Research Paper

The Relationship Between Hip and Knee Flexibility and Post-coronary Angiography Pain

Fatimah Khalifeh[1], Noureddin Karimi[1*], Parastoo Baraghoosh[1], Mehrdad Naghikhani[1]

1. Department of Physiotherapy, Faculty of Rehabilitation Sciences, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.

Use your device to scan and read the article online

Citation Khalifeh F, Karimi N, Baraghoosh P, Naghikhani M. The Relationship Between Hip and Knee Flexibility and Post-coronary Angiography Pain. Physical Treatments. 2023; 13(3):187-194. http://dx.doi.org/10.32598/ptj.13.3.560.2

doi: http://dx.doi.org/10.32598/ptj.13.3.560.2

Article info:
Received: 21 May 2023
Accepted: 15 Jun 2023
Available Online: 01 Jul 2023

Keywords:
Coronary angiography, Femoral angiography, Pain, Muscle flexibility

ABSTRACT

Purpose: Coronary angiography can cause post-procedural pain, and limited flexibility in the hips and knees may contribute to this discomfort. This study was designed to assess the flexibility of the hip and knee and its relationship with pain after femoral angiography.

Methods: This cross-sectional study was conducted on 42 participants (27 men and 15 women, aged 30-85 years) after non-emergency angiography at Dr. Shariati Hospital. Demographic data, employment status, and angiography history were collected through an individual data questionnaire. Muscle flexibility was assessed using a goniometer and tape measure, and visual analog scale (VAS) was applied to evaluate the score of pain. A Spearman correlation coefficient and Kruskal-Wallis tests were used to examine the relationship between variables and pain.

Results: The analysis revealed no significant difference in mean pain scores between men and women (P=0.662), employment status (P=0.265), or history of angiography (P=0.262). We observed positive correlations between pain and the modified Thomas test for hip extension, active knee extension test, and forward bending test (rho=0.745, rho=0.594, and rho=0.433; P=0.00, P=0.00, and P=0.04, respectively). Conversely, the modified Thomas test for knee flexion showed a negative correlation with pain (rho=-0.591, P=0.00). No significant differences were found between the sit-and-reach test and pain (rho=0.337, P=0.29). Age demonstrated a positive correlation with pain (rho=0.312, P=0.04). However, weight did not show a significant correlation with pain (rho=-0.074, P=0.64).

Conclusion: A relationship was observed between some flexibility tests and pain. Reduced hip and knee flexibility correlated with higher pain levels after femoral angiography. While age showed a positive relationship with pain, weight did not show any relationship with pain. These results emphasize the importance of considering flexibility in managing pain after femoral angiography.

*** Corresponding Author:**
Noureddin Karimi, PhD.
Address: *Department of Physiotherapy, Faculty of Rehabilitation Sciences, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran.*
Phone: *+98 (21) 22180039*
E-mail: *karimi@uswr.ac.ir*

Highlights

• Femoral angiography is the most commonly used technique for coronary angiography due to the accessibility of the femoral artery.

• Muscle flexibility is crucial for optimal physical performance and preventing injuries.

• Patients with decreased muscle flexibility can experience pain and discomfort during the mandatory rest after femoral angiography.

Plain Language Summary

Coronary angiography is a medical procedure used to examine the blood vessels that supply the heart. After femoral angiography, which involves inserting a catheter into the groin area to access the blood vessels, some patients may experience pain or discomfort. Muscle flexibility refers to the ability of muscles to stretch and move without discomfort. Patients with lower muscle flexibility may be more prone to pain after femoral angiography. These findings suggest that muscle flexibility may play a role in pain after femoral angiography. By taking measurements and analyzing them, we found that reduced flexibility in the hip and knee joints is associated with higher levels of pain. While age is related to pain, weight is not. This study provides crucial insights into considering a patient's flexibility when managing pain after femoral angiography.

1. Introduction

Coronary angiography is a diagnostic procedure to evaluate heart function and cardiac diseases. It involves inserting a catheter into an artery in the groin or arm [1]. While the procedure itself is relatively safe, some patients may experience pain and discomfort afterward. Following this procedure through the femoral artery in the thigh area, patients are required to lie flat on their back with their legs straight for approximately 2–8 hours [2]. Pain and muscle contraction following this mandatory rest period are common problems, in which patients experience some degree of pain after the procedure [3].

