THE USE OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION FOR INCREASING THROWING PERFORMANCE

USO DA FACILITAÇÃO NEUROMUSCULAR PROPRIOCEPTIVA PARA AUMENTAR O DESEMPENHO DO ARREMESSO

USO DE FACILITACIÓN NEUROMUSCULAR PROPIOCEPTIVA PARA MEJORAR EL RENDIMIENTO DEL LANZAMIENTO

Original Article
Artigo Original
Artículo Original

Thatiana Lacerda Nobre[1]
(Physiotherapist)
Leandro Yanase Rocha[1]
(Physical Education Professional)
Carla Cristina Ramos[1]
(Physical Education Professional)
Flávia de Andrade e Souza Mazuchi[2]
(Physiotherapist)
Patrícia Oliva Carbone[1]
(Physical Education Professional)
Diana Madureira[1]
(Physical Education Professional)
Bruno Rodrigues[3]
(Physical Education Professional)
Érico Chagas Caperuto[1]
(Physical Education Professional)

1. Human Movement Laboratory, São Judas Tadeu University - USJT, São Paulo, SP, Brazil.
2. University of Ottawa, Canada.
3. School of Physical Education, University of Campinas - UNICAMP, Campinas, SP, Brazil.

Correspondence:
Thatiana Lacerda Nobre; Érico Chagas Caperuto
Rua Taquari 546, Mooca, São Paulo, SP, Brazil. 03166-000.
thatianalacerda@gmail.com; ericocaperuto@gmail.com

ABSTRACT

Introduction: Throwing is considered the most important technical skill in Handball. However, it requires the athlete to perform this movement with maximum speed and accuracy, as it can define the final score of the game. Objective: The aim of this study was to evaluate the effect of Proprioceptive Neuromuscular Facilitation, known as the Kabat method, on the throwing performance of handball athletes. Methods: An experimental study of 18 male handball athletes with a mean age of 14 ± 1.13 years. The athletes were divided into two groups: control group (CG) and Kabat method group (KG). The athletes performed 16 training sessions, with analyses at the beginning and end of each session. Range of motion (ROM) of internal and external shoulder rotation, strength, muscle imbalance, throwing speed and accuracy were measured. The results were compared by the Student t-test of repeated measures. Results: KG significantly increased external shoulder rotation and muscle strength in all the analyzed shoulder complex muscles. CG also increased strength, but not in all muscles. KG significantly increased the speed and accuracy of the pitch. Conclusion: The Kabat method, through proprioceptive neuromuscular facilitation, significantly increased throwing performance, speed and accuracy in handball athletes when compared to the control group. ***Level of evidence III; Randomized Experimental Study.***

Keywords: Proprioceptive neuromuscular facilitation; Sport; Shoulder; Muscle strength; Speed meters.

RESUMO

Introdução: O arremesso é considerado a habilidade técnica mais importante do handebol. Porém, exige que o atleta realize esse movimento com máxima velocidade e precisão, visto que ele pode definir a pontuação final do jogo. Objetivo: O objetivo deste estudo foi avaliar o efeito da facilitação neuromuscular proprioceptiva, conhecida como método Kabat, no desempenho de arremesso em atletas de handebol. Métodos: Estudo experimental com 18 atletas de handebol masculino, com média de idade de 14 ± 1,13 anos. Os atletas foram divididos em dois grupos: grupo controle (GC) e grupo método Kabat (GK). Os atletas realizaram 16 sessões de treinamento com análise inicial e final. A amplitude de movimento (ADM) da rotação interna e externa do ombro, a força, o desequilíbrio muscular, a velocidade e precisão do arremesso foram medidos. Os resultados foram comparados com o teste t de Student de medidas repetidas. Resultados: O GK teve aumento significativo da rotação externa do ombro e da força muscular em todos os músculos do complexo do ombro analisados. O GC também teve aumento da força, mas não em todos os músculos. O GK teve elevação significativa da velocidade e da precisão do arremesso. Conclusão: O método Kabat, com a técnica de facilitação neuromuscular proprioceptiva, aumentou significativamente o desempenho, a velocidade e a precisão do arremesso nos atletas de handebol quando comparado com o grupo controle. ***Nível de evidência III; Estudo Experimental Randomizado.***

Descritores: *Facilitação neuromuscular proprioceptiva; Esportes; Ombro; Força muscular; Medidores de velocidade.*

