Normal neurodynamic responses of the femoral slump test

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A B S T R A C T

Femoral slump test is a neurodynamic testing, which could be used to assess the mechanosensitivity of the femoral component of the nervous system. Although Trainor and Pinnington reported the diagnosis accuracy of the femoral slump test, the neurodynamic responses of the femoral slump test have never been studied. The purposes of this study were to evaluate whether maneuvers that changed the nerve tension altered the responses of the femoral slump test and if these responses were influenced by gender and leg dominance; and to identify the correlations between flexibility and measured hip extension angle. Thirty-two asymptomatic subjects (16 males, 16 females) were recruited. The femoral slump test was performed in trunk slump and neutral positions, and cervical extension was used as the structure differential technique. Hip extension angle and visual analog scale (VAS) of thigh pain was measured during the test. Our results showed the decrease of nerve tension significantly increased hip extension ROM $P < 0.001$ and lowered pain intensity $P < 0.001$. The hip extension ROM was similar between genders but smaller for the dominant leg, as compared to the non-dominant side $P < 0.05$; and the hip ROM did not correlate with any of the flexibility indices $P > 0.05$. These findings indicated that femoral slump test resulted in normal neurodynamic responses in individuals free of lower extremity problems, and these responses were independent of the influence of muscle flexibility or gender. Future research should emphasize the use of femoral slump test in patient groups such as low back and anterior knee pain.

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1. Introduction

Neurodynamic examination is designed to assess minor nerve disorders, which does not necessarily show conduction abnormalities but often accompany increased mechanosensitivity of the nerve. The test comprised of sequences of movements over multijoints to tension the nervous system (Louis, 1981; Coppieters et al., 2006; Gilbert et al., 2007a, b; Shacklock, 2007). In asymptomatic subjects, application of the neurodynamic test results in a reduction of range of motion (ROM) of the joint and individuals may have unpleasant feelings such as tingling, pricking or burning. These changes are called normal neurodynamic response (Butler, 2000). To gain information on whether neurodynamic responses participate in the mechanism of clinical symptoms, the structure differential maneuver could be added to glide the neural tissues and change the neural tension in question while minimizing the movement of the musculoskeletal tissues in the target region (Butler, 2000; Shacklock, 2005). In patients, the test is considered positive if the clinical painful symptoms can be reproduced and if the intensity of the symptoms can be influenced by changing the nerve tension (Butler, 2000; Shacklock, 2005).

Researchers have described the responses of neurodynamic tests in both healthy adults and in patients (Gajdosik et al., 1985; Johnson and Chiarello, 1997; Lew and Briggs, 1997; Yeung et al., 1997; Boland and Adams, 2000; Walsh et al., 2007; Herrington et al., 2008; Boyd et al., 2009; Petersen et al., 2009; McHugh et al., 2010; Méndez-Sánchez et al., 2010; Vanti et al., 2010; Lohkamp and Small, 2011). During the slump test, several authors showed that knee flexion angle increased with the flexion of the neck (Johnson and Chiarello, 1997; Yeung et al., 1997; Herrington et al., 2008; McHugh et al., 2010). The additional ankle dorsiflexion during the straight leg raising (SLR) test was found to decrease the range of hip flexion (Gajdosik et al., 1985; Boland and Adams, 2000; Herrington et al., 2008; Boyd et al., 2009; Lew and Briggs (1997) reported 39% pain increase when applying neck flexion during the slump test (Lew & Briggs, 1997). Walsh et al. (2007) found that 80% of subjects reporting a response had complete or partial relief of this response following cervical
extension. These data provided evidence that tensioning the nerve led to a decrease of movement range and an increase in pain. In symptomatic subjects, range of motion of the limb which showed positive slump or SLR test was significantly reduced when compared with the contralateral side or with the subjects who showed negative testing results (Walsh and Hall, 2009).