Several studies have investigated the effects of various interventions on post-coronary angiography pain. One study found that early mobility within 1.5 to 4 hours after the procedure has a positive effect and reduces back pain [4]. Another study found that placing patients at a 45-degree angle is the best angle to reduce patients' pain after the procedure [5]. In a study conducted by Valiee et al, researchers investigated the effect of changing the duration of sandbag placement on the occurrence of acute complications of femoral angiography during catheter use. They found that if the sandbag was removed three hours after the operation, it resulted in lower pain scores and greater comfort [6]. Another study conducted by Bayindir investigated the effectiveness of placing an ice pack on the femoral region in individuals undergoing coronary intervention for vascular complications and back pain. The results showed a decrease in pain severity in the femoral region and back pain [7]. Furthermore, Abdollahi et al investigated the effect of early mobility and position changes on the complications of coronary angiography. The study showed that the intervention group, who had early mobility and position changes earlier than 6 hours, reported less urinary retention and less average pain [8]. However, another study has found that changing the patient's position did not affect the severity of back pain in patients with back pain [9]. Studies have shown that early mobilization of patients after angiography results in fewer pain symptoms, fewer postoperative complications, and higher satisfaction [10-14]. Therefore, many researchers suggest changing the position of patients in bed during the first few hours after angiography to have a positive effect on the patient's pain and comfort during the mandatory rest period after femoral angiography.

Various factors can contribute to post-coronary angiography pain. Flexibility is an essential component of musculoskeletal health and is crucial for maintaining proper alignment and reducing strain on the joints during movement [15]. Lack of flexibility in the hip and knee joints has been linked to an increased risk of pain and injury [16, 17]. For elderly patients in particular, reduced flexibility in the hip and knee joints can make it difficult to lie flat on their back for an extended period, especially

in the pelvic and knee areas [18]. In some cases, patients may need to move due to intolerance to the position, leading to bleeding from the angiography site and other complications [2].

It is essential to find an appropriate solution to reduce pain and complications during the mandatory rest period after angiography. This may include developing new pain management strategies or providing additional support to patients to reduce the shear and compressive forces on their joints during the mandatory rest period. By addressing these issues, patients can have a more comfortable and successful recovery after undergoing femoral angiography. Therefore, it is essential to conduct a study to examine the flexibility of the hip and knee and its relationship with the severity of patients' pain during mandatory rest after femoral angiography.

2. Materials and Methods

The present cross-sectional study was performed on patients referred to Dr. Shariati Hospital's angiography center for non-emergency angiography during 2017-2018. The sample size was determined based on the results of a pilot study. With a 90% confidence level, 80% power, and a 10% dropout rate, the required number of participants was calculated to be 42 patients. The participants were selected by convenience sampling method. A total of 27 men and 15 women aged 30-85 years were included in the study based on inclusion and exclusion criteria.

The following inclusion and exclusion criteria were considered, patients with coronary artery involvement who were candidates for angiography via the femoral artery, no history of fracture or surgery, or structural deformities in the lumbar spine, thighs, and pelvis, and no transfer to the cardiac intensive care unit after angiography. In addition, people who did not want to cooperate or could not implement the study program were excluded from the research process.

Tools

Demographic information questionnaire: This questionnaire contained information, such as age, gender, weight, employment status, and history of angiography based on individual statements.

Visual analog scale (VAS): Visual analog scale (VAS) was used to measure the intensity of pain at the sixth hour. Individuals were asked to indicate the number on a 10 cm line representing their pain intensity, where zero represented no pain and 10 represented the worst possible pain [19]. The flexibility of the hip and knee joints was measured using the modified Thomas test, sit-and-reach test, active knee extension test, and forward bending test which were conducted in the hospital's angiography department before surgery. The tests were performed three times, and the average score was recorded.

Goniometer: A standard goniometer was used to measure the range of motion of hip and knee joints. Each measurement was repeated three times to allow evaluation of intratester reliability. The goniometric reliability to measure the range of motion in limb joints is considered good to excellent [20]. The tested limb, which was the lower limb used for angiography, was assessed for each participant.