RESUMEN

Introducción: El lanzamiento se considera la habilidad técnica más importante del balonmano. Sin embargo, requiere que el atleta realice este movimiento con la máxima velocidad y precisión, ya que puede establecer el puntaje final del juego. Objetivo: El objetivo de este estudio fue evaluar el efecto de la facilitación neuromuscular propioceptiva, conocida como el método Kabat, en el rendimiento del lanzamiento de atletas de balonmano. Métodos: *Estudio experimental de 18 atletas de balonmano masculino con edad promedio de 14 ± 1,13 años. Los atletas se dividieron en dos grupos: grupo control (CG) y grupo método Kabat (GK). Los atletas realizaron 16 sesiones de entrenamiento con análisis inicial y final. Se midió el rango de movimiento (RDM) de la rotación interna y externa del hombro, la fuerza, el desequilibrio muscular, la velocidad y la precisión de lanzamiento. Los resultados se compararon con la prueba t de Student de medidas repetidas. Resultados: El GK tuvo un aumento significativo en la rotación externa del hombro y la fuerza muscular en todos los músculos del complejo del hombro analizados. El CG también tuvo aumento en la fuerza, pero no en todos los músculos. El GK tuvo un aumento significativo en la velocidad y precisión del lanzamiento. Conclusión: El método Kabat, con la facilitación neuromuscular propioceptiva, aumentó significativamente el rendimiento, la velocidad y la precisión del lanzamiento en los atletas de balonmano en comparación con el grupo control.* ***Nivel de evidencia III; Estudio experimental aleatorizado.***

Descriptores: *Facilitación neuromuscular propioceptiva; Deportes; Hombro; Fuerza muscular; Medidores de velocidad.*

DOI: http://dx.doi.org/10.1590/1517-869220202604185184
Article received on 09/11/2017 accepted on 11/06/2019

INTRODUCTION

Handball is a high intensity and short duration sport that emphasizes motor capacities such as speed and strength, especially explosive strength and power because of the high speed demanded in the execution of movements.[1] During practice and games, athletes perform many jumps, blocks, sprints and throws.[2]

Throw is considered the most important technical ability of this modality, and it is the main gesture performed by the players, since it can set the final score.[3,4] Therefore, upper dominant limb injuries are considered common in this sport.[1,5]

During the training sessions, or even during the preparation that precedes a sport competition, the team usually performs some exercises to warm up as well as to stretch the major muscle groups required by the sport by doing some specific movements, all this in order to prepare the body for the sport.[6,7]

There are several physiological reasons for performing such practices, increasing the muscle and body temperature, energy metabolism and stimulating tissue elasticity (muscles, tendons and ligaments). The production of synovial fluid, increases in the cardiac output and peripheral blood flow, improvement in central nervous system function, motor unit's recruitment and an increase in nerve impulse conduction are some other reasons to warm up.[8] All these changes improve the efficiency and fluidity of the sport gesture.[9]

The Kabat method, also known as Proprioceptive Neuromuscular Facilitation, is a physical therapy technique that uses specific diagonal and spiral movement patterns in all three body planes, as well as stimuli to the neuromuscular trigger potential, to improve the musculoskeletal system responses.[9] This technic is based on the principles of maximum stimulation of the neuromuscular apparatus, followed by the support of auditory, visual, tactile and proprioceptive stimuli.[10]

The main objectives of this technique are to provide learning and motor coordination, increase performance, restore or increase flexibility and range of motion, strengthen weakened muscles or muscle groups and decrease the imbalance between muscle groups.[11,12]

Although it was developed as a treatment for patients with organic and sedentary disorders, it can also be applied to health patients; however, it has not been used before to improve athlete's physical performance.[13] So the purpose of this study was to evaluate how the proprioceptive neuromuscular facilitation technique, the Kabat method, influences the throwing of Handball athletes.

So the purpose of this study was to evaluate how the proprioceptive neuromuscular facilitation technique, the Kabat method, influences the throwing of Handball athletes.

METHODS

This study was approved by the Ethics Committee of the University São Judas Tadeu – São Paulo/ Brazil under the protocol number CAAE 14522513.8.0000.0089.

Initial sample was composed of 21 male handball athletes with a mean age of 14 ± 1.13 years. Participants were divided in two groups randomly, a control group (CG), with an initial number of subjects of 10 athletes and the Kabat group (KG), with an initial number of 11 subjects. The study ended with seven subjects in CG (three athletes gave up practive) and eleven subjects in KG.

