical JPE's and reduced neck muscle endurance holding ability. In clinical practice, therapists should be aware of these findings, incorporate proprioceptive and muscle

endurance assessments, and formulate rehabilitation strategies for NSNP individuals with GJM.

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Abstract

21 **Abstract**

22 **Background:**

23 Cervical proprioception and muscle endurance are essential for maintaining cervical functional

24 joint stability. Proprioception and muscle endurance may be impaired in those with general joint

25 hypermobility (GJH). Examining these aspects is crucial. This study's aims are to 1) compare the

26 cervical joint position error (JPE) and muscle endurance holding capacities in GJH individuals

27 with and without non-specific neck pain (NSNP). 2) to assess the relationship between

28 hypermobility Beighton scores, cervical JPE's, and muscle endurance in GJH individuals with

29 and without NSNP.

30 **Methods:**

31 In this cross-sectional comparative study, 33 GJH participants with NSNP (mean age 21.7 ± 1.8

32 years) and 35 asymptomatic participants GJH (mean age 22.42 ± 1.7 years) participated.

33 Beighton's score of ≥ 4 of 9 tests was used as criteria to diagnose GJH. Cervical JPE's are

34 estimated in degrees using a cervical range of motion device, and muscle endurance (flexor and

35 extensor) were estimated in seconds using a stopwatch.

36 **Results**

37 GJH participants with NSNP showed significantly larger cervical JPE's ($p<0.001$) and decreased

38 muscle endurance holding times ($p<0.001$) compared to asymptomatic participants. Beighton

39 hypermobility scores showed a significant moderate positive correlation with cervical JPE's

40 (flexion: $r=0.43$, $p=0.013$), left rotation: $r=0.47$, $p=0.005$, right rotation: $r=0.57$, $p=0.001$) in

41 NSNP individuals. Also, Beighton hypermobility scores showed a moderate negative correlation

42 with muscle endurance in NSNP (flexor muscles: $r= -0.40$, $p=0.020$, extensor muscles: $r= -0.41$,

43 p=0.020, and asymptomatic individuals (flexor muscles: -0.34, p=0.045, extensor muscles: r= -

44 0.45, p=0.007).

45 **Conclusion:**

46 GJH individuals with NSNP showed increased cervical JPE's and reduced muscle endurance

47 compared to asymptomatic. Individuals with GJH with higher Beighton scores demonstrated

48 increased cervical JPE's and reduced neck muscle endurance holding ability. In clinical practice,

49 therapists should be aware of these findings, incorporate proprioceptive and muscle endurance

50 assessments, and formulate rehabilitation strategies for NSNP individuals with GJM.

51 **Keywords:** Hypermobility syndrome, Joint kinaesthesia, joint position sense, cervical muscle

52 endurance, Sensorimotor deficits

53

54

Introduction

General joint hypermobility (GJH) is an inherited condition that may predispose to musculoskeletal pain (Alsiri 2017). Mutations in the genes that code for collagen, elastin, and tenascin are associated with this condition(Alsiri 2017). The prevalence of hypermobility syndrome in adults ranges from 0.6 percent to 31.0 percent (Demes et al. 2020). The hypermobility in females is 1.5 to 3 times more when compared to males (Demes et al. 2020). GJH allows the joints to move beyond their normal range of motion, leading to increased laxity, joint instability, and severe injuries (Demes et al. 2020). Skin, tendon, bone, ligament, and cartilage have a considerable amount of tensile strength and are more likely to fail mechanically in hypermobile subjects compared to others. This unavoidably has a detrimental effect on many individuals who are drawn to performing physically demanding pursuits where physical demands may surpass the body's capacity to bear them (Molander et al. 2020).

Together with the visual and vestibular systems, the proprioceptive system is crucial in maintaining balance and joint stability. (Alahmari et al. 2017a; Riemann & Lephart 2002; Uzunkulaoğlu & Çetin 2019). Previous studies have shown impaired proprioception in the peripheral joints in individuals with GJH (Smith et al. 2013; Uzunkulaoğlu & Çetin 2019). Decreased proprioceptive acuity might lead the hypermobile joints to instability and increased risk of injury (Smith et al. 2013). In addition, previous research demonstrates that impaired proprioception is crucial in developing and maintaining pain, tissue injury, and degenerative joint diseases (Alahmari et al. 2020a; Alahmari et al. 2017b; Alahmari et al. 2017c; Asiri et al. 2021; Kristjansson & Treleaven 2009; Reddy et al. 2021a; Reddy et al. 2020). Therefore, assessing cervical proprioception is vital in evaluating and managing subjects with GJH.

