[Sports Physical Therapy]

Torque Measures of Common Therapies for the Treatment of Loss of Knee Flexion

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Background: Conservative treatment protocols to effectively treat knee flexion motion restrictions are dependent in part on the torque applied to the joint.

Hypotheses: Clinicians apply greater torque with the test leg in a simulated prone position than in a seated position. Clinicians also apply greater torque than a dynamic splint or a static progressive stretch brace. Finally, clinicians apply a torque equal to the high-intensity stretch device.

Study Design: Observational study.

Methods: An instrumented test leg was used to record peak torque applied by 14 licensed clinicians (7 women, 7 men; age, 44.3 ± 10.2 years; height, 172.9 ± 13.2 cm; weight, 72.6 ± 13.0 kg) during knee flexion mobilizations and 3 types of mechanical therapy (dynamic splint, static progressive stretch, and high-intensity stretch).

Results: The dynamic splint applied 5.1 ± 0.1 N·m, while the static progressive stretch brace applied 20.8 ± 2.2 N·m. Clinicians applied 49.5 ± 22.4 N·m with the test leg in a seated position and 55.8 ± 22.0 N·m with the leg in a prone position. The high-intensity stretch device applied up to 214.7 ± 29.2 N·m. All comparisons were statistically significant ($P \leq 0.02$) with the exception of the 2 testing positions ($P = 0.94$).

Conclusions: The results demonstrate that the torques applied to the knee differ between passive stretching therapies. Clinicians should be cognizant of these torque differences when constructing treatment protocols for patients with limited knee flexion range of motion.

Keywords: rehabilitation; knee; flexion; manual therapy; mechanical therapy

The degree of knee range of motion is associated with postoperative clinical, functional, and radiographic outcomes.[6,19,23] Ten years following anterior cruciate ligament reconstruction, patients who lacked full knee extension or flexion demonstrated significantly worse subjective outcome scores and quadriceps muscle strength as well as significantly greater radiographic evidence of knee arthrothis.[23] Postoperative arthrofibrosis is one cause of limited postoperative knee range of motion.[13] Over the course of the past 3 decades, the prevalence of knee flexion contractures has decreased because of an improved understanding of the etiology.[17,18] Less invasive surgical techniques and more aggressive pre- and post-operative rehabilitation protocols have reduced the rates of knee flexion loss to 4% or less after anterior cruciate ligament reconstruction.[3,18] However, complicated injuries and/or surgeries result in increased intra-articular bleeding and/or prolonged immobilization, thus increasing the risk of motion loss. The prevalence of arthrofibrosis for patients tibial plateau fractures has been reported to reach 42% and up to 58% for patients with multiple ligament injuries.[22,25]

Conservative treatment options, including physical therapy, home exercise programs, and mechanical therapy, are often used to treat knee range of motion restrictions. The effectiveness of a conservative treatment protocol to improve the range of knee motion is a function of the intensity, frequency, and duration of treatment.[14] Supplementing outpatient physical therapy with either home exercises or home mechanical therapy allows for increased duration and frequency of treatment. Focused treatment protocols, such as physical therapy and the home use of mechanical therapy devices, effectively improve the range of knee flexion or extension for patients that have failed standard conservative treatment.[5,27]

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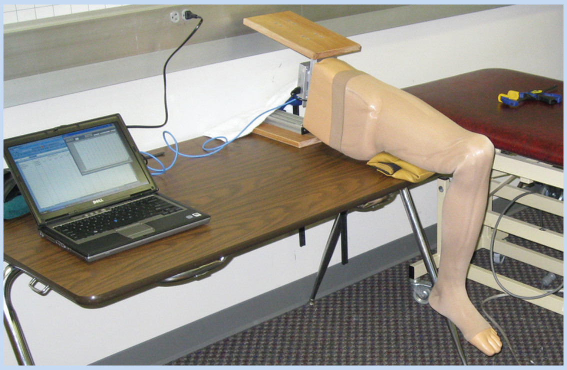

Figure 1. The instrumented test leg used for torque data collection.