All participants and their parents/guardians signed the consent form authorizing and consenting participation in this study.

Before the start of the protocol, all including criteria were observed. All athletes should be training and have attended at least one full competitive season. In addition to not do any weight training or some other type of strength training. Athletes were excluded if they reported any type of pain, swelling and orthopedic injuries associated with the dominant upper limb, if they were unable to achieve maximum voluntary speed in a throw; or any other signs or characteristics that would indicate not to apply the proprioceptive neuromuscular facilitation technique through Kabat method.

Participant's dominant member range of motion (ROM) of the shoulder internal and external rotation was evaluated, using a goniometer (Carci®).

For muscle strength and balance measurements, we used the manual muscle test proposed by Kendall,[14] with a grade ranging from 0 to 10, in the following muscles: anterior deltoid, middle deltoid, posterior deltoid, biceps brachial, coracobrachialis, supraspinatus, pectoralis major, pectoralis minor, infraspinatus, teres larger, teres minor, subscapularis, latissimus dorsi, upper trapezius, middle trapezius, lower trapezius, rhomboids, serratus anterior, triceps brachial, levator scapulae.

The throw speed (km/h) was evaluated using a portable gun shaped radar, (Bushnell® Speedster III). To standardize the assessment of speed, the evaluator remained positioned two meters away, behind the athlete, with the radar facing the goal and at the time of the throw the radar button was held down for measuring speed.

The accuracy of the throw was assessed by the number of hits in the right and left top corner of the goal post, in a specific area marked by red tape. The athletes were instructed to perform the throw alternately to the right and then to the left, if the throw hit any other places of the goal post or out of it, it would be counted as an error.

Participants had five rounds for familiarization and then performed the test with ten throws, standing in the seven meters line. The throw should be of the higher kind, that is, above the shoulder line.

The control group (CG) continued with its training routine proposed by their coach. This routine was composed of a set of warm up exercises and a training session that comprised drills and tactical exercises.

The Kabat group did the Kabat session and joined the training right after the warm up exercises.

During the first session the athletes received training notions to be presented to and experience the technique of rhythmic initiation.

In the following sessions the technique used was the dynamic reversion, which is characterized by the alternation of the resistance against the active movement from one direction (agonist) to the opposite direction (antagonist) without any interruption or relaxation.

The execution of the movement was performed according to the method standard, individuals should be in a supine position, with shoulder flexion to 90°, elbow extension, wrist in a neutral position and extended fingers. Dynamic reversion was made in diagonal patterns of the upper limb: Flexion - Abduction external-rotation and extension - Adduction internal-rotation; Flexion - Adduction - External Rotation and Extension - Abduction - Internal Rotation.

In the beginning of the sessions we also used the technical approach of ending the movement gradually and slowly, followed by a stimulation technique and stretch reflex. For each diagonal we used two sets of fifteen repetitions each, with 30 seconds interval between the sets. On every three sessions there were five repetitions added to the total amount.

At the end of each session, it was presented to the athletes the modified Borg scale, where each of them (in isolation from other teammates), pointed to the number that symbolized their rate of perceived exertion. Each training session lasted approximately 10 to 15 minutes.

The Kolmogorov Smirnov test was initially used to determine the normality of the data, after that, we used repeated measures, one way ANOVA to compare between the different assessment moments (initial and final – within subjects) and to compare the different groups (Control and Kabat groups – between subjects) respectively. T test was used for paired comparisons and significance was set to $p<0.05$.

RESULTS

The groups were compared at different time points (Initial and Final) for range of motion variables, muscle strength graduation, speed and accuracy of the throw.

The amplitude of internal and external rotation of the shoulder showed significant increase only for KG in the external rotation movement. (Table 1)

When muscle strength was analyzed, CG showed a significant increase in the strength of some muscles of the shoulder complex. However, this result was not observed in the following muscles: anterior deltoid, supraspinatus and teres minor; muscles that actively participate in the three stages of the throw (preparation, acceleration and deceleration), the teres larger muscle, which only presents itself activated during the acceleration phase, and the Rhomboids muscle, more active in the phases of acceleration and deceleration of the throw.