77   In both static and dynamic circumstances, neck muscles play a vital function in supporting the

78   cervical spine (Fountain et al. 1966; Grimmer 1994; Schieppati et al. 2003; Winters & Peles 1990).

79   The deep cervical and dorsal neck muscles create a sleeve that protects the cervical spine from

80   gravitational forces to maintain stable neck postures during activities of daily living. Impaired

81   cervical muscle function, it is thought, will disrupt the balance between the anterior and posterior

82   aspects of the neck, resulting in a loss of cervical lordosis and consequently tend to contribute to

83   cervical dysfunction. Pain and fatigue are common complaints in individuals with GJH (Reddy et

84   al. 2012). Neck muscle fatigue may contribute to altered motor control and reduced proprioceptive

85   sensibility at the neck in individuals with GJH. Different authors demonstrated that cervical

86   reposition sense improved with neck muscular endurance retraining (Jull et al. 2007; Rezasoltani

87   et al. 2010). This finding shows that proprioception and muscle endurance are interrelated and can

88   influence one another. However, the magnitude of these effects may be more influenced by pain

89   in GJH individuals. To date, no researcher had looked at alterations in cervical JPS or muscle

90   endurance capabilities in GJH patients with non-specific neck pain (NSNP) and their associations

91   with hypermobility or vice versa. Rehabilitation therapists' understanding of these aspects will

92   help assess and manage GJH patients with NSNP. Therefore, the objective of this study is to 1)

93   assess and compare the cervical JPS and muscle endurance capabilities in GJH participants with

94   and without NSNP, 2) to evaluate the relationship between GJH Beighton score and cervical JPS

95   scores, neck muscle endurance capabilities in participants with and without NSNP.

96

97   **Materials and Methods**

98   **Design:**

99   This cross-sectional comparative study data was collected between April 2021 to October 2021 at

100 the Physical therapy outpatient clinics department, King Khalid University. Research Ethics

101 Committee at King Khalid University (HAPO-06-B-001) reviewed and accepted this study

102 protocol (ECM#2021-4404).

103 **Participants:**

104 Thirty-three GJH individuals presenting with NSNP were referred to the physical therapy clinic

105 by an orthopedic doctor. Participants have included if the Beighton score was $\geq 4/9$, with NSNP

106 aged between 20 and 45 and able to follow physical therapists commands. NSNP participants were

107 excluded 1) if they had a history of previous surgery, 2) had signs of cervical myelopathy, 3) had

108 general fibromyalgia symptoms, 4) neurological disease, and 5) Ehlers-Danlos Syndrome. This

109 study recruited 35 GJH asymptomatic participants aged between 20 and 30 years who volunteered

110 to participate and followed the physical therapist's instructions. This research followed the

111 principles of the Helsinki Declaration. All participants signed informed consent before the

112 commencement of the study and after being briefed about the study methods.

113 **Outcome measures**

114 **Beighton score:**

115 The Beighton score is a prominent hypermobility screening tool (Malek et al. 2021). This nine-

116 point scale needs five maneuvers, four passive bilateral and one active unilateral. It was created

117 for epidemiological research to detect hypermobility in populations (Malek et al. 2021). Across all

118 cultures and ages, the Beighton score has been utilized to characterize generalized joint laxity

119 (Malek et al. 2021). Several prevalence studies use various cutoffs, ranging from 3 to 6

120 hypermobile joints (thumbs, little fingers, elbows, knees, and the trunk), and others only analyze

121 the dominant side. However, a score > 4 out of 9 indicates the presence of hypermobility (Malek

122 et al. 2021). The Beighton scale's components included in this study are 1) Passive - dorsiflexion

123 and hyperextension of the fifth metacarpophalangeal joint in a passive manner beyond 90°

124 (Bilateral), 2) Passive - apposition of the thumb to the flexor aspect of the forearm (bilateral), 3)

125 Passive -hyperextension of the elbow beyond 10° (bilateral), 4) Passive - hyperextension of the

126 knee beyond 10° and 5) Active - forward flexion of the trunk with the knees fully extended so that

127 the palms of the hands rest flat on the floor.

