Türkiye Fizyoterapistler Derneği 1969

ISSN: 2651-4451 • e-ISSN: 2651-446X

Turkish Journal of Physiotherapy and Rehabilitation

2023 34(1)21-28

THE ACUTE EFFECT OF STATIC VERSUS PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION STRETCHING COMBINED WITH KINESIOLOGY TAPING® OF HAMSTRING MUSCLES ON FUNCTIONAL TESTS IN ADOLESCENT TAEKWONDO ATHLETES

Negin ARJANG[1], MSc, PT
Holakoo MOHSENIFAR[1], PhD, PT
Ali AMIRI[1], PhD, PT
Mehdi DADGOO[1], PhD, PT
Golnaz RASAEIFAR[1], MSc, PT

1 Iranian Center of Excellence in Physiotherapy, Rehabilitation Research Center, Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.

Correspondence (İletişim):

Holakoo MOHSENIFAR
Iranian Center of Excellence in Physiotherapy, Rehabilitation Research Center, Department of Physiotherapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.
Phone Number: +989123807685
E-mail: Mohsenifarpt@gmail.com
ORCID: 0000-0002-9053-0552

Negin ARJANG
E-mail: negin.arjang@gmail.com
ORCID:0000-0001-6978-0955

Ali AMIRI
E-mail: amiri.a@iums.ac.ir
ORCID: 0000-0001-7123-8882

Mehdi DADGOO
E-mail: dadgoo.m@iums.ac.ir
ORCID: 0000-0003-2662-9352

Golnaz RASAEIFAR
E-mail: Golnaz.rasaeifar@gmail.com
ORCID: 0000-0003-2073-6528

Received: 5.08.2021 (Geliş Tarihi)
Accepted: 2.12.2022 (Kabul Tarihi)

ORIGINAL ARTICLE

ABSTRACT

Purpose: In taekwondo, muscle flexibility specifically in the lower limb is of great importance for athletic performance. In this study, we evaluated the acute effects of static versus proprioceptive neuromuscular facilitation (PNF) stretching combined with kinesiology taping (KT) of the hamstring muscle on functional tests in adolescent taekwondo athletes.

Methods: 20 adolescent taekwondo athletes aged 9 to 18 years with red, black belt color participated in this study. They performed static, or PNF stretching in both legs, then two I strips with 30% tension as an inhibitory fashion was applied over the hamstring muscles of one leg and the other leg was determined as control. Single leg vertical jump test, single leg hop test, and taekwondo specific agility test (TSAT) were performed before, just after, and 24 hours after interventions.

Results: Repeated measures ANOVA test was used for statistical analysis of the data. All functional tests results demonstrated significant improvement over time (Single leg vertical jump (p=0.005), single leg hop test (p=0.01), and TSAT (p=0.03)) but none of the stretching or the KT groups affected the functional performance of the participants (Single leg vertical jump (p=0.36) and single leg hop test (p=0.50)).

Conclusion: We think that both static and PNF stretching exercises improve the functional performance of adolescent taekwondo athletes for up to 24 hours, however KT application has no significant effect.

Keywords: Athletes, Functional Tests, Kinesiology Taping, Stretching

ADÖLESAN TEKVANDO SPORCULARINDA KİNEZYOLOJİK BANTLAMA® İLE BİRLİKTE UYGULANAN STATİK GERMEYE KARŞI PROPRİOSEPTİF NÖROMUSKÜLER GERMENİN FONKSİYONEL TESTLERE AKUT ETKİSİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Özellikle alt ekstremitedeki kas esnekliği, tekvandoda sportif performans için büyük önem taşımaktadır. Bu çalışmada, adölesan taekwondo sporcularında hamstring kasına uygulanan kinezyolojik bantlama ile birlikte statik veya proprioseptif nöromüsküler fasilitasyon (PNF) germe egzersizinin akut etkilerini fonksiyonel testler üzerinde değerlendirdik.