KG showed a statistically significant increase in the strength in all analyzed muscles from the shoulder complex. (Table 2)

Regarding throwing speed, Kabat group was the only group that showed a significant increase in the throwing velocity values as shown in the graph below. (Figure 1)

When we measured accuracy, once again, Kabat group was the only group that showed significant increase, as shown in the following graph. (Figure 2)

After each training session, the Borg scale values were collected in order to evaluate the level of effort used in the Kabat procedure, those can be seen in the table below. (Table 3)

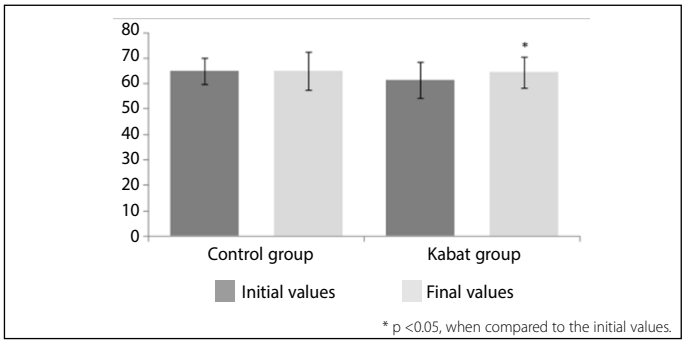

Figure 1. Initial and final values for throwing speed (km/h) for both groups (means and standard deviations).

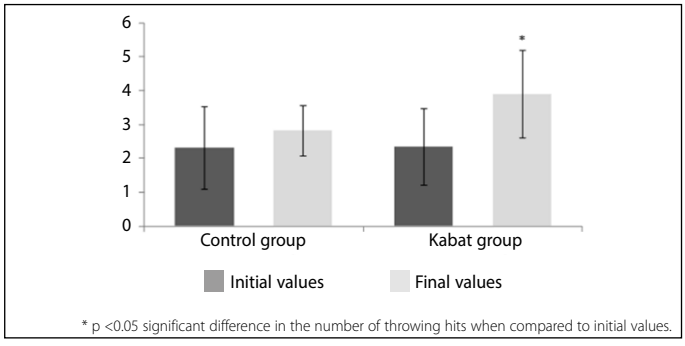

Figure 2. Initial and final values of accuracy of the throw (target hits) for both experimental groups (means and standard deviations).

Table 1. Range of motion (degrees), internal and external rotation, initial and final values of the dominant shoulder.

Range of motion (Degrees) in the internal and external rotation of the shoulder				
	Control group		Kabat group	
	Initial values	Final values	Initial values	Final values
Internal rotation	44.29 ± 10.97	39.29 ± 10.18	43.36 ± 9.51	48.18 ± 9.82
External rotation	79.29 ± 13.05	74.29 ± 11.57	77.73 ± 12.72	86.82 ± 5.60*#

* p <0.05, when compared to the initial values # p <0.05, when compared to control group.

Table 2. Strength grading of each shoulder complex muscle related to the throw movement (mean and standard deviation of the initial and final values).

Throwing muscles strength grade.				
	Control group		Kabat group	
Muscles	Initial values	Final values	Initial values	Final values
Anterior deltoid	6.86 ± 0.90	7.71 ± 0.76	6.45 ± 0.52	9.27 ± 0.65*
Middle deltoid	6.71 ± 0.95	7.57 ± 0.53*	6.91 ± 0.70	9.45 ± 0.52*
Posterior deltoide	7.14 ± 0.90	7.86 ± 0.69*	7.00 ± 0.63	9.73 ± 0.47*
Biceps brachial	7.00 ± 0.82	8.57 ± 0.53*	7.00 ± 1.00	9.82 ± 0.40*
Coracobrachialis	7.14 ± 0.69	7.86 ± 0.38*	6.64 ± 0.92	9.36 ± 0.50*
Supraspinatus	7.57 ± 0.79	7.71 ± 0.49	7.09 ± 0.94	9.27 ± 0.47*
Pectoralis major	7.00 ± 1.00	8.00 ± 0.58*	6.73 ± 0.79	9.36 ± 0.67*
Paectoralis minor	7.29 ± 0.95	7.86 ± 0.69*	7.27 ± 0.65	9.73 ± 0.47*
Infrastructure	6.57 ± 0.53	8.00± 0.58*	6.55 ± 0.69	9.55± 0.52*
Teres larger	7.14 ± 0.69	7.86 ± 0.90	7.36 ± 0.92	9.18 ± 0.40*
Teres minor	7.00 ± 0.82	7.57 ± 0.53	6.91 ± 0.83	9.27 ± 0.79*
Subscapularis	6.71 ± 0.49	7.86 ± 0.38*	7.18 ± 0.40	9.64 ± 0.50*
Latissimus dorsi	6.71 ± 0.49	7.86 ± 0.69*	6.82 ± 0.60	9.18 ± 0.75*
Upper trapezius	7.29 ± 0.76	8.00 ± 0.82*	6.55 ± 0.82	9.18 ± 0.60*
Middle trapezius	6.29 ± 0.76	7.43 ± 0.53*	5.82 ± 0.75	8.91 ± 0.70*
Lower trapezius	6.29 ± 0.49	7.43 ± 0.53*	5.45 ± 0.69	8.64 ± 0.67*
Rhomboids	6.71 ± 0.76	7.00 ± 0.58	6.00 ± 1.00	8.91 ± 0.54*
Serratus anterior	7.14 ± 0.69	8.14 ± 0.38*	7.18 ± 0.60	9.45 ± 0.52*
Triceps brachial	6.86 ± 0.69	7.71 ± 0.49*	6.36 ± 0.50	9.09 ± 0.70*
Levator scapular	7.14 ± 0.38	8.29 ± 0.76*	7.00 ± 0.63	9.73 ± 0.47*