128 **Cervical proprioception (reposition accuracy) measurement**

129 Cervical proprioceptive accuracy is estimated as joint position error (JPE) in degrees. The cervical

130 target position sense is measured using a Cervical range of motion (CROM) device. The full

131 cervical range of motion in each direction is recorded, and 50% of the available range was selected

132 as the target position the individuals had to reposition.

133 Individuals sat straight on a stool and both feet flat on the ground. The examiner secured the

134 CROM device on the participant's head and asked them to determine their self-selected neutral

135 head position (Figure 1). Following that, the examiner calibrated the CROM device to zero

136 position. All the participants closed their eyes before the commencement of the test. Next, the

137 physical therapist moved the participant's head into the target position (50 percent of the maximum

138 ROM) and held it for five seconds before asking them to memorize this target position. Following

139 this, the examiner guided the participant's head back to the neutral (beginning) position. Following

140 this, the individuals were instructed to move their heads to the previously memorized target

141 position. After the individuals positioned their heads to the target position, the precision of their

142 repositioning was measured in degrees (JPE). The sense of target head repositioning was evaluated

143 in the cervical flexion, extension, and left and right rotation directions. The test was repeated thrice

144 in each direction, and the mean of these trials was used for analysis. No additional feedback was

145 provided to the participants throughout the testing period. The order of testing directions was

146 randomized using a simple chit method.

Cervical Flexor Endurance Testing

148 The test was performed with the individuals lying in supine and crook lying positions (Cagnie et

149 al. 2007; Harris et al. 2005). A JTech Dualer IQ Digital Inclinometer (JTech Medical, Salt Lake

150 City, Utah) was placed on the lateral aspect participant's forehead and secured with a Velcro

151 (Figure 2). When compared to an isokinetic dynamometer, the digital inclinometer had a high level

152 of validity (ICC = 1.0, SEM = 0.09, p=0.001), and there was excellent intra- and inter-tester

153 reliability for reading the inclinometer (ICC = 1.0, SEM = 0.85, p 0.001) (Romero-Franco et al.

154 2019; Romero-Franco et al. 2017).The participants raised their head and neck until the head was

155 roughly 2.5 cm off the plinth while keeping the chin retracted and held isometrically to the chest,

156 as shown in figure 1. The participants were instructed to maintain this position as long as they

157 possibly could. The test was terminated if 1) the participant's head touched with the investigator's

158 palm for more than one second, 2) the skin folds began to separate due to a loss of chin tuck, 3)

159 could not maintain the head in the horizontal position (>5º variation as measured by digital

160 inclinometer), 4) the participant showed a desire to end the test due to exhaustion or pain. The

161 muscle endurance holding time was recorded in seconds using a stopwatch, and the reason for

162 terminating the test was noted in a logbook. Each endurance test was repeated three times, and an

163 average of three values was used for analysis. Between measurements, a minimum of five minutes

164 of resting time was allowed.

Cervical extensor endurance testing

166 The endurance test was adapted from Lee et al. (Lee et al. 2005).The participants were asked to lie

167 prone on the examination couch with their heads protruding from the examination couch and their

168 heads supported by the examiner. A strap was used and wrapped around the participant's thoracic

169 spine at the level of T7 to stabilize the thoracic spine (Figure 3). A digital inclinometer was

170 strapped to the participant's head to measure the participant's head's alignment in the horizontal

171 plane. A 2 kg weight was placed on the participant's head and secured around the participant's

172 forehead using tape, which the examiner initially supported. Extensor endurance was measured by

173 the examiner slowly leaving the patient's head along with 2 kg weight, allowing the weight to hang

174 just above the floor as a pendulum freely. The participants were asked to maintain this head

175 position with the chin steadily retracted as long as possible. The test terminated if 1) the

176 participant's head was tilted, or its position shifted more than 5 degrees away from the horizontal

177 plane (as assessed by a digital inclinometer), 2) the participant was unable to maintain the test

178 position due to exhaustion or pain during the test. Each endurance test was repeated three times,

179 and an average value was used for analysis. Between measurements, a minimum of five minutes

180 of resting time was allowed.

