ORIGINAL ARTICLE

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Measurement of Muscle Flexibility and Speed in Sprinters Following Stretching - Applicability of a New Range of Motion Instrument

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ABSTRACT

Background: The study aimed to compare static stretching (SS) and proprioceptive neuromuscular facilitation stretching (PNFS) on tight hamstrings in sprinters and use a new range of motion instrument instead of a traditional goniometer to document knee extension deficit.

Methods: The study involved 80 male subjects(age of 18.75±1.94 years), randomized into SS and PNFS groups. Data on age, height, weight, BMI, hamstring flexibility, and speed parameters were recorded at the beginning and 12 weeks. The material includes an examination couch, a Pheezee device for Knee ROM, a Mobile device for Pheezee data display, and a synthetic track for a 30-meter sprint.

Results: Ranges and averages of all parameters calculated, and the significance of the differences in flexibility and speed within and between groups tested. SS group knee extension deficit (KED) 27.1±3.84 decreased to 11.67±5.3.49 and in the PNF group, 27.3 ±4.41 to 10.3±3.33. Thirty-meter sprint test performance in the SS group improved from 5.75±0.47 to 4.77± 0.45, and in the PNF group, 5.77±0.45 to 3.99± 0.26 within group results of both speed and flexibility in both groups was significant (P=< .001). Group KED and speed results differences were clinically significant in pre and post-intervention, but statistically, the results were similar.

Conclusion: Hamstring flexibility impacts knee extension deficit and sprinting speed. Both stretching types showed an impact on knee extension deficit and speed. PNF stretching enhanced speed-related functional outcomes better than Static stretch. The study supports the applicability of the Pheezee instrument and its ability to record Knee extension deficits in field and clinical research.

Keywords: Hamstrings stretching, knee extension deficit, active knee extension test, 30-meter sprint test, Pheezee, Range of motion instrument, Hamstrings flexibility, Hamstrings tightness.

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INTRODUCTION

Sprinting relies on the speed and flexibility of lower limb muscles, which are crucial for an athlete's performance. High-speed runners require good eccentric and concentric control of their hamstring muscles, as sustained hamstring muscle strain injuries have a high re-injury rate. Hamstring strain injuries are common in sports like track and field, soccer, football, rugby, and sprint, accounting for up to 29% of all injuries. Athletes who sustain a hamstring strain injury typically need 2 to 8 weeks to recover and return to pre-injury activity levels, resulting in significant time and financial losses[1].

The hamstring muscle complex is located in the posterior region of the thigh and comprises up to four muscles each. These muscles play a crucial role in various human actions, such as leg flexion, knee extension, hip extension, stabilization of the hip and knee joints, and explosive action like sprinting and jumping. Hamstring muscle pathomechanics refers to abnormal movement patterns or mechanics of the hamstring muscles often associated with injury or dysfunction[2]. Causes may include imbalances, muscle tightness, weakness, altered biomechanics, compensatory movements, hamstring strains, and neuromuscular control issues [3,4]. Addressing hamstring muscle pathomechanics often requires a comprehensive approach, including physical therapy, stretching and mobility exercises, targeted strengthening exercises, neuromuscular training, and gait analysis. Hamstring injuries are slow to heal and frequently recur, with nearly one-third of people who have suffered a hamstring injury reinjuring themselves within one year of returning to their sport.

The Pheezee is a mobile phone-based wearable prognostic device designed for physical rehabilitation, which plays a crucial role in assessing range of motion (ROM) and muscle activity [5]. The device provides comprehensive insights into changes in muscle activity and range of motion. Current research suggests that Pheezee is a time-efficient alternative that can overcome the limitations of conventional evaluation techniques of goniometric range of motion measurement in physiotherapy settings. The Pheezee system, developed by Startoon laboratories, accurately measures ROM in real-time during physical exercise, with a 96% accuracy rate compared to conventional goniometers. This suggests that Pheezee can accurately measure dynamic ROM for lower limb joint motions.