Measurement

We used the modified Thomas test to evaluate rectus femoris muscle flexibility. The subject was positioned at the end of the examination table. The subject was then asked to lie down while bringing both knees to their chest. Then, they performed a posterior pelvic tilt. The examiner palpated the lumbar spine to confirm that it remained in contact with the Table. The subject held the opposite limb in maximal flexion with the arms, while the tested limb was lowered towards the floor [21]. Two angles were measured for the tested leg. The thigh position was also monitored to prevent abduction. When the final test position was achieved, the examiner palpated bony landmarks for goniometer alignment. The stationary arm was aligned with the lateral midline of the trunk; the axis was the greater trochanter of the femur, and the moving arm was aligned with the lateral epicondyle of the femur for the hip joint. The stationary arm was aligned with the greater trochanter of the femur, the axis was the head of the fibula, and the moving arm was aligned with the lateral malleolus for the knee joint [22].

To measure the extensibility of the hamstrings, we used the sit-and-reach test [23]. To perform the test, the subject sat at the end of the bed with their straight knees. The examiner ensured that the participant's knee remained extended. The patient slowly reached forward with extended arms, placing one hand on top of the other, facing palms down, as far as possible, and holding this position for approximately 2 s. The distance between the fingertip of the middle finger and the big toe was measured using a meter. If the middle finger reaches the big toe, a zero point is set [24].

The active knee extension test was used to assess hamstring muscle length and the range of active knee extension in the position of hip flexion. The subject was positioned on the examination table in a supine position, and the opposite lower limb was stabilized on the support surface. The tested limb was elevated so that the hip was at 90 degrees of flexion and the knees were extended to reach a position perpendicular to the ground. A lag of 20 degrees from full extension was considered normal; anything less than 20 degrees was considered hamstring tightness. To measure the range, a goniometer is placed at the knee with the axis at the lateral epicondyle, the stationary arm parallel to the thigh pointing to the greater trochanter, and the moving arm parallel to the leg pointing to the lateral malleolus [25].

To assess the total mobility of the lumbopelvic region, we used the forward bending test. The subject was asked to bend forward and attempt to reach for the floor with their fingertips by keeping their elbow joint straight. The examiner then measured the distance between the subject's middle finger and the floor using a standard measuring tape. If the patient achieves full flexibility and their hand reaches the ground, it scores zero [26].

Statistical analysis

IBM SPSS software, version 23 was used for statistical tests. Central inclination and dispersion indices were used to describe the quantitative data. To examine the correlation coefficient between variables, Spearman's correlation test was used. The Shapiro-Wilk statistical test was also conducted to evaluate the distribution of numerical variables in terms of their conformity with the normal theoretical distribution.

3. Results

The age and weight of 42 participants were 55.3±12 and 76.6±11.1, respectively. Their age ranged from 30 years to 85 years, and their weight ranged from 45 kg to 100 kg (Table 1).

Table 2 presents information on the distribution of participants based on their gender, employment status, and history of angiography. Among the 42 patients, 27 were men and 15 were women. The employment status of the patients was categorized as 10 employed, 18 self-employed, 10 homemakers, and 4 retired; 12 patients had a history of angiography, while 30 patients did not.

Table 1. Demographic characteristics of the participants (n=42)

Variables	Mean±SD	Minimum	Maximum
Age (y)	55.3±12	30	85
Weight (kg)	76.6±11.1	45	100

PHYSICAL TREATMENTS

Table 2. Frequency of qualitative variables

Variables	Patient	
	Type	No. (%)
Gender	Male	27(63.4)
	Female	15(35.7)
Employment status	Employed	10(23.8)
	Self-employed	18(42.9)
	Homemaker	10(23.8)
	Retired	4(9.5)
History of angiography	P	12(28.6)
	N	30(71.4)

PHYSICAL TREATMENTS

Table 3. Assessment of normality in the distributions of measurement tests and pain score

Variables		Mean±SD	Minimum	Maximum	Shapiro-Wilk P
Modified Thomas test	Hip	22.6±8.9	7.3	43.3	0.420
	Knee	57.3±12.2	30	82	0.570
Sit-and-reach test		15.6±9	0	39	0.049 *
Active knee extension test		168.5±6.05	155	180	0.682
Forward bending test		11.9±8.7	0	30	0.028 *
Pain score		4.3±2.2	0	8	0.039 *

*P=0.05.