181 **Visual Analog Scale (VAS):** The current level of neck pain was measured on a 100 mm

182 continuous scale, with "0" indicating no pain and "100" indicating the most excruciating pain. The

183 participants mark a point on the scale to represent their current pain intensity. The VAS is a reliable

184 tool widely used to assess pain intensity in different cervical disorders (Parazza et al. 2014;

185 Tishelman et al. 2019).

186 A single examiner who has experience as a musculoskeletal physical therapy specialist for more

187 than 15 years assessed all the outcome measures, and the examiner was blinded to the group

188 allocation.

189 **Statistical Analysis**

190   The study data were analyzed using SPSS version 22.0 (IBM Corp., Armonk, NY, USA). The

191   sample Shapiro–Wilk test was used to determine the normal distribution of the data. An

192   independent t-test was used to compare the cervical JPE's and muscle endurance in participants

193   with GJH with and without NSNP. In addition, we calculated the effect size in terms of Cohen's

194   d. Minimal detectable change (MDC) is computed to differentiate between random measurement

195   error and real change. MDC was calculated as follows: (Standard Error Mean (SEM) x 1.65 x

196   √2) (Furlan & Sterr 2018). Pearson's correlation coefficient (r) was used to assess the association

197   between hypermobility Beighton scores and cervical JPE's, neck muscle endurance capabilities

198   in GJH individuals with and without NSNP. According to Schober et al.(Schober et al. 2018), we

199   considered this statistic as fair when the correlation (r) value was less than 0.30, moderate when

200   the r value was between 0.31 and 0.60, and good when the r-value is more than 0.60. General

201   Linear Model was used to verify if there are interactions between groups x Beighton scores for

202   each outcome (cervical JPE's and cervical muscle endurance) and to see interactions between

203   group x Beighton x gender. A 95% confidence level was used to investigate statistical

204   significance, and a p-value of ≤ 0.05 was considered statistically significant.

205

206   **Results**

207   **Demographics**

208   Thirty-three NSNP (mean age: 21.7 years) and 35 asymptomatic (mean age: 22.4 years)

209   participants were enrolled in this study. Table 1 summarizes the descriptive and demographic

210   characteristics of the study population. Age, height, weight, BMI, and Beighton scores did not

211   differ across groups (all p>0.05). The Shapiro–Wilk test revealed that the study variables were

212   normally distributed.

213   **The difference in cervical JPE's and cervical muscle endurance**

214   The magnitude of cervical JPE's was significantly larger in the NSNP group (p<0.001) when

215   compared to the asymptomatic group (Table 2). These differences were seen in all the directions

216   tested. The magnitude of JPE's was largest in extension direction (NSNP group: 6.45º ± 1.20º,

217   asymptomatic group: 2.29º ± 1.32º) compared to other directions tested. The SEM ranged from

218   0.29º to o.39º, and MDC ranged from 0.67º to 0.91º (table 2). The effect size (Cohen's d) ranged

219   between 0.46 to 0.73.

220   The endurance holding capacities of the cervical flexor and extensor muscles was significantly

221   lower in the NSNP group than in the asymptomatic group (p<0.001). The NSNP group's mean

222   cervical flexor endurance holding capacity was 44.39 ± 4.74 sec, and the asymptomatic group

223   was 60.20 ± 4.37 seconds (Table 2). The SEM was 1.10, MDC was 3.03 sec, and the Cohen's d

224   was 0.75 (Table 2). The mean extensor endurance capacity in the NSNP group was 72.30 ±

225   13.84 seconds, and the asymptomatic group was 163.63 ± 22.74 sec (Table 2). The SEM was

226   3.68, MDC was 10.17 sec, and the Cohen's d was 0.91 (Table 2).

227   **Relationship between Beighton score and cervical JPE's, cervical muscle endurance**

228   The results of the Pearson's correlation showed a significant positive moderate correlation

229   between Beighton score and cervical JPE's in the flexion (r=0.43, p=0.013), left rotation (r=0.47,

230   p=0.005) and right rotation (r=0.57, p=0.001) directions in NSNP group (Table 3). The results

231   indicate that the greater is the hypermobility, as indicated by the Beighton score, the greater are

232   the cervical JPE's in the NSNP group. There were no significant correlations between Beighton's

233   score and cervical JPE's in the asymptomatic group (table 3).

