Türkiye Klinikleri Spor Bilimleri Dergisi
Turkiye Klinikleri Journal of Sports Sciences
Turkiye Klinikleri J Sports Sci. 2020;12(3):267-73

ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

DOI: 10.5336/sportsci.2020-73978

The Acute Effect of Nerve-Gliding Exercises on the Handgrip Strength of Adolescent Tennis Players

Adölesan Tenis Sporcularında Nöral Kaydırma Egzersizlerinin El Kavrama Kuvveti Üzerine Akut Etkisinin İncelenmesi

Bihter AKINOĞLU[a,b], Ezgi ÜNÜVAR[b], Tuğba KOCAHAN[b], Adnan HASANOĞLU[b]

[a]Department of Physiotherapy and Rehabilitation, Ankara Yıldırım Beyazıt University Faculty of Health Sciences, Ankara, TURKEY
[b]Department of Health Services, Sports General Directorship The Ministry of Youth and Sports, Center of Athlete Training and Health Research, Ankara, TURKEY

ABSTRACT Objective: Neural mobilization technique is one of the manual therapy methods that provide mobilization of soft tissues surrounding the neural structures. This study aimed to evaluate the effectiveness of nerve-gliding exercises on the handgrip strength of adolescent tennis players. **Material and Methods:** Thirty-six tennis players (mean age 15.11±1.45 years, mean body height 1.69±0.07 meters and mean body weight 59.01±8.95 kg) were included in the study. The players got nerve-gliding exercises to the median nerve of the dominant side (racket arm) by a physiotherapist for three sets of four minutes. The dominant and non-dominant side handgrip strength was assessed before and after the nerve-gliding exercises. **Results:** It was determined that there was a difference between the dominant and non-dominant extremity handgrip strength and the dominant extremity was stronger before the exercises ($p<0.05$). After the exercises, there was a difference between dominant and non-dominant extremity handgrip strength and the dominant extremity was found to be stronger similarly ($p<0.05$). It was determined that the handgrip strength was similar before and after the nerve-gliding exercises in the dominant side ($p>0.05$). Also, it was found that there was no statistically significant difference between the handgrip strength of the non-dominant side before and after the nerve-gliding exercises ($p>0.05$). **Conclusion:** Nerve-gliding exercises of the median nerve does not have an acute effect on handgrip muscle strength in adolescent tennis players. Studies are needed to investigate the chronic effects of the neural gliding mobilization methods on grip strength in adolescent tennis players.

Keywords: Athletes; median nerve; muscle strength

ÖZET Amaç: Nöral mobilizasyon tekniği, sinir yapısını çevreleyen yumuşak dokuların mobilizasyonunu sağlayan manuel terapi yöntemlerinden biridir. Bu çalışma, sinir kayma egzersizlerinin adölesan tenis sporcularının kavrama kuvveti üzerindeki etkinliğini değerlendirmeyi amaçlamaktadır. **Gereç ve Yöntemler:** Çalışmaya 36 tenis sporcusu dahil edildi (ortalama yaşı 15,11±1,45 yıl, ortalama boy uzunluğu 1,69±0,07 metre ve ortalama vücut ağırlığı 59,01±8,95 kg). Sporcuların baskın taraf (raket kolu) üst ekstremitelerinin median sinirine sinir kaydırma egzersizleri üç set ve her set dört dakika olacak şekilde bir fizyoterapist tarafından uygulandı. Sporcuların baskın ve baskın olmayan taraf kavrama kuvveti sinir kaydırma egzersizlerinden önce ve sonra değerlendirildi. **Bulgular:** Sinir kaydırma egzersizleri öncesinde baskın ve baskın olmayan taraf kavrama kuvveti arasında bir fark olduğu ve baskın ekstremitenin daha güçlü olduğu belirlendi ($p<0,05$). Benzer şekilde egzersizlerden sonra, baskın ve baskın olmayan taraf kavrama kuvveti arasında bir fark olduğu ve baskın tarafın daha güçlü olduğu saptandı ($p<0,05$). Sinir kaydırma egzersizi uygulanan baskın taraf kavrama kuvvetinin sinir kayma egzersizlerinden önce ve sonra benzer olduğu ($p>0,05$), baskın olmayan taraf kavrama kuvvetinde ise sinir kayma egzersizlerinden önce ve sonra istatistiksel olarak anlamlı bir fark olmadığı belirlendi ($p>0,05$). **Sonuç:** Median sinire uygulanan sinir kaydırma egzersizleri adölesan tenis sporcularının kavrama kuvveti üzerinde akut bir etkiye sahip değildir. Adölesan tenis sporcularında sinir kaydırma egzersizlerinin kronik etkilerinin kavrama kuvvetine olan etkilerini araştıracak çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Sporcular; medyan sinir; kas kuvveti