The current study was aimed at documenting the effectiveness of two methods of stretching (Static stretching (SS) vs. proprioceptive neuromuscular stretching (PNFS)) on flexibility of hamstrings (range of motion (ROM)) and speed of sprinters [6]. Monitoring the rehabilitation process and recovery prognosis is vital in modifying treatment [7]. A goniometer measured hamstring tightness (the knee extension deficit on 90-90 position) in degrees while performing an active knee extension test. Conventional goniometers need a stationary arm on the longitudinal axis of the femur and a movable arm on the longitudinal axis of the moving leg segment and the fulcrum at the knee joint. Any change in the placement or axis of the segment may lead to variations in ROM results. Since conventional goniometric measurement has limitations in the accuracy and reproducibility of results, the hamstring flexibility of study subjects was measured by a new ROM instrument called Pheezee.

MATERIALS AND METHODS

The study involved a group of 80 sprinters (age of 18.75±1.94 years) divided into two groups (40 in each group): Static Stretching (SS) and Proprioceptive Neuromuscular Stretching (PNFS). The participants were informed about the study's purpose and given informed consent. The study parameters (Knee range of motion: active knee extension deficit on active knee extension test) and speed were documented before and after the intervention. Pre and post-test joint range of motion of knee measured through Pheezee device modules for hamstring flexibility. Sprinters were tested on synthetic running with a marking of 30 meters for speed evaluation. The participants were under a stretching program for three months. Data was obtained at recruitment and the end of the study period. They advised me to follow the assigned hamstring stretching method, warm up, and sports training for three months. The investigator was available for clarification throughout the study. The study flow (Figure 1: Study flow) involved screening the population, sample selection, randomization, baseline evaluation, assigned stretching programs, re-evaluation, data tabulation and analysis, and conclusion.

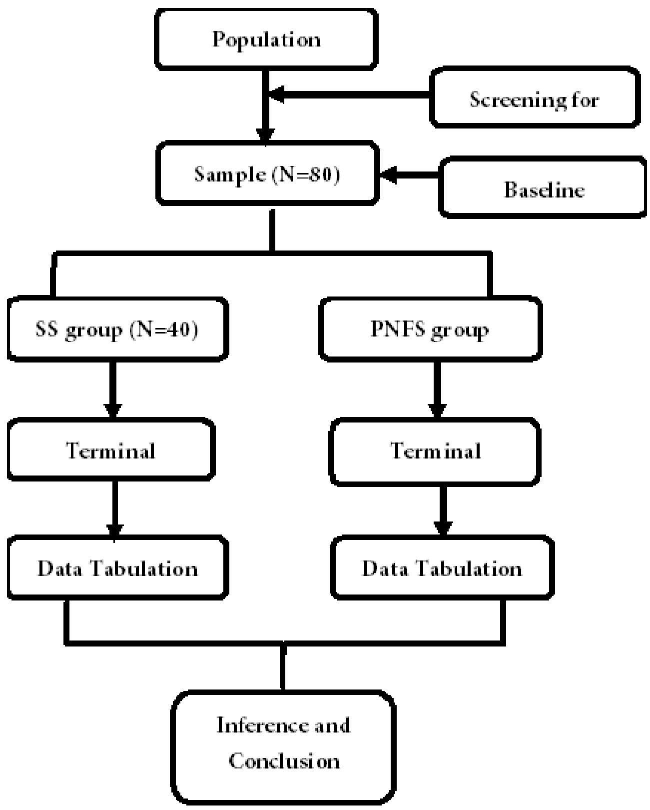

Figure 1: Study flow

2.1 The Active Knee Extension Test (AKET):

AKET is a method used to measure the flexibility of the hamstring muscle (knee extension deficit: range of motion). The test involves the subject lying on a couch with the lower limb at a 90-degree hip and knee flexion, and the knee extension deficit (KED) is measured using a Pheezee ROM device while the subject performs knee extension. This test helps assess the available hamstring flexibility [8,9].

The knee extension deficit (KED) range of motion was documented using the active knee extension test (AKET). The subject performs the AKET, and their demographic details are entered into the registration process. Modules connected to the mobile application via Bluetooth connectivity. The subject is trained to perform the motion before recording. The reliability of AKE tests is good to exceptional, as indicated by inter-rater and intra-rater reliability coefficients (ICC-0.886). The therapist calibrates the pheezee device with the knee joint to establish a zero reference point before movement. As the subject performs active knee extension from the 90-90, the Pheezee instrument displays the angular displacement on an Android display.