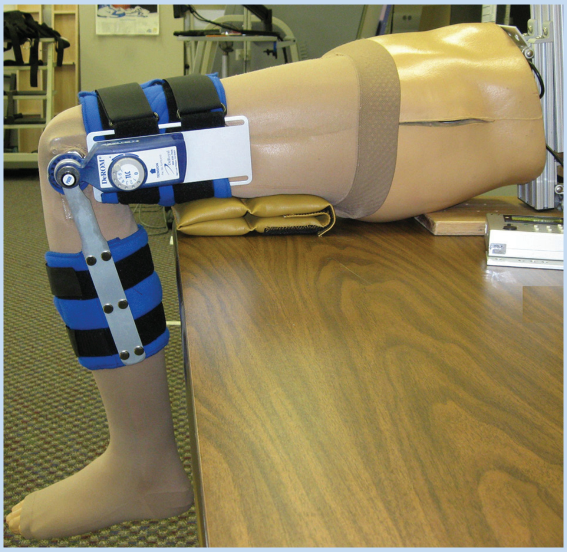

Figure 2. The dynamic splint applied to the instrumented test leg.

Although clinicians and mechanical therapy devices are able to quantifiably adjust the duration and/or frequency to modify the dose of treatment for a given patient, little is known about the intensity of the stretches provided by these commonly used therapies. We previously evaluated the torques applied to the joint during different treatments for knee flexion contractures; however, the intensities, or torques, applied by clinicians and mechanical therapy devices for the treatment of knee flexion have not been quantified to date. The purpose of this study was to compare the torque applied by clinicians with 3 types of mechanical therapy devices in the simulated treatment of knee flexion motion restrictions. It was hypothesized that clinicians would apply greater torque with the test leg in a simulated prone position than in a seated position, that clinicians would apply greater torque than a dynamic splint and a static progressive stretch (SPS) brace, and that clinicians would apply a torque equal to the high-intensity stretch (HIS) device.

METHODS

The university institutional review board approved a waiver of informed consent for this laboratory-based study, and participants included 14 licensed physical therapists (7 women, 7 men; age, 44.3 ± 10.2 years; height, 172.9 ± 13.2 cm; weight, 72.6 ± 13.0 kg). All clinicians had clinical experience treating patients with restricted knee flexion range of motion, with the mean years of experience of the group being 18.2 (range, 3-34 years). At the time of data collection, 11 clinicians were employed in a clinical outpatient setting; the remaining 3 worked in an academic setting but had extensive previous clinical experience.

As part of a previous investigation, we constructed an instrumented test leg that captured the torque being applied to the knee by the clinicians and mechanical therapy devices (Figure 1).[26] The instrumented test leg could be locked at either 0° of knee extension or 90° of knee flexion, and it featured a torque sensor (DI-3N-IP500, Imada, Inc, Northbrook, Illinois) at the knee joint. The sensor is rated by the manufacturer to be accurate within ±0.5% from 3 to 500 N·m. The system allowed for 2° of joint motion at the initiation of each test repetition to create a realistic feel for the clinicians.[26] The length of the lower leg segment was 43.2 cm (17 in), and the length of the thigh segment was 49.5 cm (19 in), with both the segment lengths and the overall leg length consistent with anthropometric measurements of a person standing 175.3 cm (5 ft 9 in) tall.[8]

The instrumented test leg was clamped to a plinth in the simulated seated and prone positions. Clinicians were allowed to adjust the height of the plinth, and hand placement was not controlled. Clinicians were instructed to perform 5 repetitions of 10-second mobilizations just as they would if performing mobilizations with an actual patient, and the peak torque of each repetition was recorded. No feedback was provided to the clinicians during testing, and they were not able to see the visual display of the torque transducer. Peak torque was corrected for gravity, and the peak torque generated by the clinician was used for statistical analysis. Similar to the manner in which mobilizations are performed clinically, clinicians were instructed to gradually increase the force during the first 2 seconds of each repetition. Two clinicians used an oscillatory mobilization technique described by Maitland as a grade 4 mobilization at the end range of motion.[11] The other 12 clinicians used a static mobilization technique involving steady, consistent application of force.[12]

A single clinician performed the testing of 3 types of mechanical therapy devices: a dynamic splint (DeRom Knee, DeRoyal Industries, Powell, Tennessee; Figure 2), an SPS brace (Static-Pro Knee, DeRoyal Industries; Figure 3), and an HIS device (Knee Flexionater, ERMI Medical Devices, Atlanta,