The handgrip strength is defined as the muscular force that the individuals reveal with their intrinsic and extrinsic hand muscles.[1] Handgrip strength is associated with many parameters such as general body muscle strength, wrist and shoulder muscle strength, sport performance, respiratory function, body com-

Correspondence: Bihter AKINOĞLU
Department of Physiotherapy and Rehabilitation, Ankara Yıldırım Beyazıt University Faculty of Health Sciences, Ankara, TURKEY/TÜRKİYE
E-mail: rgkardelen@yahoo.com

Peer review under responsibility of Turkiye Klinikleri Journal of Sports Sciences.

Received: 31 Jan 2020 ***Received in revised form:*** 31 Jan 2020 ***Accepted:*** 29 Apr 2020 ***Available online:*** 09 May 2020

position and nutrition.[2-9] In many sports branches which require power transmission from the arm, a high handgrip strength is necessary to achieve optimal sports performance and prevent injuries.[5]

Handgrip strength is one of the physical parameters that determine the level of racing such as speed, explosive force, upper and lower extremity muscle strength in tennis players.[10] The handgrip strength is a very important parameter for service throwing, forehand and backhand strokes.[11,12] Because about 75% of the strokes in the tennis consists of forehand and service strokes and this requires very strong service strokes and solid ground.[13] During these high-speed activities, the handgrip strength and the stabilization of the wrist are important to hold the racket firmly, to move the racket in accordance with the ball and to perform an effective stroke. This is even more important in sports, such as tennis, which give rise to extreme external rotation in the shoulder and forehand strokes.[14,15]

Neural mobilization technique is one of the manual therapy methods that provides mobilization of soft tissues surrounding the neural structures.[16] The purpose of neural mobilization is to improve neural tissue circulation, reduce edema and pain in the neural tissue, regulate the neuromechanical function and physiological functions in the nerve cell.[16,17] Neural mobilization is a treatment used to rearrange the neural tissue and the dynamic balance around it by providing the appropriate physiological function and is often used in cases of neuro-dynamic (neural mobility) dysfunction.[16,17] Several neural mobilization techniques are available, such as neural gliding, neural stretching, and neural relaxation, each of which is preferred in different situations. In the neural mobilization techniques of the median nerve, the nerve-gliding exercises produce the most mobility in the median nerve bed and neural gliding is a neural mobilizing technique applied to the neural stem to slide the neural body in which one end of a neural stem is extended while the other end is relaxed.[18] The mobilization of the neural structures reduces the pressure in the nerve and thus increases the blood flow to the nerve. It may also increase the neuronal and axonal transport.[19] These dynamic changes in the intraneural structures can increase neural functions.