Yöntem: Bu çalışmaya 9-18 yaş arası kırmızı, siyah kuşaklı 20 adölesan tekvando oyuncusu katıldı. Her iki bacağa statik veya PNF germe uygulandı. Ardından bir bacağın hamstring kasına inhibisyon amacıyla %30 gerimli iki adet I bandı uygulanırken diğer bacak kontrol olarak belirlendi. Müdahalelerden önce, hemen sonra ve 24 saat sonra tek bacak dikey sıçrama testi, tek bacak hoplama testi ve tekvandoya özgü çeviklik testi (TÖÇT) uygulandı.

Sonuçlar: İstatistiksel analizler için tekrarlanan ölçümlerde ANOVA testi kullanıldı. Tüm fonksiyonel test sonuçları zaman içinde artış gösterdi (tek bacak dikey sıçrama testi p=0,005, tek bacak hoplama testi p=0,01 ve TÖÇT p=0,03) ancak germe veya KT gruplarının hiçbirinde katılımcıların fonksiyonel performansının etkilenmediği görüldü (tek bacak dikey sıçrama testi p=0,36 ve tek bacak hoplama testi için p=0,50).

Tartışma: Herhangi belirgin bir fark olmadan hem statik hem de PNF germe egzersizlerinin, adölesan tekvando oyuncularının fonksiyonel performansını 24 saate kadar iyileştirebilir. KT uygulamasının önemli bir etkisi olmamıştır.

Anahtar Kelimeler: Sporcular, Fonksiyonel Testler, Kinezyolojik Bantlama, Germe

INTRODUCTION

Taekwondo has evolved into an Olympic combat sport in the modern day. Taekwondo movements require a high degree of flexibility, particularly in the lower limbs (1). Additionally, kicking techniques are preferred over upper extremity blows due to their higher ratings. According to cinematic and isokinetic analysis, adequate hip and knee joint range of motion, particularly in end range, during a kick movement is critical for optimal task performance, which can be influenced in a variety of ways by antagonist muscle stiffness (2). Sufficient muscle flexibility is believed to be one of the critical components, and it has been noted that insufficient flexibility can predispose an athlete to injury and even delay the recovery period (3-5).

Stretching exercises are extensively utilized by athletes for a variety of goals, including improving flexibility and functional performance or preventing injury, as part of their warm-up routines and before to their primary athletic activity (6). Static and PNF stretching techniques are known to be popular among athletes and to enhance range of motion in both the short and long term (7,8). There has recently been disagreement about the effect of pre-activity stretching on athletes' functional performance, with some studies reporting harmful impacts on athletic performance when stretching was applied just before the sport activity (9,10).

Kinesiology taping (KT) is a method which utilizes an elastic tape that represents the behavior of the skin (11). It was first developed by Dr. Kase in 1990 and recently a growing number of athletes use it for different purposes like muscle activity and extensibility and functional performance modifications (6,12,13). However, available evidence about KT's effectiveness and mechanism of action is sparse, and current research in the sports and musculoskeletal domains has not produced consistent results (11,12,14).

In light of the aforementioned discrepancies, we hypothesized that combining KT with stretching techniques could yield positive effects in terms of enhancing flexibility and functional performance.

METHODS

Participants

Our study included 20 adolescent taekwondo athletes aged between 9 to 18 years with red, black belts who had practiced taekwondo sessions at least one hour, three times a week for the previous two years. From October 2018 to April 2019, we conducted research at the Iran Taekwondo Federation. Using pain medication and having a history of lower limb injury or neuromuscular issues within the last year, as well as being unable to do the functional tests effectively or maintain KT for 24 hours, were exclusion factors (6). We obtained approval for the study from the Research Council and Ethics Committee affiliated with Iran University of Medical Science, as well as individual signed informed permission. Additionally, individuals were permitted to withdraw from the survey at any point during the study. Table 1 summarizes the participant's demographic characteristics.