* p <0.05 significant differences between initial and final values.

Table 3. Perceived exertion values (Modified Borg Scale) in each training session reported by the athletes (mean values and their standard deviations).

Modified borg scale values after the Kabat procedure	
Session 1	3.55 ± 2.07
Session 2	3.59 ± 1.39
Session 3	3.73 ± 2.00
Session 4	4.36 ± 1.69
Session 5	4.55 ± 1.37
Session 6	3.91 ± 1.38
Session 7	5.45 ± 1.57
Session 8	4.36 ± 1.36
Session 9	4.55 ± 1.57
Session 10	5.27 ± 1.95
Session 11	4.64 ± 1.43
Session 12	5.18 ± 1.47
Session 13	5.45 ±1.37
Session 14	5.00 ± 1.41

DISCUSSION

The practice of throwing gives the handball athlete a marked change in the mobility of the complex of the dominant shoulder, presenting greater angles for external rotation and smaller angles to shoulder internal rotation.[15,16]

The findings of this study confirm the reports in the literature since both groups showed angle values of shoulder external rotation larger than the values of internal rotation.

Almeida et al.[17] believe that the deficit in internal rotation and increased external rotation is a result of a natural morpho-functional adaptation in the dominant shoulder of the athletes. The increase in external rotation is associated with the presence of the static and dynamic microtrauma that restricts the shoulder, leading to the contraction of the posterior capsule, the stretching of the anterior capsule and adaptations of the humerus bone region, causing changes in the soft tissues of the shoulder complex region as a result of the frequency of the sport gesture.[15,18,19]

However, in our study, due to the Kabat method intervention, we could observe an increase in the angle of motion in internal and external rotation of the shoulder. But, only the range of motion of the external shoulder rotators achieved a statistically significant increase.

Sports that involve throwing motion require their participants to coordinate actions of the shoulder muscles and their interaction with other regions of the body.[15] Chelly et al[18] reported that strength training provides an increase in multi-joint operations. These authors state that strength training is also important in tasks considered either simple or complex, due to the neuromuscular activation, because it is able to activate muscle more efficiently in the early development of strength, and that can help to stabilize a joint, considered, so far, as unstable.

In this study we could see increased muscle strength in the control group. However, the significant increase in muscle strength did not happen in certain muscles, such as the anterior deltoid, supraspinal and teres minor, which are activated in the three phases of the throw (preparation, acceleration and deceleration). The same happened to the teres minor, which is only used in the acceleration phase and the rhomboids, more active in the phases of acceleration and deceleration of the throw. It is believed that this deficit in the strength of these muscles can cause some kind of imbalance in the shoulder complex muscle synergy, changing the throwing gesture and, thus, its results in the sport.

Kabat group showed an increase in the strength of all evaluated muscles from the shoulder complex. This result suggests greater harmony in the throwing gesture and synergism between the muscles activated during each phase of the throw. Proprioceptive Neuromuscular Facilitation is an excellent technique for muscle strength training as it is based on the application of specific resistance to help muscle contraction from a neuromuscular point of view, thus favoring gains in muscle strength in a more comprehensive and synergistic manner.[9,20]

According to Kofotolis and Kellis[13] the reasons for increased strength and improved coordination between the muscles involved in the sport gesture is due to increased muscle activation by the nervous system, with increased recruitment of motor units.