Despite of the agreement on the results of neurodynamic tests including the movement range and pain, speculations existed regarding whether these responses were mainly from tensioning nerves rather than the surrounding tissues such as skin, blood vessels, or fascia (Gajdosik et al., 1985; Vleeming et al., 1995; Lew and Briggs, 1997). Although in vitro studies showed that neurodynamic tests put the target nerve in tension (Coppieters et al., 2006; Gilbert et al., 2007a; Coppieters and Butler, 2008; Nee et al., 2010), the evidence is however insufficient to rule out the influence of surrounding tissues on the neurodynamic responses.

Femoral slump test is comprised of cervical flexion, trunk flexion, hip extension, and knee flexion, and is used for assessing the femoral component of the nervous system including the mid-lumbar nerve root and the femoral nerve. The test is indicated when the painful symptoms occur in the lumbar, groin, hip, thigh or knee regions (Butler, 2000; Shacklock, 2005; Trainer and Pinnington, 2011). In the study performed by Suri et al. (2011), the accuracy of physical examination including femoral slump test for diagnosing lumbar nerve root impingement was examined, and the results indicated that combinations of various tests increased likelihood ratios (LRs) for diagnosis of level-specific root impingement at the L4 level. In the recent publication by Trainer and Pinnington (2011), the upper/mid-lumbar nerve compression was assessed using the femoral slump test with the result of 100% sensitivity and 85% specificity in 16 participants of radicular leg pain. Nevertheless, these studies did not measure the range of joint motion or pain (neurodynamic responses) during the femoral slump test. In addition, whether or not the movement range (hip extension angle for the slump test), which represents the level of femoral nerve tension, would be influenced by flexibility of the adjacent soft tissues is unknown. Therefore, the purposes of the study are: (1) to describe the normal neurodynamic responses of the femoral slump test, including the hip extension angle and the pain experienced during the test in asymptomatic subjects; (2) to examine the correlation between hip extension angle and the flexibility measurements (flexibility of the hip flexors and knee extensors, and the general flexibility); and (3) to determine the effect of gender and limb dominance on the measurement of hip extension angle. Our hypotheses are: (1) increasing the nerve tension would result in decreased hip extension ROM and increased symptoms, and vice versa; (2) measurement of nerve tension (hip extension ROM) would show no correlation with any flexibility indices; and (3) there would be no significant effect of gender or limb dominance on the measurement of hip extension angle.

2. Methods

2.1. Participants

Thirty-two asymptomatic subjects (16 males, 16 females; 20.6 ± 1.7 years) were included (Table 1). All participants were naïve to the concept of neurodynamic testing. Participants had to be free of back, neck, hip, groin, and knee pain in the year prior to the start of the experiment, no spine or lower limb surgery before, and no limitation of movement range in all peripheral joints. Subjects with a history of neurogenic disorders or scoliosis were also excluded. Participants were given a full explanation of the experiment procedure, without disclosing information regarding the hypothesis of the study. All the subjects were informed of the purposes and procedures of this study and signed the consent form that was approved by the Institutional Review Board of National Yang Ming University, Taipei, Taiwan (serial number: 990038).

2.2. Testing procedure

Two examiners were involved in this study. The principle examiner first performed the physical examination for the lumbar spine and lower extremity including tests for problems of articulations, passive and active restraints of the joints, and special tests such as the forward bending test, slump test, Patrick’s test, and Clarke’s test to rule out the exclusion conditions such as scoliosis and other pathologies of the knee, hip and lumbar area (Magee, 2006). Subjects then warmed up using 10 min of stationary cycling and muscle stretching exercises. The stretching exercises consisted of 30-s static stretching of the back extensors, hip extensors and flexors, and knee extensors. The static stretching instead of dynamic lengthening exercise was chosen to better control the duration and intensity of the warm-up exercise. Afterward, flexibility of hip flexors and knee extensors and general flexibility were measured, followed by the femoral slump testing.