Procedure

Static and PNF stretching groups were assigned at random to the participants. A ball-kick test was used to determine which leg was the dominant one. In a supine position, leg length was measured from the anterior superior iliac spine

Table 1. Demographic Information of the Participants

Group	Static			PNF			
	Min	Max	Mean (SD)	Min	Max	Mean (SD)	P
Age (year)	10	15	12.2 (1.81)	9	18	12 (2.62)	0.84
Height (cm)	144	178	162 (10.28)	136	174	154 (11.65)	0.11
Weight (kg)	32	61	49.7 (7.76)	28	64	44 (11.74)	0.22
BMI (kg/m²)	15.43	20.86	18.81 (1.66)	15.13	21.75	18.45 (2.48)	0.70

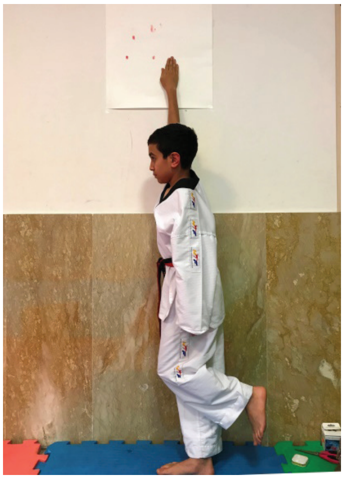

Figure 1. Single leg jump and reach test

Figure 2. Single Leg Hop Test

to the distal region of the medial malleolus (15). Ten minutes of jogging and submaximal kicking, squatting, and jumping served as the warm-up (16). Athletes repeated each functional test for familiarization (16,17). Following that, a blind examiner evaluated the participant's functional ability using three functional tests separated by one-minute rest periods. Following that, another researcher conducted static or PNF stretching to both legs and randomly tapped one of the dominant or non-dominant legs with KT. Acute and 24-hour follow-up functional assessments were performed. Both legs were completed with a single leg vertical jump (SLVJ) and a single leg hop test (SLH); one leg had KT and the other did not. As a control group, we used the other leg (without KT). We were unable to compare KT and no-KT individually because the taekwondo specialized agility test (TSAT) is done with both legs. For the Taekwondo-specific agility test, we compared static and PNF stretching groups before and after treatments (without stretch and KT) (with stretch and KT).

Functional tests

Single leg vertical jump

The athlete was advised to stand on one leg, approximately one foot away from the wall, and use their index finger to make a mark on the wall as a reference point. They then leapt to their feet and left a mark on the wall. The difference between these two points in centimeter was determined, and the test result was derived as the average of the two best results out of three attempts (see Figure 1) (18). Both legs were tested; one had KT and the other did not; the non-KT leg served as a control group. According to statistical analysis, the ICC of this test was 0.93.

Single leg hop test

The athlete was told to stand behind a starting line with his testing leg's toe tangent to the line. The patient then jumped forward as far as he could and landed on the test leg, holding the landing posture for at least two seconds. After normalizing to the subject leg length, the distance between the rare foot at landing and the start point was measured in centimeter, and the test result was the average of two best performances out of three attempts (see Figure 2). Both legs were tested, and trials with extra hop landings or instability were disqualified (17). The test was carried out on both legs, one of which had KT and the other which did not. The no-KT group served as the control group. According to statistical analysis, the ICC of this test was 0.93.

Taekwondo specific agility test

The test was conducted in a 4*4-meter area with three sparring partners who were nearly as tall as the subject and held torso-height kick targets (partner 1 and 2 held one, and partner 3 held two kick targets). The individual took a position in front of the starting/ending point. At the start of the test, the athlete stepped forward without crossing his or her feet. Then, facing partner 1, perform a round house kick (dollyo-chagi) with your left leg. Then, facing partner 2, perform a round house kick with your right leg. Then, retaining a guard position, return to the central point