234   There was a statistically significant moderate negative correlation observed between Beighton

235   score and cervical muscle endurance holding capacities in both NSNP group (flexor muscles: r=

236   -0.40, p=0.020, extensor: r= -0.41, p=0.020) and asymptomatic group (flexor muscles: -0.34,

237   p=0.045, extensor muscles: r= -0.45, p=0.007). In both NSNP and asymptomatic groups, the

238   results indicate that individuals with higher Beighton scores had reduced neck flexor and

239   extensor endurance capabilities (Table 3).

240   There were significant group interactions with Beighton scores for JPE's (p<0.001) and muscle

241   endurance (p<0.001). The NSNP group individuals with hypermobility have larger JPE's and

242   lower cervical muscle endurance capabilities. Table 4 shows the pattern of interactions. Also,

243   there were significant gender interactions between groups (p<0.001). Females had more

244   hypermobility than males in both NSNP and asymptomatic groups.

245   **Discussion**

246   The current study is, to date, the first to assess and compare cervical JPS and neck muscle

247   endurance capabilities in GJH individuals with and without NSNP. Also, this study assessed the

248   correlation between hypermobility scores and proprioceptive JPE's and muscle endurance

249   capabilities in GJH individuals with and without NSNP. The present study results showed that

250   the magnitude of cervical JPE's was larger, and muscle endurance (flexor and extensor) holding

251   capacities were lower in hypermobile participants with NSNP compared to asymptomatic. The

252   Beighton score showed a moderate positive correlation with cervical JPE's in the NSNP group

253   and no significant correlations in the asymptomatic group. Also, the Beighton score showed a

254   moderate negative correlation with cervical muscle endurance capacities in NSNP and

255   asymptomatic groups.

256   **Group differences in JPE's and endurance holding capacities**

257   This study's findings of increased JPE's in NSNP are in accordance with the results of Reddy et

258   al. study, in which cervical position sense is impaired in the NSNP group compared to the

259   asymptomatic group (Reddy et al. 2019). The JPE's were significantly larger in flexion,

260   extension, and left and right rotations, comparable to this study's results. In this study, the

261   magnitude of cervical JPE's in the asymptomatic group was smaller when compared to the

262   Reddy et al. study. This study showed a range of 1.14º to 2.29º while; the Reddy et al. study

263   showed 2.36º to 4.48º JPE's. Our study population is hypermobile, and the Reddy et al. study

264   population is normal; the JPE's were larger in the Reddy et al. study. It is likely that this is due to

265   the fact that our study participants are younger (mean age: 22.42 years) compared to Reddy et al.

266   study participants (mean age: 45.07 years). It is well established that with increasing age, the

267   cervical proprioceptive acuity is reduced (Alahmari et al. 2017b; Alahmari et al. 2017c).

268   The systematic review results conducted by de Vries et al. are in accordance with our study,

269   showing that people with neck pain have increased JPE's compared to asymptomatic participants

270   (de Vries et al. 2015). The increased magnitude of JPE in the neck pain group may be due to the

271   influence of pain that chemically mediates and alters the free nerve ending discharges and

272   produces abnormal afferent information, thus impairing proprioceptive input. In addition, studies

273   have shown a significant association between increased pain intensity and increased cervical

274   proprioception errors (Alahmari et al. 2020b; Reddy et al. 2019).

275   Our study findings are in accordance with prior research indicating decreased cervical muscle

276   endurance in NSNP patients compared to asymptomatic patients (Alahmari et al. 2019; Amiri

277 Arimi et al. 2018; Kandakurti et al. 2021; Reddy et al. 2021b). The cervical spine muscles have

278 an abundance of muscle spindle that significantly contributes to afferent motor functionality in

279 maintaining neck endurance (Boyd-Clark et al. 2002). The reasons for reduced endurance

280 holding capability in NSNP individuals may be increased pain intensity that would reflexively

281 inhibit the muscles and lead to a cycle of pain to weakness (Alshahrani et al. 2022; Reddy et al.