Other studies conducted by Huo et al.[21] and Rhyu et al[9] report that proprioceptive neuromuscular facilitation promotes improvements on motor learning, performance, flexibility, range of motion, muscle strength and motor coordination.

Escobar-Hurtado and Ramírez-Vélez[22] describe that the Kabat method promotes responses in the neuromuscular system mechanism, improving the range of motion and muscle force also due to the benefits on vascular function. The activation of large muscle groups favors the increase in blood flow during the performance of movements used in daily life activities.

For Song et al[12], PNF uses proprioceptive information, and can be used to improve physical performance of athletes, it also uses specific diagonal and spiral patterns of movement, being an important afferent stimuli, by doing that, the technique also stimulates the neuromuscular potential, providing better responses from all the musculoskeletal system.

These studies confirm the findings of our study, which are consistent with the objectives of PNF through the Kabat method, such as to enhance the coordination of the sport gesture, muscle strength, joint stability and to promote a decrease in muscle imbalance due to the execution of a specific movement using multiple muscle groups and not one single muscle isolated.

Usually, the throw movement is usually initiated by the large muscle groups in the proximal region, with fast muscles continuing to end the sequence. These fast muscles improve the accuracy due to the fewer muscle fibers that each motor neuron innervates, providing a better neuromuscular control. In a correct sequence, the proximal segments move before the distal ensuring that the muscles are stretched to develop tension.[23] Thus, one of the main objectives of training, in this sport, is to increase the speed and the throwing accuracy since the possibility of scoring the goal largely depends on these muscles.[4]

As the throw is one of the most technical movements performed in the game, it requires the player maximum voluntary contraction and speed in the gesture because the faster the ball is thrown to the goal, the less time the defense and the keeper will have to defend this move.[1,3]

Many motor abilities require performance with speed and accuracy, which is the case, for example, to throw a ball, to kick a penalty in soccer and others. These skills require fast and accurate movements to produce good results, however, there is a phenomenon known as Speed-Precision Exchange. This phenomenon, known as Fitts' Law, states that in motion tasks where precision is required, speed is influenced. Thus, precision emphasis reduces speed, in the same way that speed emphasis reduces precision. That is one fundamental principles of motor behavior.[24]

We believe that the athletes of this study presented more accurate throws because they have reached a performance level higher than the others in the control group, due to the Kabat intervention. They improved the range of motion of the shoulder complex, with direct influence on muscle strength, therefore being able to perform the task with maximum speed and accuracy, with better performance in the throwing movement. That would probably mean better results in the sport gesture and, consequently, in the game.

CONCLUSION

We concluded that Proprioceptive Neuromuscular Facilitation through the Kabat method, promoted a significant increase in the throwing performance, improving the speed and accuracy of the sport gesture of the athletes.

ACKNOWLEDGEMENTS

The authors would like to thanks Sport Club Corinthians Paulista, where the subjects were recruited and the tests were carried out.

CAPES Brazilian support agency collaborated with this research.

All authors declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: Each author made significant individual contributions to this manuscript. TLN, LYR, POC, DM, CCR and ECC: substantial contributions to the conception, design of the work, analysis and interpretation of the data for the work; TLN, FASM, BR and ECC: writing the work and critical review of the intellectual content; TLN and ECC: writing, statistical analysis and intellectual concept of the article, and preparation of the entire research project. All the authors revised and approved the final version of the manuscript

REFERENCES

1. Zapartidis I, Skoufas D, Vareltzis I, Christodoulidis T, Toganidis T, Kororos P. Factors influencing ball throwing velocity in young female handball players. Sports Med J. 2009;3:39-43.
2. Manchado C, Tortosa- Martínez J, Vila H, Ferragut C, Platen P. Performance factors in women's team handball: physical and physiological aspects - a review. J Strenght Cond Res. 2013;27(6):1708-19.
3. Marques MC, van den Tillaar R, Vescovi JD, Gonzalez-Badillo JJ. Relationship between throwing velocity, muscle power, and bar velocity during bench press in elite handball players. Int J Sports Physiol Perform. 2007;2(4):414-22.
4. Pontaga I, Zidens J. Shoulder rotator muscle dynamometry characteristics: side asymmetry and correlations with ball-throwing speed in adolescent handball players. J Hum Kinet. 2014;42:41-50.
5. **Rousanoglou EN, Noutsos KS, Bayios IA, Boudolos KD. Self-paced and temporally constrained throwing performance by team-handball experts and novices without foreknowledge of target position. J Sports Sci Med. 2015;14(1):41-6.**
6. Fradikin AJ, Gabbe BJ, Cameron PA. Does warming up prevent injury in sport? The evidence from randomised controlled trials?. J Sci Med Sport. 2006;9(3):214-20.