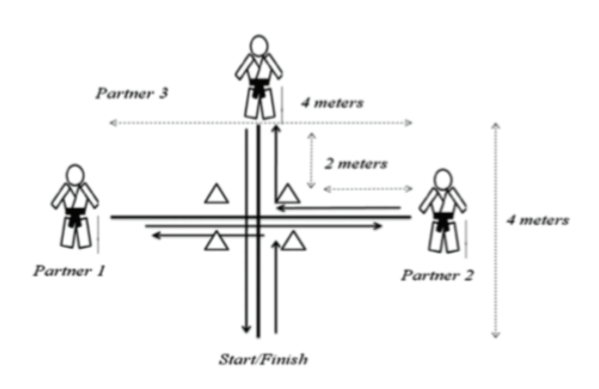

Figure 3. Taekwondo Specific Agility Test

Table 2. Functional Tests Properties in Static and PNF Stretching Groups with and without Kinesiology Taping

Tests	Stretching Group	Mean and SD	Mean Difference	Sig. (2-tailed)	95% Confidence Interval of the Difference	
					Lower	Upper
SLVJ1 no-KT (cm)	Static	20.90 (5.36)	-0.85	0.72	-5.78	4.08
	PNF	21.75 (5.13)				
SLVJ 1 KT (cm)	Static	20.75 (5.84)	-0.57	0.80	-5.29	4.14
	PNF	21.32 (4.03)				
SLVJ 2 no-KT (cm)	Static	21.55 (5.96)	-0.27	0.91	-5.63	5.08
	PNF	21.82 (5.72)				
SLVJ 2 KT (cm)	Static	21.67 (5.34)	-1.52	0.48	-6.02	2.97
	PNF	23.20 (4.15)				
SLVJ 3 no-KT (cm)	Static	22.82 (6.25)	-0.55	0.84	-6.49	5.39
	PNF	23.37 (6.40)				
SLVJ 3 KT (cm)	Static	21.90 (5.00)	-0.60	0.77	-4.88	3.68
	PNF	22.50 (4.07)				
SLHT1 no-KT (cm)	Static	130.54 (18.70)	0.98	0.90	-16.09	18.07
	PNF	129.55 (17.65)				
SLHT1 KT (cm)	Static	133.54 (25.70)	7.48	0.45	-13.16	28.13
	PNF	126.06 (17.48)				
SLHT2 no-KT (cm)	Static	138.78 (17.23)	6.02	0.52	-13.48	25.53
	PNF	132.75 (23.77)				
SLHT2 KT (cm)	Static	138.46 (23.84)	4.61	0.65	-16.47	25.70
	PNF	133.84 (20.96)				
SLHT3 no-KT (cm)	Static	135.24 (25.63)	-4.54	0.68	-27.96	18.88
	PNF	139.78 (24.21)				
SLHT3 KT (cm)	Static	140.48 (35.78)	1.32	0.92	-28.41	31.06
	PNF	139.15 (26.89)				
TSAT1 (sec)	Static	5.53 (0.56)	0.29	0.22	-0.19	0.78
	PNF	5.24 (0.47)				
TSAT2 (sec)	Static	5.32 (0.48)	0.01	0.96	-0.41	0.43
	PNF	5.31 (0.41)				
TSAT3 (sec)	Static	5.07 (0.34)	-.055	0.76	-0.43	0.32
	PNF	5.12 (0.46)				

SLVJ: Single leg vertical jump; SLHD: Single leg hop test; TSAT: Taekwondo specific agility test; 1,2,3: 1 for pre intervention, 2 for immediately and 3 for 24 hours later; KT: with kinesiology taping, no-KT: without kinesiology taping; KT or no-KT conditions for TSAT did not determine.

and do a double house kick (narae-chagi) toward partner 3 before returning to the starting/ending point. The examiner kept track of time with a chronometer and gave the best performance out of three trials as the test result (see Figure 3) (16). According to statistical analysis, the ICC of this test was 0.96.

Stretching protocol

Static stretch: The individuals were requested to lie down in a supine position. For 30 seconds, the therapist passively moved the hip joint from extension to the greatest tolerated degree of flexion while maintaining the knee joint in full extension. This procedure was performed five times with a 30-second rest period in between.