Neurodynamic tension affects muscle extensibility and stretch tolerance.[20] This tension may change the muscle dynamic and the inner range of the muscle. So that muscle strength may be affected. Because the median nerve is responsible for the innervation of the muscles involved in the deep flexors and thumb, it has a large share in the handgrip function. Therefore, neural mobilization to the median nerve may affect the handgrip strength. There are studies investigating the effect of mobilization exercises on the median nerve in the literature.[21-23] In these studies, it has been reported that neural mobilization exercises increase the hand function and handgrip strength by decreasing the symptoms in cases that cause neuro-dynamic dysfunction such as carpal tunnel syndrome and carpometacarpal osteoarthritis.[21-23] In our study, we aimed to investigate the acute effect of nerve-gliding exercises applied to the median nerve on handgrip strength in healthy population. There is no evidence in the literature that this technique is beneficial or not for healthy individuals, and no studies have been previously conducted to investigate the effect of nerve mobilization technique on muscle strength in healthy individuals. We also did not find any studies investigating this technique in athletes whose muscle strength is important. In line of these knowledge in the literature, it is important to shed light on the methods to improve the handgrip strength and thus sport performance before the competition in sports branches which handgrip strength is important as tennis. So, the aim of our study is to investigate the acute effect of the nerve-gliding exercises on the handgrip strength in adolescent tennis players.

MATERIAL AND METHODS

PARTICIPANTS

This study was designed as a single-blind, controlled trial. This study was carried out at the Ministry of Youth and Sports, Sports General Directorship, Department of Health Services, Center of Athlete Training and Health Research, Ankara, Turkey. The study was performed between January 2019 and April 2019. A total of 36 (21 female, 15 male) adolescent tennis players aged 15.11±1.45 years were included

TABLE 1: Descriptive information of players.

N=36	X±SD
Age (year)	15.11±1.45
Body height (m)	1.69±0.07
Body weight (kg)	59.01±8.95
Body mass index (kg/m^2)	20.67±2.56
Sport age (year)	8±2.00

X±SD: Mean±Standard Deviation.

in the study. Descriptive information of the players included in the study is given in Table 1. After informing the players about the study verbally, written informed consent was taken for study participation from the players and their legal guardian if the participant is under the age of 18. This study was designed according to the Declaration of Helsinki and was approved by the Training and Research Hospital Ethics Committee on Clinical Investigations on 09.01.2019 with the decision number of 2012-KAEK-15/1809. The age of the players, the dominant side, information of how many years they have been doing sports and the history of injuries were taken verbally. Body mass index (BMI) values were calculated by measuring body height and body weights of players.

Inclusion criteria were not having an orthopaedical or neurological problem related to the upper extremity, doing active tennis exercises more than 4 days per week for at least 3 years, volunteering to participate in the study. Exclusion criteria were cervical disc herniation, upper extremity peripheral neuropathies, presence of scoliosis and lateral epicondylitis and shoulder injury, and overuse injuries that may affect handgrip strength.

EVALUATION PROTOCOL

On the first day of the evaluation, handgrip strength of the players who agreed to participate in the study was measured in standing position bilaterally. The next day, the nerve-gliding exercises of the median nerve was applied by the physiotherapist only to the dominant side (racket arm) of the players. Immediately after the nerve-gliding exercises, the handgrip strength of the players was re-tested bilaterally by the same physiotherapist who had previously evaluated the handgrip strength and blinded the application side of the athlete. In statistical analysis, nondominant side was used as control group.

INTERVENTION

Nerve-gliding technique, which is one of the nerve mobilization techniques, consists of combined movements of at least two joints; while one of the movements stretching the nerve across the nerve bed by increasing the tension on the nerve, the other movement reduces the size of the nerve bed without stretching on the nerve. This technique aims to mobilize the nerve by creating minimal tension in the nerve and exposes more longitudinal displacement than techniques extending along the nerve bed such as the stretching technique.[17,18]

In our study, neural gliding to the median nerve was applied to the dominant upper extremity of the players by doing elbow extension (stretching along the median nerve bed) with the wrist flexion (does not load to the nerve) and elbow flexion (no loading) and the wrist extension (nerve stretched) movements which were changed in a consecutive manner. Elbow flexion-extension and wrist flexion-extension angles were adjusted according to the literature.[12,21,24]