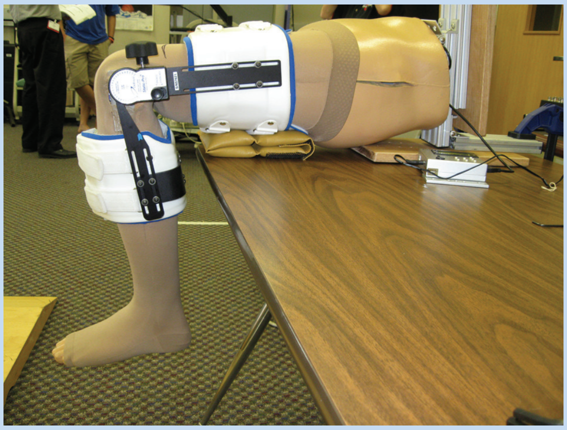

Figure 3. The static progressive stretch brace applied to the test leg.

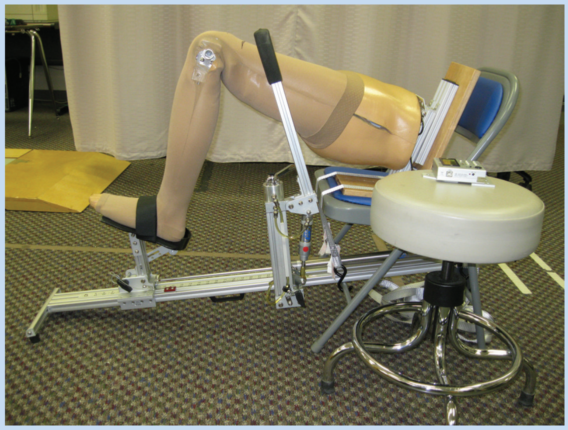

Figure 4. The high-intensity stretch device applied to the test leg.

Georgia; Figure 4). During testing of the dynamic splint and SPS brace, the test leg was securely clamped to the plinth in a seated position with the lower leg unsupported. The devices were applied to the test leg per the manufacturer's instructions. When the HIS device was tested, the test leg was clamped in the device's chair with the foot placed on the footplate. After each device was applied, the amount of torque was maximized for that specific device. Three trials were performed and the peak torque was recorded during each trial.

STATISTICAL ANALYSIS

The mean peak torque of the middle 3 repetitions performed by each clinician was used for analysis. The coefficient of variation was calculated for the 3 test repetitions for each clinician to assess the consistency at which torque was applied. Mean peak torque for the 5 therapies (seated and prone manual mobilizations, dynamic splint, SPS brace, and HIS device) was compared with a 1-way analysis of variance. Levene test of homogeneity of variances was statistically significant ($P = 0.02$), indicating that the assumption of equal variances could not be made. With small, unequal sample sizes such as those used in the current study, even moderate differences in group variance may increase Type I error. The Games-Howell post hoc test, which is designed for unequal variances and sample sizes between groups, was used to determine the location of significant differences.[10,24] All calculations were performed using SPSS 17.0, and the α level was set a priori at $P < 0.05$.

RESULTS

There was no statistically significant difference between the torque applied by the clinicians with the leg in a seated position (49.5 ± 22.4 N·m) or a prone position (55.8 ± 22.0 N·m, $P = 0.94$); however, significant differences were noted between manual mobilizations and all 3 types of mechanical therapy

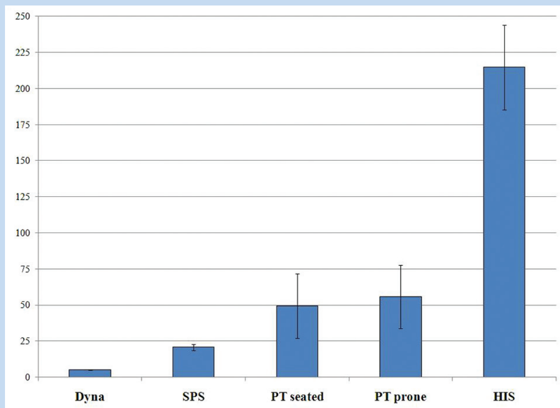

Figure 5. The mean peak torques applied by the 5 therapies: dynamic splint (Dyna), static progressive stretch (SPS) brace, torque applied by physical therapists with the test leg in a seated position (PT seated), torque applied by physical therapists with the test leg in a prone position (PT prone), high-intensity stretch (HIS) device. All pairwise comparisons were statistically significant ($P < 0.05$), except that there was no statistical difference between the torque applied by physical therapists with the test leg in either a prone or supine position ($P = 0.94$).