PNF Stretch: PNF stretching was performed in the same manner as static stretching. PNF stretching (Hold-relax) began with passively positioning the target muscle (Hamstrings) in a stretch position, followed by 9 seconds of isometric contraction at a submaximal (30% of maximal voluntary contraction) intensity. The

Table 3. Repeated Measures ANOVA Test Results

Outcome Measures	Time		Time*Stretch Group		Time*KT Group		Time*Stretch Group*KT Group	
	Sig.	Eta-Squared	Sig.	Eta-Squared	Sig.	Eta-Squared	Sig.	Eta-Squared
SLVJ (cm)	0.01	0.10	0.96	0.001	0.36	0.04	0.76	0.008
SLHT (cm)	0.005	0.09	0.97	0.002	0.50	0.03	0.26	0.02
TSAT (sec)	0.03	0.22	0.28	0.09			***	

SLVJ: Single leg vertical jump; SLHD: Single leg hop test; TSAT: Taekwondo specific agility test. ***: KT or no-KT conditions for TSAT did not determine.

target muscle was then passively placed into a larger position. This approach was repeated five times with a 30-second rest period in between (19).

Kinesiology taping method

A certified physiotherapist used the KT method to apply a standard 5-cm wide, 0.5-mm thick, and water resistant elastic adhesive kinesiology tape (Green color, K-Active, Europe GmbH) to the hamstring muscles. The athlete bowed forward to maintain a stretch in the hamstring muscle. Then, two I strips with 30% tension were introduced through the ischial tuberosity, over the muscle, and into the popliteal fossa's medial and lateral borders (14). KT was used for inhibitory application in the direction from insertion to origin.

Statistical analysis

The Statistical Package for the Social Sciences was used to analyze the data (SPSS software; version21). The alpha value has been set to 0.05. The average confidence interval for all analyses was 95%. The Shapiro-Wilk test was performed to determine the distribution's normality. The Repeated measure ANOVA test was performed to evaluate variables within groups three times (Pre-intervention, acutely post-intervention, and 24 hours later) and between groups (Static or PNF Stretching and KT or no-KT). Additionally, Independent T-Test and post hoc analyses were done on the variables within the group.

Sample size calculation

The sample size of this investigation was calculated based on a pilot study (initial n = 5) using the G*Power Statistical Package (version 3.0.10) with an α value of 0.05 to achieve a statistical power of 0.80 and an effect size of 0.30 (the least effect size in outcome measures i.e. single leg hop test). The following options were also selected: test family, f test; ANOVA repeated measures, within-between interaction and type of power analysis, a priori. Total sample size was determined 20.

RESULTS

The Shapiro-Wilk test revealed that all variables had a normal distribution. The characteristics of the subjects did not differ significantly between the two stretch groups (p>0.05). At baseline, there were no significant differences in the variables between the groups (p>0.05).

According to independent t-tests (Table 2) and repeated measure ANOVA test, it is implied that participants' functional performance changed significantly over time in all functional tests, but that there was no significant difference between the PNF and static groups, nor between the KT and no-KT groups, acutely and 24 hours after interventions. Mauchly's test was used to determine the sphericity of the data, and the Partial Eta Squared was computed (Table 3).

All functional tests results demonstrated significant improvement over time (Single leg vertical jump (p = 0.005), single leg hop test (p = 0.01), and TSAT (p = 0.03)) but none of the stretching or the KT groups did not affect the functional performance of the participants (Single leg vertical jump (p = 0.36) and single leg hop test (p = 0.50)).

DISCUSSION

The present study's findings indicated that both static and PNF stretching considerably improved functional tests both acutely and 24 hours following the intervention. To enhance the beneficial effects of stretch or to mitigate the detrimental effects of stretch, we added KT following the stretching approach. However, we observed no effect of KT on stretching groups. Despite a decline in functional performance, such as jumping ability, in certain studies (20), our findings indicated an improvement in functional performance following the application of stretching strategies. There are conflicting findings in literature; some studies indicate that stretching improves functional performance (21), while other studies indicate that stretching decreases functional capacity (14). Different stretching techniques, participant characteristics, type of sporting activities, type of functional tests, stretching dose, and time of assessments may all have an effect on these outcomes.