2.2 Pheezee Instrument and functionality:

The Pheezee® is a non-invasive, low-power (run time of 35 hours with full charge), wearable, remote monitoring device that can simultaneously track the range of motion (ROM) of a particular joint (e.g., shoulder, elbow, hip, knee, etc.) and electrical activity of muscle. The device and a custom-designed Android Pheezee application installed on the smartphone/tablet provide the user with instant status of the patient's recovery in terms of joint and muscle activity. The device is USFDA [510(k) exempt] cleared. The company is quality-oriented and ISO 13485 & ISO 9001 certified.

Figure 2: Pheezee device and its different components

The device consists of the upper module (power management, ROM circuits) and lower module (MPU, Bluetooth, sEMG, movement circuits) placed above and below the joint to be evaluated, and inter-module communication is accomplished using a 10-wired transmission cable. The data acquired from the IMU sensors (3-DOF accelerometer, gyroscope, magnetometer) in both modules provide the ROM data after calculating the angles using an onboard 32-bit ARM Cortex M3 microcontroller.

The 3-lead sEMG cable with Ag/Agcl electrodes is used to acquire the muscle EMG data. The noisy raw EMG signals are amplified, band-pass-filtered, and rectified at first, and then custom-designed digital filtering is performed using the same onboard microcontroller. Finally, the RMS of pre-processed EMG is wirelessly sent in the Pheezee application for simultaneous recording display and later report generation. Each session recording (i.e., ROM and EMG data) using the Pheezee device is displayed concurrently in the Pheezee application via Bluetooth. The recorded data is pushed to a cloud server via the Internet, where overall information is securely processed to generate a report. The report can be downloaded in .pdf format and printed via Bluetooth printer (if available). The report summarizes the patient's recovery and provides an elaborate view of the muscle activity, ROM, pain scale, and MMT grading. Figure 3 shows the block diagram of the overall Pheezee modules for acquiring the range of motion from the device modules. The data is first acquired from the IMU sensors (3-DOF accelerometer, gyroscope, magnetometer) placed in both modules. An efficient algorithm is developed to combine the angular data from these sensors and calculate the required ROM using an onboard 32-bit ARM Cortex M3 microcontroller. Each ROM session recording (EMG) using the Pheezee device is displayed concurrently on a smartphone or tablet using the Pheezee application via Bluetooth. Fig. 4 shows the Pheezee app view of ROM data recording, where the gold standard method (Goniometer) is used to verify the readings from the device. The average accuracy for ROM w.r.t. the gold standard methods are found to be 98%, where as mean correlation coefficient of 0.96 is observed for EMG.

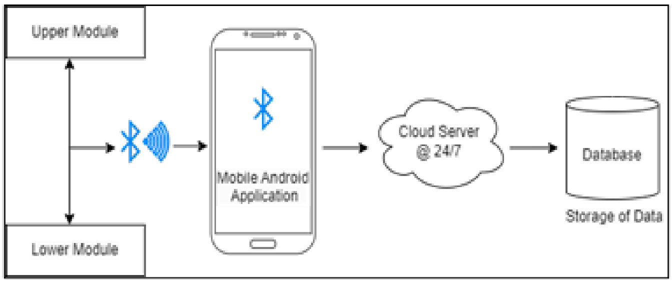

Figure 3: Data transmission between the Pheezee device, Android application, and cloud platform

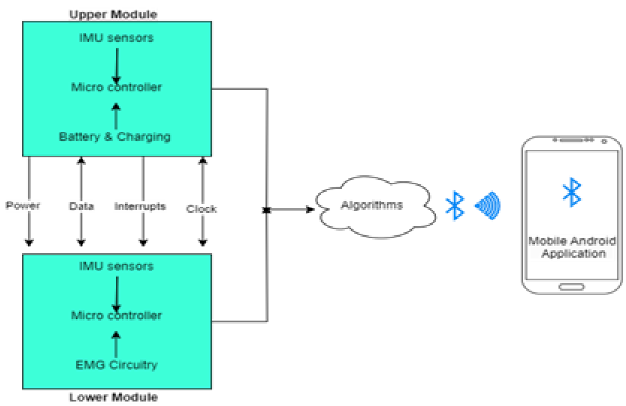

Figure 4: Block diagram of range of motion calculation in Pheezee device

Figure 5: The Pheezee app view of recording the ROM data and verification by gold standard method. (a) Pheezee app and Goniometer are showing 0 degree in angle, (b) Pheezee app and Goniometer are showing 90 degrees in angle