($P \leq 0.02$; Figure 5). In addition, the peak torque applied by the 3 types of mechanical therapy all significantly differed from one another (dynamic splint, 5.1 ± 0.1 N·m; SPS, 20.8 ± 2.2 N·m; HIS, 214.7 ± 29.2 N·m; for all paired comparisons, $P \leq 0.02$).

Each clinician was very consistent in torque application, as evidenced by the low coefficients of variation in the seated (5.6% ± 2.9%) and supine positions (6.1% ± 2.8%). However, there was a great deal of variability between clinicians,

Table 1. Calculated TERT dose for the knee flexion treatments.[a]

	Torque, N·m	Time, min	Bouts per Day	Days per Week	TERT Dose, N·m min/wk
HIS device[4,5]	26.3	8-10	4-8	7	5891-14 728
Dynamic splint[9]	2.6	120-480	1	7	2184-8736
SPS brace[1,2,21]	10.4	30	1-3	7	2184-6552
Clinician prone[7]	55.8	0.5	2-6	3	167-502
Clinician seated[7]	49.5	0.5	2-6	3	149-446

[a]TERT, total end range time; HIS, high-intensity stretch; SPS, static progressive stretch. Clinician prone, manual mobilization with test leg in prone position; clinician seated, manual mobilization with test leg in seated position.

demonstrated by the large range of applied torques in the seated (19 to 98 N·m) and prone positions (25 to 100 N·m).

DISCUSSION

High-grade mobilizations are often performed by clinicians to help improve knee range of motion. Such mobilizations are generally performed 2 to 6 bouts per session, with each bout lasting approximately 30 seconds.[7] While high-intensity mobilizations may result in immediate improvements in range of motion, these gains may be temporary.[14,16,20] Tissue lengthening from short-duration mobilizations may be related to the viscoelastic properties of connective tissue, and tissues may return to a shortened state soon after the force is removed.[14,16,20]

The seminal works by McClure et al demonstrated the inherent link among the intensity (ie, torque), duration, and frequency of a stretching activity and the efficacy of a stretching protocol.[14-16] They coined the term *total end range time*, or TERT, as being the product of all 3 factors. While the 5 therapies evaluated apply different torques to the joint, each treatment was associated with different treatment durations and frequencies. The total torque applied to the knee over the course of a week (N·m min/wk), also referred to as *TERT dose*, has been estimated for the treatment of knee flexion contractures.[26] To better understand the relative TERT dose of each therapy evaluated in the current study, we used similar methods to calculate the TERT dose based on the measured torque values and treatment durations and frequencies from previously reported treatment protocols. It was assumed that arthrofibrosis patients would be able to routinely tolerate 100% of the torque applied by the clinicians and 50% of the torque applied by the dynamic splint and SPS brace.[26] Because the HIS device evaluated in the current study was able to exceed the torque applied by the clinicians, it is unlikely that patients would tolerate 50% of the measured peak torque. In calculating the TERT dose for the HIS device, we assumed that patients could generate and tolerate 50% of the mean peak torque applied by the clinician. This value (26.3 N·m) was similar to the torque of the HIS device used in a previous study when calculating the TERT dose (26.5 N·m).[26]

Based on these assumptions and previous protocols for the joint mobilizations,[7] dynamic splints,[9] SPS braces,[1,2,21] and HIS devices,[4,5] the weekly TERT doses of the 5 therapies were calculated (Table 1). There was a range of values based on the applied torque and the number of treatment bouts. Performing 2 to 6 repetitions of seated mobilizations 3 days per week resulted in the lowest TERT dose (149 to 446 N·m min/wk). Daily use of the HIS device resulted in the greatest weekly TERT dose (5891 to 14 728 N·m min/wk).

The TERT dosage needed for successful treatment of knee flexion contractures is likely greater than 11 000 N·m min/wk.[26] However, the optimum TERT dose required for lasting gains in knee flexion is not known, so it is unclear if the same TERT dose (11 000 N·m min/wk) would be successful for the treatment of limited knee flexion. To determine a potential therapeutic TERT dose threshold, we compared the TERT doses between previously reported successful treatments for patients with limited knee flexion. A MEDLINE search (US National Library of Medicine, Bethesda, Maryland) using the terms *dynamic splint or Dynasplint* and *knee and flexion* was unable to identify any articles on the efficacy of dynamic splints in treating knee flexion restrictions, so it is unclear if the range of TERT doses presented in Table 1 for dynamic splint devices would successfully treat limited knee flexion.