Nowadays, KT is being used more frequently in athletic fields. Regardless of the effect of stretching, we expected that applying KT following stretching procedures would enhance the stretching effect or mitigate the stretching effect. Additionally, this impact may be more apparent in PNF stretching due to the fact that PNF stretching utilizes a stronger neurophysiological mechanism such as reciprocal inhibition and autogenic inhibition.

Additionally, kicking techniques are preferred over upper extremity blows due to their higher ratings. According to kinematic and isokinetic analysis, adequate hip and knee joint range of motion, particularly in end range, during a kick movement is critical for optimal task performance, which can be influenced in a variety of ways by antagonist muscle stiffness (2). As a result, we chose this activity and applied stretching techniques and KT to adolescent athletes' hamstring muscles. Adolescent taekwondo players spend more time warming up and augmenting flexibility in their lower extremities and choosing the optimum stretching strategy can benefit them.

A 2018 review article found evidence that PNF stretching can significantly improve muscular performance in six articles (21). In comparison, Bradely et al. tested healthy volunteers' jumping performance 5, 15, 30, 45, and 60 minutes after several stretching methods. They reported that after stretching, jump height was significantly reduced, particularly in static and PNF, compared to the ballistic stretching group. After 15 minutes, the decline in jump height was gone (20). Evan Peck et al. investigated the effects of static, dynamic, and PNF stretching on several functional tasks classified as power and strength-dominant, speed or agility-dominant, and endurance-dominant sports in a 2014 literature review. They reported that static stretching had a detrimental effect on functional performance across all categories. The study on PNF stretching has been sparse and contradictory. In conclusion, they advised against acute static or PNF stretching prior to primary activities (10).

Behm et al. did another systematic review on the acute effects of stretching on performance in 2015. They detected functional impairment following static stretching that was greater in strength-based exercises than in power-speed activities. Additionally, they state that, despite the paucity of evidence on the effect of PNF stretch, it appears as though functional damage is more prevalent in this mode of stretch. They believe that these adverse effects are most noticeable when functional tests are administered within 3-5 minutes of stretching, although in normal conditions, the period between stretching and sports competition is greater than 10 minutes, during which some refinements will occur (9). Additionally, they note that these impairments may vary according to clinical and athletic settings and are proportional to stretching time, implying that functional performance reductions are more feasible with stretching activities lasting longer than 60 seconds (9). Numerous factors have been proposed as possible explanations for the force and probably functional reduction observed following stretching exercises, including changes in tendon stiffness or force-length relationship, stretch-induced contractile fatigue or damage, and decreased electromechanical coupling or central drive (9).

Several possible mechanisms of action for KT have been hypothesized, including suppression of motor unit firing, increased blood circulation, cutaneous mechanoreceptor activation, and fascial unloading (12,14,22).

From a comparison standpoint, the research regarding the effectiveness of static versus PNF stretching workouts on hamstring flexibility and subject performance is inconsistent (3,9,10,20, 23,24). According to some authors, despite its primary effect on range of motion, PNF stretching may result in an additional loss in performance (3). On the other hand, past research, including our own, has demonstrated that both static and PNF stretching workouts are helpful at increasing hamstring flexibility, with no statistically significant difference between the two (6,25-27). Additionally, our study's findings confirmed that both stretching strategies significantly enhanced functional performance.

Similarly, our findings indicate that applying KT over the hamstring muscle had no influence on the participant's physical performance in either the static or PNF stretch groups. Indeed, due to the participants' functional recovery, we are unable to state categorically whether KT administration could prevent stretching-induced functional deterioration. We concluded that both static and PNF stretching exercises significantly enhanced the athletes' functional performance acutely and after 24 hours. Furthermore, there were no significant differences in functional improvement between the static stretch and PNF groups, or between the KT and no-KT groups.