The nerve-gliding exercises were made passively by a physiotherapist. While the athlete was lying in supine position, the physiotherapist depressed the athlete's right shoulder towards the inferior with his right elbow. The physiotherapist supported the right elbow of the athlete with her right hand. With her left hand, the athlete's hand grasped while athlete's forearm in supination and fingers in extension. The shoulder was positioned in external rotation during the exercises. To create the slide effect on the median nerve, when the athlete's elbow was flexed, the wrist and fingers were extended and when the athlete's elbow was extended, the wrist and fingers were placed in neutral position. Extension of the fingers was maintained throughout the exercises. The exercises were made in three sets of 4 minutes each, and a break was taken for a minute between the sets.[21]

EVALUATION OF HANDGRIP STRENGTH (KG)

The handgrip strength of the players was assessed using an adjustable hand dynamometer (Grip-D Takei, Tokyo, Japan). Players were told to squeeze the dynamometer maximally for 3 seconds while keeping a neutral upper-extremity position (standing upright, straight arm parallel next to the body, palm facing the body, and wrist neutral). To standardize each measurement, the dynamometer was adjusted for each player based on hand size. Three consecutive trials were performed on each hand, with 10 seconds of rest given between trials. Verbal encouragement by research personnel was given during the trials to help promote maximal exertion.[25] Maximal handgrip strength (kg), calculated as the average of the 3 trials, was recorded for both dominant and nondominant hands. Hand dominance was established by the preference of hand for keeping the tennis racket.

STATISTICAL ANALYSIS

Statistical analysis of the data was made by using Statistical Package for Social Sciences (version 20; SPSS Inc., Chicago, IL, ABD). The Kolmogorov Smirnov Test was used to determine whether the data were appropriate for normal distribution, and it was determined that the data fit the normal distribution. The independent samples t test was used to determine whether there was a significant difference between the baseline and after training values of the dominant and non-dominant hand values. The pre and post nerve-gliding exercises strength change of both groups was determined by paired samples t test. The significance level for all statistical analyzes was considered as $p<0.05$.

RESULTS

As a result of our study, it was determined that there was a difference between the dominant and non-dominant extremity handgrip strength before and after the nerve-gliding exercises and the dominant extremity was stronger ($p<0.05$) (Table 2). It was determined that the handgrip strength was similar before and after nerve-gliding exercises in the dominant extremity and non-dominant extremity ($p>0.05$) (Table 3).

TABLE 2: Comparison of muscle strength of dominant and non-dominant sides before and after nerve-gliding exercises.

n=36	Dominant side handgrip strength X±SD	Non-dominant side handgrip strength X±SD	Strength difference (Δ)	p*
Before nerve-gliding exercises (kg)	32.64±7.48	28.20±6.39	%15,70	0.001**
After nerve-gliding exercises (kg)	33.17±7.04	27.74±5.93	%19,60	<0.001**

* The Independent samples t, **p<0.05.

DISCUSSION

As a result of our study, we aimed to investigate the effects of neurodynamic exercises on muscle strength in healthy adolescent tennis players, we have determined that nerve-gliding exercises of median nerve has no acute effect on handgrip strength in healthy adolescent tennis players.

Although there have been studies investigating the effects of median nerve-gliding exercises on handgrip strength in both symptomatic and asymptomatic individuals in the literature, this is the first study performed in healthy players.[21-23,26,27] In studies performed in symptomatic individuals, it has been reported that median nerve neural mobilization has positive effects on handgrip strength and neural mobilization exercises increases muscle strength in cases of neurodynamic dysfunction.[21-23] It has been argued that this increase in handgrip strength is achieved by decreasing the pain level of neurodynamic applications. It has been reported that individuals can do the test more effectively with decreasing pain level. On the other hand, Likhite et al. investigated the effect of 12-day nerve-gliding exercises on median and ulnar nerve in the asymptomatic healthy individuals. They concluded that the nerve-gliding exercises had no acute or after treatment effect on the handgrip strength and they conclude that the inclusion of asymptomatic individuals is effective in this result.[26] The results of our study and the results of Likhite et al. support each other.