2.3. Flexibility measurement

Thomas’s test was used to assess the muscle length of hip flexors (hip extension range of motion, ROM) and Ely’s test was used to assess the muscle length of rectus femoris (knee flexion ROM) (Magee, 2006). Both tests were performed in the supine position. The subject flexed both hips by bringing the knee toward the chest just enough to flatten the low back and pelvis against the table. The examiner then extended the testing hip by passively lowering the thigh toward the examining table. The flexibility of the hip flexor was represented by the range of motion of the hip joint (Thomas test), which was measured using a universal goniometer with the fulcrum of the goniometer over the lateral aspect of the femur greater trochanter (Norkin, 2003). The increase in hip extension ROM indicated a higher level of flexibility of the hip flexors. After the measurement of the hip ROM, the examiner flexed the testing knee when the resistance was felt, and the ROM of the knee joint was measured to represent the flexibility of the rectus femoris (Ely’s test) (Magee, 2006). For the knee ROM measurement, the fulcrum of the goniometer was centered over the lateral epicondyle of the femur, and the proximal and distal arm was aligned with the greater trochanter and with the lateral malleolus respectively (Norkin, 2003). A larger knee flexion ROM indicated a higher level of flexibility of the rectus femoris. The intra-tester reliability of the ROM measurement for the Thomas test and Ely’s test were conducted in our pilot study. The intraclass correlation coefficient was excellent for both Thomas’s test (ICC(3,2) = 0.964; SEM = 13°) and Ely’s test (ICC(3,2) = 0.981; SEM = 13°).

Brighton scale was introduced to evaluate the general flexibility (Brighton et al., 1973). The maneuvers used in this scoring system included: (1) passive dorsiflexion of the little fingers beyond 90°
(one point for each hand, total 2 points); (2) passive apposition of the thumbs to the flexor aspect of the forearm (one point for each thumb, total 2 points); (3) hyperextension of the elbows beyond $10^\circ$ (one point for each elbow, total 2 points); (4) hyperextension of the knee beyond $10^\circ$ (one point for each knee, total 2 points); (5) forward flexion of the trunk with knees fully extended so that the palms of the hands are flat on the floor (1 point). The score was calculated by summatng the five sub-scores. The range of scoring was between 0 and 9 with the high score denoting greater joint laxity.

2.4. Femoral slump test

The femoral slump test was performed based on the recommendations of Butler (2000) and Shacklock (2005). The subject was positioned in side-lying with the testing side (right side) on the top, the trunk and neck in the slump position, and the non-testing hip flexed fully. A pillow was placed under the subject’s head to control cervical lateral flexion. We used one strap to maintain the non-testing leg in full hip flexion and the trunk in slump position, a second strap to stabilize the pelvis, and the third strap to keep the testing knee in full flexion. The testing leg was suspended using a Terapi Master suspension system, to allow movement occurring only in the horizontal level and to minimize unwanted hip rotations (adduction/abduction and internal/external rotations) during the testing (Fig. 1). Neck movement (flexion to extension) was used as the structure differential maneuver in order to change the nerve tension during the test. The testing procedure was executed by the principle examiner, and the measurement of neurodynamic responses including the hip extension angle and the level of pain/discomfort was performed by the second examiner. Two trunk positions, slump and neutral positions, were used to provide different level of nerve tension. The sequences of testing are described as following: (1) Subject’s hip joint was pushed into extension until the onset of pain/discomfort and the position was maintained for 3 s. The hip extension angle and the intensity of the discomfort were recorded. (2) The subject performed cervical extension while maintaining the rest of the body unmoved and the change of pain/discomfort was recorded. (3) With the neck kept in the extended position, the principle examiner brought the subject’s thigh back to the starting position, and then pushed the hip joint into extension until the onset of pain/discomfort and maintained at this position for 3 s. The hip extension angle and level of pain/discomfort were recorded. The measurement of neurodynamic responses was performed while maintaining the extended position of the neck. The sequences of testing are described as following: (1) Subject’s hip joint was pushed into extension until the onset of pain/discomfort and the position was maintained for 3 s. The hip extension angle and the intensity of the discomfort were recorded. (2) The subject performed cervical extension while maintaining the rest of the body unmoved and the change of pain/discomfort was recorded. (3) With the neck kept in the extended position, the principle examiner brought the subject’s thigh back to the starting position, and then pushed the hip joint into extension until the onset of pain/discomfort and maintained at this position for 3 s. The hip extension angle and level of pain/discomfort were recorded. (4) Neck movement (flexion to extension) was used as the structure differential maneuver in order to change the nerve tension during the test. The testing procedure was executed by the principle examiner, and the measurement of neurodynamic responses including the hip extension angle and the level of pain/discomfort was performed by the second examiner. Two trunk positions, slump and neutral positions, were used to provide different level of nerve tension. The sequences of testing are described as following: (1) Subject’s hip joint was pushed into extension until the onset of pain/discomfort and the position was maintained for 3 s. The hip extension angle and the intensity of the discomfort were recorded. (2) The subject performed cervical extension while maintaining the rest of the body unmoved and the change of pain/discomfort was recorded. (3) With the neck kept in the extended position, the principle examiner brought the subject’s thigh back to the starting position, and then pushed the hip joint into extension until the onset of pain/discomfort and maintained at this position for 3 s. The hip extension angle and level of pain/discomfort were recorded.
discomfort was recorded (Fig. 2). According to our pilot study, the measurement of hip extension angle was more stable after repeating 5 trials in trunk slump position, and after 3 trials in trunk neutral position. The examination was therefore first performed in the slump position for 5 times as the warm-up, and recorded the data of the next 3 trials; and then the test was carried out in the neutral position for 3 times as the warm-up and recorded the data of the next 3 trials. For a subset of 16 subjects, the neurodynamic responses of the femoral slump test were assessed for both the right and left sides to determine the effect of limb dominance on the hip extension angle measurement.