Figure 6: Upper and lower module placements

Using the Pheezee®, the knee can be assessed for ROM and EMG, Fig. 5, 6 (a). An example of the knee's lower and upper module placements: In the report generated after the completion of one movement, the sEMG and ROM temporal graphs can be observed for the recorded duration. The recording time, maximum sEMG values, muscle assessed, maximum ROM, repetitions, repetition speed, MMT gradings, etc., will also be available. An elaborate overview of the data acquisition, device placement for different joints, and session reports are available in the articles [10,11].

2.3 The 30-meter sprint test:

This test is a speed test designed to determine acceleration and speed metrics. It requires a marked track, stopwatch, cone markers, and a flat surface of at least 50 meters. The test involves a pre-test where participants are provided with information about assessment procedures, undergo health risk screening, and obtain informed consent. Documentation includes collecting basic information such as

age, height, body weight, gender, test characteristics, and test features. The participant was instructed to perform a 30-meter sprint at their maximum velocity on a track designed for this purpose. The sprint starts from a static stance with one foot positioned anteriorly to the other, with the leading foot either directly on or posterior to the designated starting line. The duration required to finish the sprint is documented and quantified in units of seconds. The investigator offers suggestions for improving speed, including maintaining a low body posture and using both upper and lower extremities. Participants are motivated to sustain their vigorous running exertion until they complete the designated endpoint. Results were documented with precision to the nearest two decimal points, starting with the initiation of the first movement and concluding when the chest region of the subject crosses the designated ending point. A maximum of two attempts is allowed, and the most advantageous time is documented precisely [12].

2.4 Static stretching

This technique keeps a muscle in a specific position for a predetermined length. Hamstring static stretching is a specific type where an external force is applied to lengthen the hamstring muscle and remains in this position for 15 to 30 seconds [13]. This technique is performed in various positions, such as prone, standing, sitting, and supine. It can enhance range of motion and aid muscle relaxation, potentially reducing the risk of injury. The therapist's position is on the patient's side, while the patient's position is supine, lying on a treatment couch. A moist therapy ministered to the contracted hamstrings to induce relaxation and increased flexibility before the stretching exercise. Moist heat packs are placed over the tight hamstrings for 10 to 15 minutes. This heat increases intramuscular temperatures, enhancing muscle flexibility within 10 to 25 minutes. The patient's lower leg flexed while stretching the knee, and the applied force targeted the hamstring muscles. The patient was assisted in transitioning to the couch for relaxation. The stretching exercise was performed daily, five days a week, for twelve weeks.

2.5 Proprioceptive neuromuscular facilitation stretching (PNF)

This is a widely used stretching technique in physical therapy and exercise science. It involves a series of stretches and exercises designed to improve an individual's flexibility [14]. The patient is lying on the edge of a couch while the therapist is in a stable position with their back straight and core muscles engaged. The equipment required is a hot pack and a couch. Both hands are placed on the distal part of the femur to prevent knee flexion during the stretch. To improve the efficiency of the hamstring stretch, moist therapy is applied to the contracted hamstrings, and the subject is elevated until they experience a manageable sense of stretching. The procedure is repeated for each subject in the PNF group for three sets of ten repetitions five days a week.

The technique involves the sequential execution of stretching and contracting movements by the targeted muscle group. The Contract-Relax Technique involves passive stretching followed by an isometric contraction with resistance applied by the therapist's hand. The muscle then enters a state of relaxation, leading to further stretching and an additional contraction. To prevent excessive strain and potential injury, precautions ensure each movement is controlled and incrementally advanced.

RESULTS

3.1 Demographic results:

The static stretch group consisted of 40 participants, with an average age of 18.75±1.94 years, height of 162.9±5.22 cm, weight of 62.62±5.2 kg, and a body mass index (BMI) of 23.69±2.73, ranging from 19.38 to 29.17. The PNF stretch group involved 40 participants aged between 16 and 22, with an average height of 161.6 cm, weight of 64.87 kg, and a BMI of 22.86±2.27, with an average BMI of 20.7-29.57.