7. Woods K, Bishop P, Jones E. Warm-up and stretching in the prevention of muscular injury. Sports Med. 2007;37(12):1089-99.

8. Taylor KL, Sheppard JM, Lee H, Plummer N. Negative effect of static stretching restored when combined with a sport specific warm-up component. J Sci Med Sport**.** 2009;12:657-61.

9. Rhyu HS, Kim SH, Park HS. The effects of band exercise using proprioceptive neuromuscular facilitation on muscular strength in lower extremity. J Exerc Rehabil. 2015;11(1):36-40.

10. Adler SS, Beckers D, Buck M. PNF: Proprioceptive Neuromuscular Facilitation - An illustrated guide. 2ed. Manole; 2007.p. 3 e 4.

11. Lee CH, Hwangbo K, Lee IS. The effects of combination patterns of proprioceptive neuromuscular facilitation and ball exercise on pain and muscle activity of chronic lowback pain patients. J Phys Ther Sci. 2014;26:93-6.

12. Song HS, Park SD, Kin JY. The effects of proprioceptive neuromuscular facilitation integration pattern exercise program on the fall efficacy and gait ability of the elders with experience fall. J Exerc Rehabil. 2014;10(4):236-40.

13. Kofotolis N, Kellis E. Effects of two 4-week propriocptive neuromuscular facilitation programs on muscle endurance, flexibility, and functional performance in women with chronic low back pain. Phys Ther. 2006;86(7): 1001-12.

14. Kendall FP, McCreary EK, Provance PG. Muscles – Testing and Function with posture and pain. 5 ed. Lippincott Williams & Wilkins; 2007. p. 23.

15. Borich MR, Bright JM, Lorello DJ, Cieminski CJ, Buisman T, Ludewing PM. Scapular angular positioning at end range internal rotation in cases of glenohumeral internal rotation deficit. J Orthop Sports Phys Ther. 2006;36(12):926-34.

16. Genevois C, Berthier P, Guidou V, Muller F, Thiebault B, Rogowski I. Effects of 6-week sling-based training of the external-rotator muscles on the shoulder profile in elite female high school handball players. J Sport Rehabil. 2014;23(4):286-95.

17. Almeida GP, Silveira PF, Rosseto NP, Barbosa G, Ejnisman B, Cohen M. Glenohumeral range of motion in handball players with and without throwing-related shoulder pain. J Shoulder Elbow Surg. 2013;22(5):602-7.

18. Chelly MS, Hermassi S, Shephard RJ. Relationships between power and strength of the upper and lower limb muscles and throwing velocity in male handball players. J Strength Cond Res. 2010;24(6):1480-7.

19. Clarsen B, Bahr R, Andersson SH, Munk R, Myklebust G. Reduced glenohumeral rotation, external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries among elite male handball players: a prospective cohort study. Br J Sports Med. 2014;48(17):1327-33.

20. Witt D, Talbott N, Kotowski S. Eletromiographic activity of scapular muscles during diagonal patterns using elastic resistance and free weights. Int J Sports Phys Ther. 2011;6(4):322-32.

21. Huo M, Maruyama H, Kaneco T, Naito D, Koiso Y. The immediate effect of lumbar spine patters of neuromuscular joint facilitation in young amateur baseball players. J Phys Ther Sci. 2013;25(12):1523-4.

22. Escobar-Hurtado C, Ramírez-Vélez R. Proprioceptive neuromuscular facilitation (PNF) and its impact on vascular function. Colomb Med. 2011;42(3):373-8.

23. Rousanoglou EN, Noutsos KS, Bayios IA, Boudolos K. Ground reaction forces and throwing performance in elite and novice players in two types of handball shot. J Hum Kinet. 2014;40:49-55.

24. Magill RA. Motor Learning and Control- Concepts and Applications. 8 ed. The McGraw Companies, 2007. p. 170-1.