PHYSICAL TREATMENTS

Based on the results of the Shapiro-Wilk test, the variables of the modified Thomas test (hip extension and knee flexion) and the active knee extension test were normally distributed. In contrast, the variables of the sit-and-reach test, forward-bending test, and pain did not follow a normal distribution. The modified Thomas test for hip extension had a mean score of 22.6±8.9, with scores ranging from 7.3 to 43.3. The modified Thomas test for knee flexion had a mean score of 57.3±12.2, with scores ranging from 30 to 82. The sit-and-reach test had a mean score of 15.6±9, with scores ranging from 0 to 39. The active knee extension test had a mean score of 168.5±6.05, with scores ranging from 155 to 180. The forward bending test had a mean score of 11.9±8.7, with scores ranging from 0 to 30. Finally, the pain variable had a mean score of 4.3±2.2, with scores ranging from 0 to 8. (Table 3)

The results of Table 4 compared gender, employment status, and history of angiography with the mean of pain intensity using the Kruskal-Wallis statistical test. The mean pain scores for men and women were 4.26±2.26 and 4.60±2.35, respectively, with no statistically significant difference between the two genders (P=0.662). Similarly, no significant relationships were observed between pain scores and employment status (P=0.265). The analysis also revealed no statistically significant difference in pain scores between participants with a history of angiography and those without angiography (P=0.262).

Based on the results presented in Table 5, a significant relationship seems to exist between variables and pain. Age showed a weak positive correlation with pain, rho=0.312 (P=0.04). However, the weight did not show any significant correlations with pain, rho=-0.074 (P=0.64). The modified Thomas test for hip extension and active knee

Table 4. Factors influencing participants pain scores

Variables	Type	No.	Mean±SD	P
		Patients	Pain Score	
Gender	Male	27	4.26±2.26	0.662
	Female	15	4.60±2.35	
Employment status	Employed	10	4.20±2.2	0.265
	Self-employed	10	4.20±2.39	
	Homemaker	18	4.11±2.32	
	Retired	4	6.50±1.29	
History of angiography	P	12	4.33±2.01	0.262
	N	30	4.40±2.40	

PHYSICAL TREATMENTS

Table 5. Correlation between age, weight, and flexibility tests with pain

Variables		Spearman Correlation Coefficient (rho)	P
Age (y)		0.312	0.04 *
Weight (kg)		-0.074	0.64
Modified Thomas test	Hip	0.745	0.00 *
	Knee	-0.591	0.00 *
Sit-and-reach test		0.337	0.29
Active knee extension Test		0.594	0.00 *
Forward bending test		0.433	0.04 *

*P=0.05.

PHYSICAL TREATMENTS

extension test exhibited strong positive correlations with pain, rho=0.745 and 0.594, respectively (P=0.00). On the other hand, the modified Thomas test for knee flexion showed a strong negative correlation with pain, rho=-0.591 (P=0.00). The sit-and-reach test did not show any significant correlation with pain (rho=0.337, P=0.29). Finally, the forward bending test showed a moderate positive correlation with pain, rho=0.433 (P=0.04).

4. Discussion

This study found that gender does not play a significant role in determining pain after femoral angiography. Similarly, the results showed no significant relationship between pain scores and employment status. This implies that being employed or unemployed does not have a notable influence on pain after femoral angiography, according to the data analyzed. Furthermore, the study explored the relationship between a history of angiography and pain scores. The results indicated no statistically significant difference in pain scores between participants with a history of angiography and those without angiography. This suggests that undergoing angiography does not appear to be associated with significant differences in pain after femoral angiography among the participants.

In our study, the results revealed significant correlations between certain flexibility tests and pain after femoral angiography. Age demonstrated a weak positive correlation with pain. This indicates that older individuals may experience more pain after femoral angiography compared to younger individuals. The weight did not exhibit any significant relationship with pain after femoral angiography in this study.

The modified Thomas test for hip extension and the active knee extension test showed strong positive correlations with pain after femoral angiography. This suggests that individuals with less flexibility in these tests experience higher levels of pain after femoral angiography. Conversely, the modified Thomas test for knee flexion displayed a strong negative correlation with pain after femoral angiography. This implies that individuals with more flexibility in this test tend to have lower pain levels. The performance in the sit-and-reach test did not appear to be a reliable indicator of pain after femoral angiography, as evidenced by the weak positive correlation with pain. Additionally, the forward bending test showed a moderate positive correlation with pain. This suggests that individuals who experience greater pain may have more limited flexibility when performing forward bending movements. Although the correlation coefficient was moderate, the significance of the relationship supports the inclusion of the forward bending test as a potential indicator of pain levels.