Table 1: Age and BMI of subjects

	Static stretch group		PNF stretch group	
	Mean± SD	**Range**	**Mean± SD**	**Range**
Age	18.75±1.94	16 - 22	18.9±1.91	16-22
Height	162.9±5.22	155 - 170	161.6±5	155-170
weight	62.62±5.2	56 - 72	64.87±5.36	55-72
BMI	23.69±2.73	19.38 - 29.17	22.86±2.27	20.7-29.57

3.2 Within group hamstrings flexibility:

The static stretching group initially had a 27.1±3.84 degrees knee extension deficit in hamstring flexibility, but by the end of the trial, the mean deficiency range decreased to 11.67±5.34, indicating statistical significance. The study found that the PNF stretching group significantly decreased knee extension deficit from 19-35 degrees to 10.325±3.331 degrees, with a range of 5-15 degrees, indicating a significant improvement in hamstring flexibility.

3.3 Between-group hamstrings flexibility:

Pre- and post-Hamstrings flexibility (KED) measurements between SS and PNF groups found that static stretching reduced the average knee extension deficit from 27.1±3.84 to 11.67±5.34. The PNF group showed significant improvement in pre- and post-hamstring flexibility values, with an initial mean of 27.3±24.41, increasing to 10.325±3.331. However, there was no statistically significant difference between the SS and PNF groups regarding initial hamstring flexibility values. Despite no significant difference, both groups showed clinical gains in hamstring flexibility, as measured by the Knee Extension Device (KED).

Table 2: Hamstrings flexibility

	Static stretch group (P Value :P=<0.05)		PNF stretch group(P Value :P=<0.05)	
	Mean± SD	**Range**	**Mean± SD**	**Range**
Hams flex pre	27.1±3.84	21 - 33	27.32±4.41	19-35
hams flex post	11.67±5.34	5 - 25	10.325±3.331	5-15

3.4 Within group speed performance:

The study measured an athlete's velocity using a 30-meter sprint, with a mean of 5.72± 0.47 seconds. The group's static stretching duration also ranged from 5.02 to 6.59 seconds. The study found an improvement in velocities, with an average of 4.02 to 5.52 seconds, with a mean of 4.77± 0.45 seconds. The findings showed statistical significance at a $p < 0.05$ level. Participants in the proprioceptive neuromuscular facilitation (PNF) stretching group showed an average speed of 5.76 seconds, with a standard deviation of 0.455 seconds. The average speed improvement was 3.99 seconds, with a range of 3.55-4.41 seconds, indicating a statistically significant performance improvement.

3.5 Between-group speed performance:

Pre- and post-30-meter sprint speeds between two groups: Proprioceptive Neuromuscular Facilitation (PNF) and Static Stretching (SS). Static stretching significantly improved speed, while PNF exercises significantly enhanced velocity. Both groups showed no significant disparity in average speed before the intervention, but SS and PNF groups showed substantial statistical differences (p=<0.05). The study suggests both groups are equivalent in terms of speed.

Table 3: 30-meter sprint test results in seconds

	Static stretch group (P Value :P=<0.05)		PNF stretch group(P Value :P=<0.05)	
	Mean± SD	**Range**	**Mean± SD**	**Range**
30mtr sprint pre	5.7±0.47	5.02 - 6.59	5.76±0.455	5.02-6.56
30mtr sprint post	4.77±0.45	4.02 - 5.52	3.99±0.26	3.55-4.41