The hip extension angle was measured using a universal goniometer. The fulcrum of the goniometer was over the lateral aspect of the hip joint, using the greater trochanter of the femur for reference, and the proximal arm was aligned with the lateral midline of the pelvis (an imaginary line between the femur greater trochanter and the iliac crest) and the distal arm with the lateral epicondyde (Norkin, 2003). The increase in hip extension indicated a lower level of femoral nerve tension. The intra-tester reliability of the hip angle measurement was excellent (ICCs(3,2) = 0.94–0.96; SEM = 1.1–1.6°), established in our pilot study. The intensity of the pain/discomfort was measured using the visual analog scale (VAS). The subject was given a hand-made scale to indicate the pain intensity (0 = no pain; 100 = worse pain). The change of pain/discomfort with the application of the structure differential maneuver (neck extension) was also categorized as increase, decrease, or unchanged for each trial and for each subject. If an individual reported pain decrease in 2 or more trials out of three tests, the subject was in the group of pain decrease. The same principle applied to the pain increase and unchanged groups.

2.5. Statistical analysis

The repeated measures analysis of variance (ANOVA) was used to compare the differences of hip extension angle between 4 different conditions: trunk slump neck extended TSNE, trunk slump neck flexed TSNF, trunk neutral neck extended TNNE, trunk neutral neck flexed TNNF, between males and females, and between dominant (D) and non-dominant (ND) limbs. Paired t-test was used to compare the VAS score measured in two neck positions. Pearson’s correlation coefficient was used to assess the relationship between muscle flexibility and the hip extension angle, and Spearman’s correlation coefficient was used to examine the relationship between Beighton scale and hip extension angle. The significant level was set at 0.05.

3. Results

3.1. Hip extension angle in different neck and trunk positions

Hip extension angle varied significantly with different combinations of trunk and neck positions, and the application of the structure differential technique (neck extension movement) resulted in an increase of hip extension angle in both trunk slump and neutral positions (P < 0.001, n = 32) (Fig. 3). Male and female subjects exhibited similar range of hip extension (P > 0.05, n = 32), but the dominant leg had significantly smaller hip extension angle as compared to the non-dominant leg in all testing conditions (D-TSNE = −15.8° ± 6.9°, ND-TSNE = −11.9° ± 7.1°, P < 0.001; D-TSNF = −14.0° ± 6.4°, ND-TSNE = −9.8° ± 6.8°, P < 0.001; D-TNNE = −11.9° ± 8.6°, ND-TNNE = −7.1° ± 6.8°, P = 0.005; D-TNNE = −10.1° ± 8.3°, ND-TNNE = −4.7° ± 7.1°, P = 0.005, n = 16).