The HIS device has been effective in a small series of sports medicine patients. Branch et al reported that knee flexion significantly improved from 70.8° to 130.6° in a series of 34 patients that used the device an average of 6.7 weeks.[4] Patients used the device 15 minutes per session, 4 to 8 sessions per day. During each session, patients dynamically stretched the knee into full flexion for 1 to 5 minutes and then relaxed the joint for an equal amount of time. They then stretched into full flexion for 1 to 5 minutes with an equal recovery period. This pattern was repeated for 15 minutes.[5] Based on the estimated applied torque of 26.3 N·m, the range of TERT doses would be 5891 to 14 728 N·m min/wk with the Branch et al protocol.[4] These TERT doses are similar to the 11 000 N·m min/wk identified as the threshold for successful treatment of knee flexion contractures.[26]

It was also hypothesized that clinicians would apply greater torque with the test leg in a prone position than with the leg in a seated position because of the mechanical advantage created by the clinician standing versus the seated position. However, there were no significant differences between the 2 test positions (P = 0.94). Of the 14 clinicians, 4 applied greater torque with the test leg in a seated position, whereas the other 10 clinicians applied greater torque with the leg in a prone position. Each clinician was consistent in application of torque as evidenced by the low coefficients of variation; torque ranges were very large in the seated (19 to 98 N·m) and prone positions (25 to 100 N·m).

STUDY LIMITATIONS

This laboratory-based study had several limitations. An a priori power analysis was not utilized to determine the number of clinicians that were necessary to detect a difference between the seated and prone test positions. It is unclear if the lack of significant differences was related to the small number of clinicians (N = 14).

Clinicians were asked to perform the mobilizations exactly as they would in the clinical setting; however, the instrumented system used in this study did not provide patient feedback (eg, verbal or visual indication of pain) that clinicians use when determining the appropriate amount of force to apply to an actual patient. Testing was performed only at 90° of knee flexion, and it is unclear how the torques of the 5 therapies would differ if tested at varying degrees of knee flexion. While the coefficient of variations demonstrated that each clinician applied similar torques during the 3 test repetitions of the knee flexion mobilizations during the single testing session, we have not evaluated the day-to-day reliability of these torque measures.

In addition, the mean torque of a given treatment was not compared, but the peak torque was. The amount of torque applied will change throughout a given treatment due to either inconsistent force application or tissue responses to the forces applied. With the mechanical devices, the location of the thigh and low leg cuffs of the SPS brace migrated toward the knee as the brace was adjusted to its maximum torque settings, even though the thigh and lower leg cuffs of the SPS brace were securely tightened (Figure 6). The migration of the cuffs most likely resulted in decreased torque to the knee over the course of the trial. Also, for measurement consistency for the mechanical devices, the maximum amount of torque that could be applied was evaluated for each device. These maximal settings most likely exceeded the intensities used by patients.

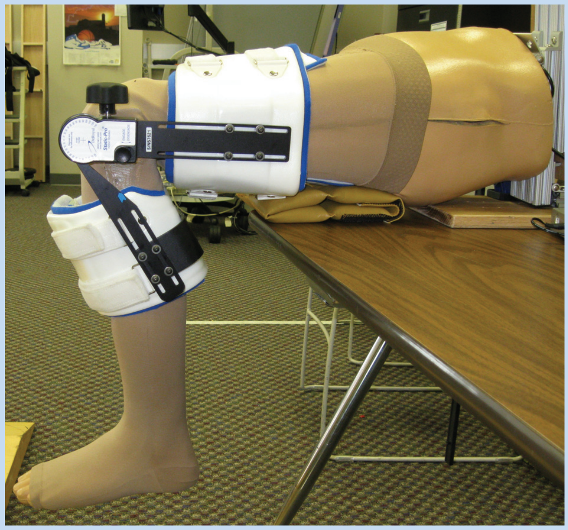

Figure 6. The static progressive stretch brace on the test leg after the brace had been adjusted to create the maximum amount of torque. The brace had clearly migrated because of slippage of the cuffs around the thigh and calf as well as compression of the soft tissue.

CONCLUSIONS

Clinicians should be cognizant of all factors that influence the TERT dose, including duration, frequency, and torques generated by various treatments when developing treatment protocols for patients with limited knee flexion range of motion.

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