Following femoral angiography, patients are required to rest for 2-8 hours, during which a sandbag is placed with pressure on the area, causing increased pressure on the hip and knee. Prolonged lying requires a normal range of hip and knee joints. Pain is a crucial factor that can make it difficult for patients to tolerate the position and keep their legs straight. The results suggest that reduced flexibility of the knee and hip joints can increase the forces on joints and muscles, leading to joint and muscle pain in the hip and knee areas during mandatory rest after femoral angiography.

5. Conclusion

While certain tests, such as the modified Thomas test for hip extension and the active knee extension test, and the forward bending test demonstrate a significant correlation with pain, the sit-and-reach test does not appear to have a significant impact on pain levels. Furthermore, the modest influence of age on pain levels highlights the importance of considering demographic factors in pain management. These results contribute to our understanding of pain perception and can inform future research and clinical practices in the field of pain management.

Limitations and future research

One limitation of this study was its sample size. The study had a relatively small sample size of 42 participants, which may limit the generalizability of the findings. Additionally, this study used a cross-sectional design. Longitudinal studies that follow patients over time provide more comprehensive information about the relationship between flexibility and pain after femoral angiography. The study only focused on the relationship between hip and knee flexibility and pain after femoral angiography. Other potentially relevant factors, such as psychological variables (e.g. anxiety, depression), were not assessed. These variables should be considered in future research. Finally, future research should investigate the effects of interventions, such as physical therapy or exercise programs on reducing pain after femoral angiography.

Ethical Considerations

Compliance with ethical guidelines

A local Ethics Committee of the University of Social Welfare and Rehabilitation Sciences approved this study. (Code: IR.USWR.REC.1396.114). Participants were informed of the objective and process of the study and filled out written informed consent forms before inclusion.

Funding

This research was supported by the research project of the University of Social Welfare and Rehabilitation Sciences.

Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank to the patients who participated in the research, for their valuable contributions. Thanks to the Physiotherapy Department of the University of Social Welfare and Rehabilitation Sciences and thank to Dr. Shariati Hospital's angiography center, in Tehran, Iran.

References

[1] DiSabatino A, Veasey J. Innovations in PAD therapy. Nursing Critical Care. 2006; 1(5):18-23. [DOI:10.1097/01244666-200609000-00005]

[2] Koutoukidis G, Stainton K. Tabbner's nursing care: Theory and practice. Amesterdam: Elsevier Health Sciences; 2020. [Link]

[3] Moorhead S, Swanson E, Johnson J, Maas ML. Nursing outcomes classification (NOC)-e-book: Measurement of health outcomes. Amesterdam: Elsevier Health Sciences; 2018. [Link]

[4] Burn KL, Marshall B, Scrymgeour G. Early mobilization after femoral approach diagnostic coronary angiography to reduce back pain. Journal of Radiology Nursing. 2015; 34(3):162-9. [DOI:10.1016/j.jradnu.2015.04.008]

[5] Younessi Heravi MA, Yaghubi M, Joharinia S. Effect of change in patient's bed angles on pain after coronary angiography according to vital signals. Journal of Research in Medical Sciences. 2015; 20(10):937-43. [DOI:10.4103/1735-1995.172767] [PMID] [PMCID]

[6] Valiee S, Fathi M, Hadizade N, Roshani D, Mahmoodi P. Evaluation of feasibility and safety of changing body position after transfemoral angiography: A randomized clinical trial. Journal of Vascular Nursing . 2016; 34(3):106-15. [DOI:10.1016/j.jvn.2016.05.001] [PMID]

[7] Bayındır SK, Çürük GN, Oguzhan A. Effect of ice bag application to femoral region on pain in patients undergoing percutaneous coronary intervention. Pain Research and Management. 2017; 2017:6594782. [DOI:10.1155/2017/6594782] [PMID] [PMCID]

[8] Abdollahi AA, Mehranfard S, Behnampour N, Kordnejad AM. Effect of positioning and early ambulation on coronary angiography complications: A randomized clinical trial. Journal of Caring Sciences. 2015; 4(2):125-34. [DOI:10.15171/jcs.2015.013] [PMID] [PMCID]