282 2022; Reddy et al. 2020; Van Wilgen et al. 2003). It is also demonstrated that the type 1 muscle

283 fiber is transformed into type 2 in neck pain individuals, resulting in decreased strength and

284 endurance of neck muscles (Amiri Arimi et al. 2018; Kandakurti et al. 2021). The mean neck

285 extensor endurance holding capacities in this study (NSNP: 163.63 22 sec, asymptomatic: 72.30

286 13.84 sec) is comparable to the findings of Reddy et al. (Reddy et al. 2021b) (NSNP: 155.88

287 11.94 sec, asymptomatic: 72.00 23.11 sec), implying that hypermobile participants with or

288 without NSNP are the comparable population with or without NSNP.

289

290 **Relationship between hypermobility, proprioception, endurance**

291 This research is the first to evaluate the correlation between hypermobility and cervical JPS, and

292 it demonstrated a moderately positive correlation in the NSNP group. There was no association

293 between hypermobility and cervical JPS in the asymptomatic group. This finding implies that

294 pain may be a factor impacting proprioception in hypermobile persons and that it may be a

295 contributing factor. Ferrell et al. (Ferrell et al. 2004) and Sahin et al. (Sahin et al. 2008a) showed

296 that hypermobility individuals had larger JPE's in the knee joints. Joint laxity and impaired

297 proprioception may make unstable joints vulnerable to trauma (Sahin et al. 2008a).

298 Experimentally produced pain models indicated a link between pain and proprioception (Capra

299 & Ro 2000). Sensitization may modify free nerve ending discharges, resulting in abnormal pain

300   afferents (gamma-motor neuron and muscle spindle), thereby compromising proprioceptive input

301   (Lima et al. 2021). Unlike our investigation, Lee et al. found no relation between neck pain

302   severity and cervical position sense in neck pain patients; rather, they found a link between pain

303   frequency and JPE's (Lee et al. 2008).

304   This study showed a significant moderate negative correlation between hypermobility and neck

305   muscle endurance capabilities in NSNP and asymptomatic groups. Different studies have

306   demonstrated decreased muscle strength, physical fitness, and impaired proprioception in

307   individuals with hypermobility syndrome (Engelbert et al. 2006; Sahin et al. 2008b; Smith et al.

308   2013). Decreased muscle strength and endurance will further place the joint for further injury

309   and functional disability (Beighton et al. 2012). The degree of hypermobility is determined by

310   genetics (Beighton et al. 2012). Increased ligamentous extensibility is caused by changes in

311   connective tissue such as elastin, collagen tenascin, and fibrillin (Beighton et al. 2012). Non-

312   inflammatory joint and muscle discomfort is a common symptom of widespread or pauciarticular

313   joint laxity. A previous study showed a correlation between arthralgia and joint hypermobility

314   (Beighton et al. 2012).

315   Reduced joint stability and muscle strength, when combined with hypermobility, can play a

316   significant role in the development of neck pain disorders or other musculoskeletal injuries and

317   should be researched further to understand their relationships so that prevention and treatment

318   strategies can be planned in this situation. In addition, hypermobility syndrome has been linked

319   to increased risk of upper and lower limb sports injuries, discomfort, and poor dynamic trunk

320   stability (Jindal et al. 2016; Konopinski et al. 2012; Simmonds & Keer 2007). In light of these

321   findings, a complete routine assessment of GJH is required when investigating neck pain issues.

322   **Limitations**

323   This study's findings should be seen within certain constraints. The lack of a healthy control

324   group without GJH makes it difficult to conclude the effects of hypermobility combined with

325   pain on proprioception and muscle endurance. Only absolute errors were examined in the study;

326   however, if variable and constant errors were also evaluated, the magnitude and direction of

327   errors would have provided more useful information.

328   **Conclusion**

329   From the results of this study, it can be concluded that GJH individuals with NSNP have

330   demonstrated increased cervical JPE's and reduced cervical muscle (flexor and extensor)

331   endurance compared to asymptomatic. Beighton hypermobility scores showed a significant

332   positive moderate correlation with cervical JPE's in the NSNP group and a significant moderate

333   negative correlation with cervical muscle endurance in individuals with and without NSNP. In

334   current clinical practice, therapists should evaluate cervical proprioception and muscle

335   endurance, and these factors should be considered during the rehabilitation of neck pain patients

336   with GJH.