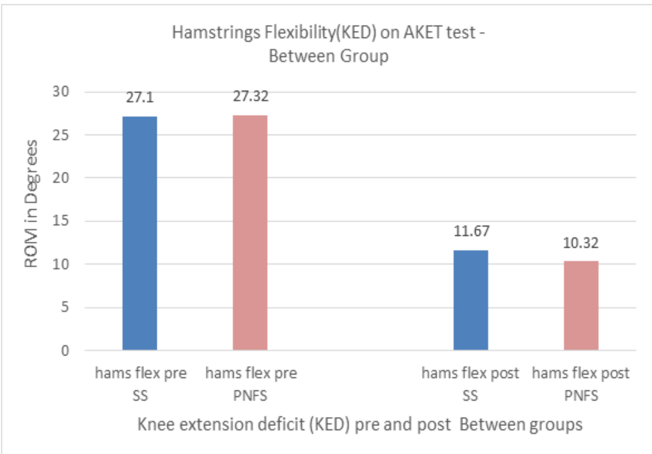

Figure 7: Hamstrings Flexibility (KED) – between groups

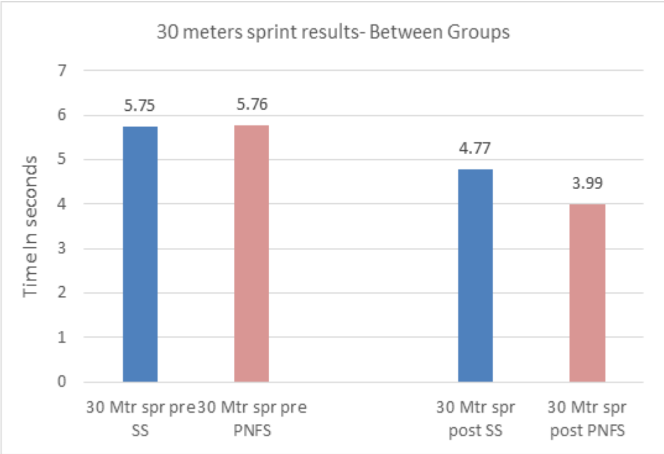

Figure 8: 30-meters sprint- Between Groups

DISCUSSION

The study aimed to assess the effect of static, and PNF stretching on tight hamstrings in sprinters before and after an intervention and Determine the utility of the Pheezee device in assessing knee extension deficiency. A novel range of motion device (Pheezee) measured knee extension restriction rather than a typical goniometer as an appropriate evaluation equipment. Nirav et al. 2020, stated that Hamstring strain injuries (HSI) are prevalent in sports that involve running at high speeds, and having a clear understanding of how the hamstring muscles operate during running may help prevent and rehabilitate these injuries. The present study revealed similar findings; almost every participant had some degree of tightness in their hamstrings, suggesting that sprinters have the greatest likelihood of tightness. Previous studies attributed this phenomenon to the inherent diversity (orientation of fibers) observed across the different components of the hamstring muscles, such as the semitendinosus (ST), semimembranosus (SM), and biceps femoris (BF) (Koichi Takeda et al.2022) [15].

80 Subjects underwent 12 weeks of the program designed to affect their speed and flexibility while sprinting. Static stretching was performed on the PNF group (N=40), while the PNF group(N=40) underwent the PNF stretching procedure. Static stretching involves sustained muscle stretch and optimizing muscular length. In contrast, PNF stretching, which incorporates neural components and sarcomere elongation, is more suitable for sprinters to enhance speed-related functional outcomes. The study showed that static and PNF stretching methods consistently improved sprinters' hamstring flexibility and speed (Ibrahim et al. 2021; Sieun Park et al. 2020) [16] [17]. However, the results are comparatively more favorable towards those who underwent PNF intervention with better hamstring flexibility than those who underwent static stretching, adding more evidence to the study published by Abdulrahim Zakaria et al. 2012[18]. PNF stretch might have induced better neural mechanisms responsible for the simultaneous contraction and elongation of muscles, enhancing muscle tone and facilitating relaxation.

Regarding knee extension deficit (KED) measured with Pheezee demonstrated its accuracy and reproducibility, and we were able to detect change on small degree up to 1 degree, as mentioned in the study of Kamalakannan et al.2021 and Haaris et al.2019 [11]. This device's reliable evaluation and advanced technology help professionals plan treatment strategies more efficiently by detecting changes in ROM. We were able to use the new range of motion device Phezee and integrate it to modulate stretch ranges for better results. This device demonstrated its accuracy and reproducibility in measuring the range of motion of Knee extension deficit.

This study showed the physiological benefits of static and PNF stretching on flexibility and the ability to run a 30-meter sprint faster. Still, statistically, the PNF group had better results in speed tests, possibly due to the integration of neural pathways and optimization of muscle contractions. These results can be extrapolated to the selection choice of stretching methods during the off-season and on-season sprint training camps and competitions.