Studies in the literature reported that neural gliding is effective in symptomatic individuals, but has no effect on asymptomatic individuals.[21-23,26-29] In our study, neural mobilization was applied to asymptomatic players who did not have any health problem and it was determined that the handgrip strength of the players did not show a statistically significant increase as a result of our study. However, it was observed that before the neural exercises the difference in handgrip strength between the extremities was 15.7% in favor of the dominant extremity and this difference reached 19.6% after the nerve-gliding exercises in our study. Similarly, Table 3 shows that the handgrip strength was increased by 0.53 kg in the dominant extremity and decreased 0.46 kg in the non-dominant extremity. This increase in the dominant side, also the decrease in the non-dominant side may be clinically significant but is not statistically significant. However, we did not find any information in the literature about how much of an increase or decrease in handgrip strength will reflect the performance positively or negatively. Therefore, we think that there is a need for studies to examine how much the amount of increase or decrease in handgrip strength is at least clinically significant. In addition, it was determined that the handgrip strength of dominant side of our study group, which has a mean age of 15 years, was 32.64 kg before the nerve-gliding exercises. Fernandez-Fernandez et al. reported in their study on the handgrip strength of tennis players according to their age, that the dominant side handgrip strength of U16 level (14-16 years old) tennis players should be between 40-43 kg, and if they are less than 40 kg their handgrip strength needs to be developed.[30] It is seen that the handgrip strength of our study group is low. We think that the fact that the handgrip strength of our study group is less than the values stated in the literature may have affected the results of our study.

TABLE 3: Comparison of dominant and non-dominant sides of handgrip strength before and after nerve-gliding exercises.

	Before nerve-gliding exercises X±SD	After nerve-gliding exercises X±SD	p*
Dominant side handgrip strength (kg)	32.64±7.48	33.17±7.04	0.334
Non-dominant side handgrip strength (kg)	28.20±6.39	27.74±5.93	0.334

* Paired sample t test.

LIMITATIONS

Including asymptomatic players, not evaluating any other parameters, such as the range of motion, using a single neural mobilization exercises and the use of untreated extremities of the players as the control group are the limitations of our study. In addition, the fact that the age of the players we have included in our study may restrict the generalization of our study results. Applying just a single session and the investigation of acute effects is another limitation of our study. Studies will investigate the effects of different neural mobilization exercises with longer intervention of the nerve-gliding technique on different parameters in symptomatic players are needed.

CONCLUSION

In conclusion, our result suggest that neural gliding mobilization of the median nerve does not have an acute effect on handgrip strength in healthy adolescent tennis players. Studies are needed to investigate the chronic effects of the neural gliding mobilization methods on grip strength in adolescent tennis players.

Ethical Approval

Ethical approval for this study was obtained from by the Ethics Committee of Ankara Keçiören Education and Research Hospital Ethical Committee on Clinical Investigations on 09.01.2019 with the decision of 2012-KAEK-15/1809.

Informed Consent

Written informed consent was obtained from each subject.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Bihter Akınoğlu, Tuğba Kocahan; **Design:** Bihter Akınoğlu, Ezgi Ünüvar; **Control/Supervision:** Bihter Akınoğlu, Tuğba Kocahan, Adnan Hasanoğlu; **Data Collection and/or Processing:** Bihter Akınoğlu, Ezgi Ünüvar, Tuğba Kocahan; **Analysis and/or Interpretation:** Bihter Akınoğlu, Tuğba Kocahan; **Literature Review:** Bihter Akınoğlu, Ezgi Ünüvar, Tuğba Kocahan, Adnan Hasanoğlu; **Writing the Article:** Bihter Akınoğlu, Ezgi Ünüvar, Tuğba Kocahan, Adnan Hasanoğlu; **Critical Review:** Bihter Akınoğlu, Tuğba Kocahan, Adnan Hasanoğlu; **References and Fundings:** Tuğba Kocahan, Adnan Hasanoğlu; **Materials:** Tuğba Kocahan, Adnan Hasanoğlu.*