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Figure 1

Figure 1: Evaluation of cervical joint position errors using a cervical range of motion device

Figure 2

Figure 2: Measurement procedure of cervical flexor endurance

Figure 3

Figure 3: Measurement procedure of cervical extensor endurance
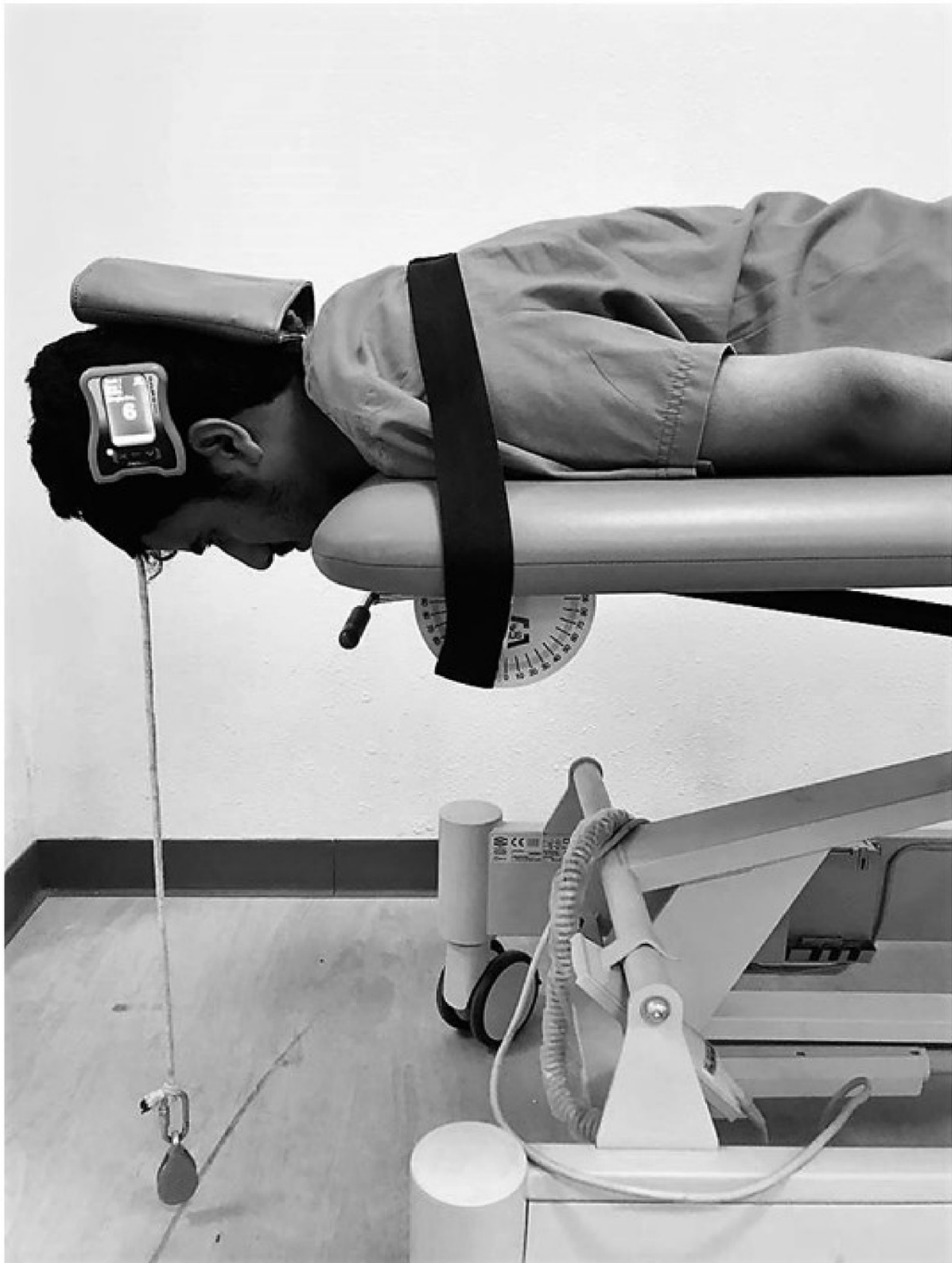
Table 1 Demographic characteristics of the study population