The study's limitations include the fact that participants were restricted to healthy adolescent athletes without hamstring muscle shortening. We examined the role of stretching as a warm-up strategy, not as a meaning of resolving movement limitations. Future research can examine the effect of static or PNF stretching combined with KT on muscle shortening. Additionally, in our study design, we compared KT to a control group that did not receive KT. In future research, sham KT could be used in place of a no-KT group. Another limitation of our study was that we investigated only the immediate effect of KT and further research is warranted to evaluate the effect of prolonged or repeated applications of KT.

Sources of Support: None

Conflict of Interest: The authors declare no conflict of interest.

Author contributions: Concept – NA, HM, AA, MD, GR; Design – NA, HM, AA, MD, GR; Supervision – HM, AA, MD; Resources and Financial Support – GR, MD; Materials – NA; Data Collection and/or Processing – NA, HM, AA, MD, GR; Analysis and/or Interpretation – NA, HM; Literature Research – NA, HM; Writing Manuscript – NA, HM, AA, MD, GR; Critical Review – NA, HM, AA, MD, GR.

Ethical Approval: The study protocol was accepted by the Ethics Board for Clinical Research at Iran University of Medical Sciences (Approved Date: 2018/8/11 and Approval Number: IR.IUMS.REC.1396.9411452001).

Informed Consent: A written informed consent form was obtained from all participants.

Acknowledgment: None.

REFERENCES

1. Bridge CA, da Silva Santos JF, Chaabene H, Pieter W, Franchini E. Physical and physiological profiles of taekwondo athletes. Sports Medicine. 2014;44(6):713-33.
2. Preuschl E, Hassmann M, Baca A. A Kinematic Analysis of the Jumping Front-Leg Axe-Kick in Taekwondo. Journal of sports science & medicine. 2016;15(1):92.
3. Hill KJ, Robinson KP, Cuchna JW, Hoch MC. Immediate Effects of Proprioceptive Neuromuscular Facilitation Stretching Programs Compared With Passive Stretching Programs for Hamstring Flexibility: A Critically Appraised Topic. Journal of Sport Rehabilitation. 2017;26(6).
4. Mendonça LDM, Bittencourt NFN, Guimarães CQ, da Silva AA, da Fonseca ST, editors. Isokinetic Analysis Of Hamstrings And Quadriceps Muscles In The Male And Female Taekwondo Brazilian National Team. ISBS-Conference Proceedings Archive; 2007.
5. Nuri L, Ghotbi N, Faghihzadeh S. Acute effects of static stretching, active warm up, or passive warm up on flexibility of the plantar flexor muscles of Iranian professional female taekwondo athletes. Journal of Musculoskeletal Pain. 2013;21(3):263-8.
6. Ozmen T, Gunes GY, Dogan H, Ucar I, Willems M. The effect of kinesio taping versus stretching techniques on muscle soreness, and flexibility during recovery from nordic hamstring exercise. Journal of Bodywork and Movement Therapies. 2017;21(1):41-7.
7. Ghram A, Damak M, Costa P. Effect of acute contract-relax proprioceptive neuromuscular facilitation stretching on static balance in healthy men. Science & Sports. 2017;32(1):e1-e7.
8. Konrad A, Tilp M. Increased range of motion after static stretching is not due to changes in muscle and tendon structures. Clinical Biomechanics. 2014;29(6):636-42.
9. Behm DG, Blazevich AJ, Kay AD, McHugh M. Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: a systematic review. Applied physiology, nutrition, and metabolism. 2015;41(1):1-11.