3.2. Level of pain/discomfort

Most subjects reported tensioning discomfort over the anterior thigh during the femoral slump test, and the level of pain reduced when they performed neck extension in both trunk slump (84% of subjects and 76% trials) and trunk neutral position (71% of subjects and 69% trials) (Fig. 4). The VAS pain score decreased with neck extension in both trunk slump and neutral positions (P < 0.001, n = 32) (Fig. 5) (Table 1).

3.3. Correlation between flexibility and hip extension angle

Muscle flexibility of the hip flexors (D: −15.9° ± 6.5°; ND: −15.5° ± 5.0°) and rectus femoris (D: 94.6° ± 13.5°; ND: 95.9° ± 14.7°) were similar between two limbs (P > 0.05, n = 16). The measurement of nerve tension (the hip extension angle) showed no significant correlation with general flexibility (r = −0.07 to −0.117, P > 0.05, n = 32), or with the flexibility of hip flexors (r = −0.066 to −0.167, P > 0.05, n = 32) and rectus femoris (r = −0.115 to −0.175, P > 0.05, n = 32) (Table 2).

4. Discussion

When the neural tension was changed, the produced pain, the range of joint motion, and the resistance to movement changed simultaneously. These changes were called neurodynamic responses. To the best of our knowledge, this is the first study to investigate the neurodynamic responses of femoral slump test in asymptomatic subjects. The results of our study showed that the measurement of hip extension angle, representing the level of femoral nerve tension, varied with different combinations of trunk and neck positions, and the application of neck extension movement (the structure differential technique) increased the angle of hip extension (2.1°–2.5°) and decreased pain. Although this is the first study reporting the responses of the femoral slump test, similar responses in the measurement of joint angle and pain have been observed for other neurodynamic tests. The increase in knee flexion angle with the addition of neck flexion was reported for the slump test, and a decrease in hip flexion ROM with the addition of ankle dorsiflexion was shown in studies of SLR test (Maitland, 1985; Gajdosik et al., 1985; Johnson and Chiarello, 1997; Lew and Briggs, 1997; Yeung et al., 1997; Boland and Adams, 2000; Herrington et al., 2008; Boyd et al., 2009; McHugh et al., 2010). Changes in the level of pain were observed in asymptomatic subjects that the application of neck flexion to tension the nerve resulted in higher level of pain during the slump test (Lew and Briggs, 1997; Walsh et al., 2007).
According to the theory of neurodynamics, trunk and neck movement change the nerve tension. The flexion of the spine increases the nerve tension whereas extension of the spine decreases it. The application of neurodynamic testing which alters the nerve tension would result in changes of measured joint angle and pain (Shacklock, 2007). This hypothesis of neural tissue movement was examined both in vivo and in vitro (Babin and Capesius, 1976; Shacklock, 2007; Coppieters and Butler, 2008; Nee et al., 2010). Using radiography, Babin and Capesius (1976) observed that the posterior aspect of the spinal canal increased in length by 23%–30% during spinal flexion. The photographs of neural structures of the cadavers showed that cervical flexion produced a separation of the cut neural tissues whereas the neutral position enabled the tissue to approximate (Breig, 1978; Shacklock, 2007).

Fig. 4. Percentage of the pain level change after the application of neck extension during femoral slump test. *Subjects received three trials of testing at each testing position. If a subject reported a decrease of pain in 2 or more trials out of three, then the subject was in the category of pain decrease. Same principle applied to pain unchanged and pain increase category.

Table 2
Correlations between flexibility measurement and hip extension angle.