1   Table 1 Demographic characteristics of the study population

Variables	Neck pain group (n=33) (Mean ± SD)	Asymptomatic group (n=35) (Mean ± SD)	p-value
Age (yrs.)	21.7 ± 1.8	22.42 ± 1.7	0.13
Height (Mts)	1.7 ± 0.1	1.6 ± 0.1	0.74
Weight (kg)	62.6 ± 12.6	64.6± 14.6	0.55
BMI (kg/m^2)	22.8 ± 3.9	23.7± 4.1	0.38
Beighton score (0 to 9)	5.70 ± 1.0	6.09 ± 1.04	0.12
Pain Intensity (0 to 10 cm)	4.6 ± 1.0	-	-
NDI score (%)	22.1 ± 3.9	-	-

3   SD= standard deviation; BMI= body mass index; NDI= neck disability index

Table 2 Comparison of JPE between NSNP and asymptomatic groups

1   Table 2 Comparison of JPE and muscle endurance between NSNP and asymptomatic groups

Variables	NSNP group (n=33) (Mean ± SD)	Asymptomatic group (n=35) (Mean ± SD)	Cohen's d	95% CI of the Difference		SEM	MDC	p value
				Lower	Upper			
JPE in flexion (⁰)	4.94 ± 1.52	1.97 ± 1.71	0.46	2.18	3.75	0.39	0.91	<0.001
JPE in extension (⁰)	6.45 ± 1.20	2.29 ± 1.32	0.73	3.56	4.78	0.31	0.72	<0.001
JPE in left rotation (⁰)	5.15 ± 1.37	1.14 ± 1.12	0.72	3.40	4.61	0.30	0.70	<0.001
JPE in right rotation (⁰)	5.21 ± 1.29	1.97 ± 1.04	0.67	2.67	3.81	0.29	0.67	<0.001
Cervical flexor endurance (sec)	44.39 ± 4.74	60.20 ± 4.37	0.75	-18.01	-13.60	1.10	3.03	<0.001
Cervical extensor endurance (sec)	72.30 ± 13.84	163.63 ± 22.74	0.91	-102.38	-87.70	3.68	10.17	<0.001

3   JPE= Joint position error, NSNP= non-specific neck pain, Cohen's d = effect size, CI= Confidence Interval, SEM= Standard error of
4   measurement, MDC= Minimal detectable change.

Table 3. Correlation between Beighton score and JPE's, neck flexor, and extensor endurance.

1   Table 3 Correlation between Beighton score and JPE's, neck flexor, and extensor endurance.

	Beighton score			
	NSNP group (n=33)		Asymptomatic group (n=35)	
Variables	r	p	r	p
JPE in Flexion (º)	0.43	0.013	0.08	0.630
JPE in extension (º)	0.25	0.156	0.153	0.380
JPE in left Rotation (º)	0.47	0.005	0.26	0.125
JPE in right rotation (º)	0.57	0.001	0.16	0.357
Neck flexor endurance (sec)	-0.40	0.020	-0.34	0.045
Neck extensor endurance (sec)	-0.41	0.020	-0.45	0.007

3   NSNP= non-specific neck pain, JPE= Joint position error, NDI= Neck disability index,

Generalised linear model (GLM) for the interactions of Beighton scores with JPEs and muscle endurance.

1   Table 4 Generalised linear model (GLM) for the interactions of Beighton scores with JPEs and muscle endurance.

Interaction effect with Explanatory variables	B	Standard Error	95% CI Lower, Upper	p-value
Group * JPE in flexion (°)	5.72	0.24	5.23, 6.21	<0.001
Group * JPE in extension (°)	5.64	0.32	4.99, 6.30	<0.001
Group * JPE in left rotation (°)	6.09	0.23	5.62, 6.56	<0.001
Group * JPE in right rotation (°)	5.81	0.33	5.13, 6.49	<0.001
Group * Cervical flexor endurance (sec)	9.92	1.29	7.33, 12.51	<0.001
Group * Cervical extensor endurance (sec)	8.45	0.78	6.89, 10.01	<0.001
Group * Gender	6.22	0.24	5.74, 6.70	<0.001

3   B = coefficient, 95% CI= 95% confidence interval, JPE= joint position error