REFERENCES

1. Wang YC, Bohannon RW, Li X, Sindhu B, Kapellusch J. Hand-grip strength: normative reference values and equations for individuals 18 to 85 years of age residing in the United States. J Orthop Sports Phys Ther. 2018;48(9):685-93. [Crossref] [PubMed]
2. Wind AE, Takken T, Helders PJM, Engelbert RHH. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? Eur J Pediatr. 2010;169(3):281-7. [Crossref] [PubMed]
3. Horsley I, Herrington L, Hoyle R, Prescott E, Bellamy N. Do changes in hand grip strength correlate with shoulder rotator cuff function? Shoulder Elbow. 2016;8(2):124-9. [Crossref] [PubMed] [PMC]
4. Lee DR, Kim JSL. Effects of hand grip exercise on shoulder joint internal rotation and external rotation peak torque. J Back Musculoskelet Rehabil. 2016;29(3):521-5. [Crossref] [PubMed]
5. Cronin J, Lawton T, Harris N, Kilding A, McMaster DT. A brief review of handgrip strength and sport performance. J Strength Cond Res. 2017;31(11):3187-217. [Crossref] [PubMed]
6. Kocahan T, Akınoğlu B, Mete O, Hasanoğlu A. Determination of the relationship between respiratory function and respiratory muscle strength and grip strength of elite athletes. Med J Islamic World Acad Sci. 2017;25(4):118-24. [Crossref]
7. Talupuru PK, Kulandaivelan S, Haripriya U, Singh V. Effect of BMI on hand grip strength in elite cricket players. Int J Physiother Res. 2016;4(5):1696-700. [Crossref]
8. Norman K, Stobäus N, Gonzalez MC, Schulzke JD, Pirlich M. Hand grip strength: outcome predictor and marker of nutritional status. Clin Nutr. 2011;30(2):135-42. [Crossref] [PubMed]
9. Flood A, Chung A, Parker H, Kearns V, O'Sullivan TA. The use of hand grip strength as a predictor of nutrition status in hospital patients. Clin Nutr. 2014;33(1):106-114. [Crossref] [PubMed]
10. Girard O, Millet GP. Physical determinants of tennis performance in competitive teenage players. J Strength Cond Res. 2009;23(6):1867-72. [Crossref] [PubMed]
11. Hazar Z, Eker L, Yüksel İ. Demographic and anthropometric factors predicting the grip strength and endurance in adolescent tennis players. Turkiye Klinikleri J Sports Sci. 2015;7(1):24-8. [Crossref]
12. Dimitrova A. Hand grip strength in prepubescent tennis players. Acta Morphol Anthropol. 2017;24(1-2):63-7. [Link]
13. Ellenbecker TS, Roetert EP, Riewald S. Isokinetic profile of wrist and forearm strength in elite female junior tennis players. Br J Sports Med. 2006;40(5):411-4. [Crossref] [PubMed] [PMC]
14. Hernández-Davó JL, Moreno FJ, Sanz-Rivas D, Hernández-Davó H, Coves Á, Caballero C. Variations in kinematic variables and performance in the tennis serve according to age and skill level. Int J Perf Anal Sport. 2019;19(5):749-62. [Crossref]
15. Horsley I, Herrington L, Hoyle R, Prescott E, Bellamy N. Do changes in hand grip strength correlate with shoulder rotator cuff function? Shoulder Elbow. 2016;8(2):124-9. [Crossref] [PubMed] [PMC]
16. Dwornik M, Białoszewski D, Korabiewska I, Wroński Z. Principles of neuro mobilization for treating musculoskeletal disease. Ortop Traumatol Rehabil. 2007;9(2):111-21. [PubMed]
17. Martins C, Pereira R, Fernandes I, Martins J, Lopes T, Ramos L, et al. Neural gliding and neural tensioning differently impact flexibility, heat and pressure pain thresholds in asymptomatic subjects: a randomized, parallel and double-blind study. Phys Ther Sport. 2019;36:101-9. [Crossref] [PubMed]
18. Coppieters MW, Hough AD, Dilley A. Different nerve-gliding exercises induce different magnitudes of median nerve longitudinal excursion: an in vivo study using dynamic ultrasound imaging. J Orthop Sports Phys Ther. 2009;39(3):164-71. [Crossref] [PubMed]
19. Wolny T, Linek P. The effect of manual therapy including neurodynamic techniques on the overall health status of people with carpal tunnel syndrome: a randomized controlled trial. J Manipulative Physiol Ther. 2018;41(8):641-9. [Crossref] [PubMed]
20. Ferreira J, Bebiano A, Raro D, Martins J, Silva AG. Comparative effects of tensioning and sliding neural mobilization on static postural control and lower limb hop testing in football players. J Sport Rehabil. 2018;1-7. [Crossref] [PubMed]
21. Villafa-e JH, Silva GB, Fernandez-Carnero J. Short-term effects of neurodynamic mobilization in 15 patients with secondary thumb carpometacarpal osteoarthritis. J Manipulative Physiol Ther. 2011;34(7):449-56. [Crossref] [PubMed]
22. Basson A, Olivier B, Ellis R, Coppieters M, Stewart A, Mudzi W. The effectiveness of neural mobilization for neuromusculoskeletal conditions: a systematic review and meta-analysis. J Orthop Sports Phys Ther. 2017;47(9):593-615. [Crossref] [PubMed]
23. Wolny T, Saulicz E, Linek P, Shacklock M, Myśliwiec A. Efficacy of manual therapy including neurodynamic techniques for the treatment of carpal tunnel syndrome: a randomized controlled trial. J Manipulative Physiol Ther. 2017;40(4):263-72. [Crossref] [PubMed]
24. Coppieters MW, Butler DS. Do 'sliders' slide and 'tensioners' tension? An analysis of neurodynamic techniques and considerations regarding their application. Man Ther. 2008;13(3):213-21. [Crossref] [PubMed]
25. Toong T, Wilson KE, Urban K, Paniccia M, Hunt AW, Keightley M, et al. Grip strength in youth ice hockey players: normative values and predictors of performance. J Strength Cond Res. 2018;32(12):3494-502. [Crossref] [PubMed]