<table>
<thead>
<tr>
<th>Testing condition</th>
<th>Flexibility measurement</th>
<th>Thomas test*</th>
<th>Ely’s test**</th>
<th>Beighton scale***</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSNF</td>
<td>r = −0.12</td>
<td>r = −0.18</td>
<td>r = −0.12</td>
<td></td>
</tr>
<tr>
<td>TSNE</td>
<td>r = −0.17</td>
<td>r = −0.16</td>
<td>r = −0.04</td>
<td></td>
</tr>
<tr>
<td>TNNF</td>
<td>r = 0.07</td>
<td>r = −0.17</td>
<td>r = −0.07</td>
<td></td>
</tr>
<tr>
<td>TNNE</td>
<td>r = −0.06</td>
<td>r = −0.12</td>
<td>r = −0.08</td>
<td></td>
</tr>
</tbody>
</table>

TSNF = Trunk slump, neck flexed; TSNE = Trunk slump, neck extended; TNNF = Trunk neutral, neck flexed; TNNE = Trunk neutral, neck extended.

* Pearson correlation coefficient.

** Spearman correlation coefficient.

*** No significant comparison were found, \( P > 0.05 \).
Even with the evidence showing that neural tension alters with trunk movement, it remains a challenge for neurodynamic research to isolate tension of the nerve tissue, or to prove that the neurodynamic responses were from tensioning of the nerve structures. To minimize the influence from the surrounding soft tissues, we strap-stabilized the subject's trunk and thigh to prevent any unwanted body movement. When the structure differential maneuver (neck extension movement) was performed, the trunk, pelvis and hip, and knee joint were un movimiento and therefore the influence from adjacent soft tissues on the decrease of thigh discomfort and the increase of hip joint angle should be minimal.

To further prove that the measurement of hip extension during the femoral slump test was not influenced by flexibility of soft tissues, we recorded the flexibility of the hip flexors and knee extensors and the general flexibility, and found none of these flexibility indices correlating with the measurement of hip extension angle. This finding gave additional evidence that the responses in femoral slump test were independent of soft tissue flexibility of the lower extremity. We believe this is the first study showing the relationship between the muscle flexibility and the measurements of joint angle of the neurodynamic test.

Limb dominance has been suggested to influence human neuromuscular performance (Herrington et al., 2008). In this study, the hip extension angle was smaller for the dominant leg as compared to the non-dominant leg. Herrington et al. (2008) however reported the similar “change” of knee flexion angle with the application of structure differential method between dominant and non-dominant legs during the slump test and SLR test. Because our measurement was the range of motion at the first onset of pain during the femoral slump test rather than the change of ROM, used by Herrington et al., we re-calculated the change of hip joint angle between neck flexion and extension positions, and found that the change of hip extension angle was similar between dominant and non-dominant leg (P > 0.05, n = 16). These data indicated that limb dominance might influence the measurement of nerve tension, but the change of nerve tension following the application of structure differential maneuver was independent of the influence of side dominance. We suggested that future studies should take this into consideration if bilateral comparison is performed or when limb dominance is a concern of the investigation.

In the current study, pain and the movement range were examined during the femoral slump test, but not the change in resistance to movement. Quantifying the resistance to movement is not easy. There was only one study in the literature trying to measure the movement resistance (Laessoe and Voigt, 2004). Laessoe and Voigt (2004) assessed the resistance to movement in the slump and neutral position of the trunk during the slump test, and found the tension resistance changed with trunk position. How the resistance to movement might impact the testing results of the femoral slump test, and if it would be a variable worth quantifying required further study to clarify.

In this investigation, we recruited only asymptomatic young adults. Whether or not similar neurodynamic responses could be reproduced in different age groups or in individuals with clinical symptoms should be researched in the future. In addition, our subjects were composed of mainly Asian population, who were slightly shorter and lighter compared to the westerners. Generalization of our findings should take this consideration into account. Although we identified no correlation between measurement of nerve tension and lower extremity muscle flexibility, the generalization of this result should be cautious because our study population was of normal flexibility in general. For individuals of older age who might experience some soft tissue tightness, the influence of soft tissue flexibility on the neurodynamic responses should be examined further.

5. Conclusion

This is the first study describing neurodynamic responses of the femoral slump test. We found that maneuvers that changed the nerve tension altered the neurodynamic responses of the femoral slump test. Although these neurodynamic responses of the femoral slump test were not affected by the flexibility or gender, a significant effect of leg dominance was identified. Further studies should focus on the responses of femoral slump test in symptomatic subjects and the validity of diagnosing problems related to femoral component of nervous system.

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