CONCLUSION

The study reveals that hamstring flexibility significantly influences knee extension deficit and sprinting speed. Both static stretching and proprioceptive neuromuscular facilitation (PNF) stretching are effective therapeutic interventions for improving knee extension deficit and speed. ROM tool improved the sensitivity of ROM recording. The phezee device was helpful in the study evaluation to detect the changes in Knee extension deficit caused by hamstring tightness and it was able to detect changes pre and post-intervention.

REFERENCES

[1] Shellock FG, Prentice WE. Warming-up and stretching for improved physical performance and prevention of sports-related injuries. Sports Med. 1985;2(4):267–78.
[2] Rodgers CD, Raja A. Anatomy, Bony Pelvis and Lower Limb, Hamstring Muscle. StatPearls 2023 Apr 1.
[3] Heiderscheit BC, Sherry MA, Silder A, Chummanov ES, Thelen DG. Hamstring strain injuries: recommendations for diagnosis, rehabilitation, and injury prevention. J Orthop Sports Phys Ther. 2010 ;40(2):67–81.
[4] Maniar N, Schache A, Heiderscheit B, Opar D. Hamstrings biomechanics related to running. Prev Rehabil Hamstring Inj. 2020 Mar 21;65–81.
[5] 3_Pheezee Clinical case study Neuro - Published (1). pdf - Zoho WorkDrive.
[6] Barbosa GM, Trajano GS, Dantas GAF, Silva BR, Vieira WHB. Chronic Effects of Static and Dynamic Stretching on Hamstrings Eccentric Strength and Functional Performance: A Randomized Controlled Trial. J strength Cond Res. 2020 Jul 1;34(7):2031–9.
[7] View of Acute effect of dynamic stretching versus combined static dynamic stretching on speed performance among male Sukma Sarawak 2016 sprinters.
[8] Norris CM, Matthews M. Inter-tester reliability of a

self-monitored active knee extension test. J Bodyw Mov Ther. 2005 Oct 1;9(4):256–9.
[9] Kuilart KE, Woollam M, Barling E, Lucas N. The active knee extension test and Slump test in subjects with perceived hamstring tightness. Int J Osteopath Med. 2005 Sep [cited 2024 Jun 30];8(3):89–97.
[10] Kaarengala V, Battina V, Singh S, Kondapi M, Susurla S. Importance of wearable devices in generating quantitative data in stroke rehabilitation: An observational case study. J Soc Indian Physiother. 2022 ;6(2):59.
[11] Kamalakannan S, Battina V, Susurla S, Kondpapi M, Vathsalya P. Feasibility and acceptability of Pheezee Tm: a mobile phone based Wearable prognostic device for physical rehabilitation. 2021.
[12] Young W, Russell A, Burge P, Clarke A, Cormack S, Stewart G. The use of sprint tests for assessment of speed qualities of elite Australian rules footballers. Int J Sports Physiol Perform. 2008;3(2):199–206.
[13] Massachusetts Institute of Technology, Education. Stretching and flexibility - types of stretching. [Internet] 2007-08, https://web.mit.edu/tkd/stretch/stretching_4.html.
[14] Kristen Barta, Peggy Pletcher. PNF Stretching: A How-To Guide, Technique and Guidelines [Internet], July 9, 2017. https://www.healthline.com/health/fitness-exercise/pnf-stretching.
[15] Takeda K, Kato K, Ichimura K, Sakai | Tatsuo. Unique morphological architecture of the hamstring muscles and its functional relevance revealed by analysis of isolated muscle specimens and quantification of structural parameters. 2023.
[16] Moustafa, Ibrahim M.Ahbouch, Amal, Palakkottuparambil, Faseela, Walton, Lori M. Optimal duration of stretching of the hamstring muscle group in older adults: a randomized controlled trial.57(6):931-939,2021.
[17] Park, Sieun,Lim, Wootaek. Effects of proprioceptive neuromuscular facilitation stretching at low-intensities with standing toe touch on developing and maintaining hamstring flexibility. 24(4):561-567, 2020.
[18] Abdulrahim Zakaria, Ganeswara Rao. Melamand Syamala Buragadd.Efficacy of Pnf stretching techniques on hamstring tightness in young male adult population. World Journal of Medical Sciences 7 (1): 23-26, 2012.