[9] Olson NC. Comparison of head elevation protocols following femoral artery sheath removal after coronary angiography. Critical Care Nurse. 2016; 36(3):20-34. [DOI:10.4037/ccn2016560] [PMID]

[10] Chair SY, Taylor-Piliae RE, Lam G, Chan S. Effect of positioning on back pain after coronary angiography. Journal of Advanced Nursing. 2003; 42(5):470-8. [DOI:10.1046/j.1365-2648.2003.02646.x] [PMID]

[11] Benson G. Changing patients' position in bed after non-emergency coronary angiography reduced back pain. Evidence-Based Nursing. 2004; 7(1):19. [DOI:10.1136/ebn.7.1.19] [PMID]

[12] Yılmaz E, Gürgün C, Dramalı A. Minimizing short-term complications in patients who have undergone cardiac invasive procedure: A randomized controlled trial involving position change and sandbag. Anatolian Journal of Cardiology. 2007; 7(4):390-6. [Link]

[13] Gillane O, Pollard M. Early ambulation of patients post-angiography with femoral puncture. British Journal of Cardiology. 2009; 16:137-40. [Link]

[14] Bakhshi F, Namjou Z, Andishmand A, Panabadi A, Bagherinasab M, Sarebanhassanabadi M. Effect of positioning on patient outcomes after coronary angiography: A single-blind randomized controlled trial. The Journal of Nursing Research. 2014; 22(1):45-50. [DOI:10.1097/jnr.0000000000000020] [PMID]

[15] McHugh MP, Cosgrave CH. To stretch or not to stretch: The role of stretching in injury prevention and performance. Scandinavian Journal of Medicine & Science in Sports. 2010; 20(2):169-81. [DOI:10.1111/j.1600-0838.2009.01058.x]

[16] Gajdosik RL. Passive extensibility of skeletal muscle: Review of the literature with clinical implications. Clinical Biomechanics. 2001; 16(2):87-101. [DOI:10.1016/S0268-0033(00)00061-9] [PMID]

[17] Dugan SA, Bhat KP. Biomechanics and analysis of running gait. Physical Medicine and Rehabilitation Clinics. 200; 16(3):603-21. [DOI:10.1016/j.pmr.2005.02.007] [PMID]

[18] Norkin CC, White DJ. Measurement of joint motion: A guide to goniometry. Philadelphia: FA Davis; 2016. [Link]

[19] Jensen MP, Chen C, Brugger AM. Interpretation of visual analog scale ratings and change scores: A reanalysis of two clinical trials of postoperative pain. The Journal of Pain. 2003; 4(7):407-14. [DOI:10.1016/S1526-5900(03)00716-8] [PMID]

[20] Sacco IC, Alibert S, Queiroz BW, Pripas D, Kieling I, Kimura A, et al. Reliability of photogrammetry in relation to goniometry for postural lower limb assessment. Brazilian Journal of Physical Therapy. 2007; 11(5):411-7. [DOI:10.1590/S1413-35552007000500013]

[21] Dutton M. Dutton's orthopedic survival guide: Managing common conditions. New York: McGraw Hill Profession; 2011. [Link]

[22] Clapis PA, Davis SM, Davis RO. Reliability of inclinometer and goniometric measurements of hip extension flexibility using the modified Thomas test. Physiotherapy Theory and Practice. 2008; 24(2):135-41. [DOI:10.1080/09593980701378256] [PMID]

[23] Mayorga Vega D, Viciana J, Cocca A, Merino Marban R. Criterion-related validity of toe-touch test for estimating hamstring extensibility: A meta-analysis. Journal of Sports Science & Medicine. 2014; 9(1):188-200. [DOI:10.4100/jhse.2014.91.18]

[24] Pescatello LS. ACSM's guidelines for exercise testing and prescription. Philadelphia: Lippincott Williams & Wilkins: 2014. [Link]

[25] Gajdosik R, Lusin G. Hamstring muscle tightness. Reliability of an active-knee-extension test. Physical Therapy. 1983; 63(7):1085-90. [DOI:10.1093/ptj/63.7.1085] [PMID]

[26] Konin JG, Lebsack D, Snyder Valier A, Isear (Jr.) JA. Special tests for orthopedic examination. San Francisco: Slack; 2006. Inc. [Link]