26. Likhite AS, Balthillaya GM, Prabhu A, Gangavelli R. Effect of upper limb neural mobilization on vibration threshold and hand grip strength in asymptomatic individuals: a randomized controlled trial. J Clin Diagn Res. 2017;11(11):5-8. [Crossref]

27. Wolny T, Linek P. Is manual therapy based on neurodynamic techniques effective in the treatment of carpal tunnel syndrome? A randomized controlled trial. Clin Rehabil. 2019;33(3):408-17. [Crossref] [PubMed]

28. Hesami O, Haghighatzadeh M, Lima BS, Emadi N, Salehi S. The effectiveness of gabapentin and exercises in the treatment of carpal tunnel syndrome: a randomized clinical trial. J Exerc Rehabil. 2018;14(6):1067-73. [Crossref] [PubMed] [PMC]

29. Oskay D, Meriç A, Kirdi N, Firat T, Ayhan C, Leblebicioğlu G. Neurodynamic mobilization in the conservative treatment of cubital tunnel syndrome: long-term follow-up of 7 cases. J Manipulative Physiol Ther. 2010;33(2):156-63. [Crossref] [PubMed]

30. Fernandez-Fernandez J, Ulbricht A, Ferrauti A. Fitness testing of tennis players: how valuable is it? Br J Sports Med. 2014;48 Suppl 1(Suppl 1):i22-31. [Crossref] [PubMed] [PMC]