10. Peck E, Chomko G, Gaz DV, Farrell AM. The effects of stretching on performance. Current sports medicine reports. 2014;13(3):179-85.
11. Lee Y-Y, Chang H-Y, Chang Y-C, Chen J-M, editors. The effect of applied direction of Kinesio taping in ankle muscle strength and flexibility. ISBS-Conference Proceedings Archive; 2012.
12. Merino-Marban R, Fernandez-Rodriguez E, Lopez-Fernandez I, Mayorga-Vega D. The acute effect of kinesio taping on hamstring extensibility in university students. Journal of physical education and sport. 2011;11(2):133.
13. Pourahmadi MR, Bagheri R, Jannati E, Takamjani IE, Sarrafzadeh J, Mohsenifar H. Effect of Elastic Therapeutic Taping on Abdominal Muscle Endurance in Patients With Chronic Nonspecific Low Back Pain: A Randomized, Controlled, Single-Blind, Crossover Trial. Journal of manipulative and physiological therapeutics. 2018;41(7):609-20.
14. Lumbroso D, Ziv E, Vered E, Kalichman L. The effect of kinesiology tape application on hamstring and gastrocnemius muscles in healthy young adults. Journal of bodywork and movement therapies. 2014;18(1):130-8.
15. Chaabene H, Negra Y, Capranica L, Bouguezzi R, Hachana Y, Rouahi MA, et al. Validity and reliability of a new test of planned agility in elite taekwondo athletes. 2018;32(9):2542-7.
16. Chaabene H, Negra Y, Capranica L, Bouguezzi R, Hachana Y, Rouahi MA, et al. Validity and reliability of a new test of planned agility in elite taekwondo athletes. The Journal of Strength & Conditioning Research. 2018;32(9):2542-7.
17. Munro AG, Herrington LC. Between-session reliability of four hop tests and the agility T-test. The Journal of Strength & Conditioning Research. 2011;25(5):1470-7.
18. Shin S-H, Woo H-J. Correlation of single leg vertical jump, single leg hop, and single leg squat distances in healthy persons. Physical Therapy Rehabilitation Science. 2013;2(1):57-61.
19. Sharman MJ, Cresswell AG, Riek S. Proprioceptive neuromuscular facilitation stretching. Sports medicine. 2006;36(11):929-39.
20. Bradley PS, Olsen PD, Portas MD. The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. Journal of Strength and Conditioning Research. 2007;21(1):223.
21. Kaya F. Positive effects of proprioceptive neuromuscular facilitation stretching on sports performance: A review. Journal of Education and Training Studies. 2018;6(6):1-12.
22. Martínez-Gramage J, Merino-Ramirez M, Amer-Cuenca J, Lisón J. Effect of Kinesio Taping on gastrocnemius activity and ankle range of movement during gait in healthy adults: a randomized controlled trial. Physical Therapy in Sport. 2016;18:56-61.
23. Jung HC, Lee NH, Ok G, Jeon S, Lee S. Acute Effects of Different Stretching Protocols Combined with Potentiating Exercise on Flexibility and Power Performance in Males: 1823 June 2, 2: 30 PM-2: 45 PM. Medicine and science in sports and exercise. 2016;48(5 Suppl 1):498.
24. Eftekhari S, Khayambashi K, Marandi SM, Yosefzadeh M. To compare immediate, 24 and 48 hours effects of static, dynamic and PNF stretching techniques on hamstring flexibility. Journal of Modern Rehabilitation. 2015;9(3):64-71.
25. Arjang N, Mohsenifar H, Amiri A, Dadgoo M, Rasaeifar G. The Immediate Effects of Static versus Proprioceptive Neuromuscular Facilitation Stretching with Kinesiologylogy Taping on Hamstring Flexibility in Teenage Taekwondo Players. Journal of Clinical Physiotherapy Research. 2018;3(4):132-8.
26. Beltrão N, Ritti-Dias R, Pitangui A, De Araújo R. Correlation between acute and short-term changes in flexibility using two stretching techniques. International journal of sports medicine. 2014;35(14):1151-4.
27. Minshull C, Eston R, Bailey A, Rees D, Gleeson N. The differential effects of PNF versus passive stretch conditioning on neuromuscular performance. European journal of sport science. 2014;14(3):233-41.