J. Appl. Environ. Biol. Sci., 5(11)53-58, 2015
© 2015, TextRoad Publication

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Effects of Strength Training on Neuromuscular Coordination in Male Pool Players

Karim Salehzadeh*[1], Behrouz Ghorbanzadeh[2]

[1, 2] Assistant Professor, Dept. of Physical Education, Faculty of Educational Sciences, Azarbaijan Shahid Madani University, Tabriz, Iran.

Received: June 15, 2015
Accepted: September 23, 2015

ABSTRACT

Weight lifting trainings play an important role in improving overall sports performance through increasing muscle power, hypertrophy, kinetic performance, balance and neuromuscular coordination. The present study aims to investigate the effects of strength training on neuromuscular coordination in poll players. In this study, 30 pool players were randomly assigned into control (n=15) and experimental (n=15) groups. The experimental group participated in a 12-week strength exercise program along with their regular pool training. Exercise regimen consisted of 90 minutes strength training 3 sessions/week.. The control group participated merely in pool training. Prior to and following experimental period data were collected using arm ruler, dart and ball tests and electromyography measurements. Data were analyzed using Statistical test of kolmogrov-smirnof, Pierson Correlation Coefficient and independent t-test at significance level of $P<0$.

Results of the study revealed that the relationship between strength training and reaction time, neuromuscular coordination, target tracking and neuromuscular compatibility of dominant hand was significant; however, the relationship between strength training and neuromuscular compatibility and target tracking of non-dominant hand was insignificant. Findings revealed that strength training increase neuromuscular coordination and compatibility in pool players and improve their targeting.

KEYWORDS: Strength training, neuromuscular coordination, Reaction time, neuromuscular compatibility, Pool Players.

INTRODUCTION

Muscular strength is the base of physical health and fitness and is fundamental for all sports (Khajeh Ne'mat, et al. 2014). Increasing muscular power and neuromuscular coordination is an important physical fitness factor for both body builders and physically active individuals and a minimum level of strength is needed to live a healthy life (Rahimi, et al. 2014). Poor coordination between muscular groups can cause abnormal movements in body parts and this may lead to poor performance and malformation (Hemayat Talab, 2012). Strength trainings improve physical performance by increasing muscle mass, power, strength, speed, kinetic performance, balance and neuromuscular coordination and (Kraeme & Ratamess, 2004). Most researchers believe that muscular power increases through neural or muscular compatibilities or a combination of both. They believe that before beginning a structural change in the muscle, its strength may increase as a result of the change in motor units (Banayi Far, et al. 2011). In other words, strength trainings create new neural channels ending in higher coordination between muscular groups involved in a specific muscular activity (Damirchi, et al. 2007). Several studies have investigated the effects of strength training on the number of Acetylcholine receptors (AchR) and have reported that strength training significantly increases AchR in the muscle (Parnow, et al. 2012). However, in spite of the undeniable effect of strength training on muscle structure and underlying neural mechanisms, recent studies have focused on the effects of strength training on performance. For instance, Kavei, et al. (2014) demonstrated that plyometric and speed trainings have similar mechanism and the plyometric exercise or plyometric exercise combined with speed running induce similar performance improvements. They suggested that these improvements might have been originated from neural adaptations probably caused by further motor units recruitment and faster neural discharge. Yet, it does not seem that changes in motor reflex play roles in these adaptations. In contrast, Hamre (2013) indicated that fitness factors including reaction time and neuromuscular coordination did not change following a six-week plyometric training. In spite of this contradiction, other studies have reported bilateral effects between strength training and neuromuscular coordination. Enoka, et al. (2012) suggested that the most important factor increasing neuromuscular strength and coordination is the neural system. They found that without neural adaptations strength would not increase. Regarding physiological effects of strength training on neuromuscular system Zarei, et al (2013) showed that that plyometric training induce great changes in neuromuscular coordination and compatibility which leads to increased muscles power, faster reaction and improved sports performance. Accordingly, studies conducted by McCarthy, et al. (2012), Tine-Alkjear, et al. (2013) and Menz, et al. (2013) approved of the relationship between two variables.

***Corresponding Author:** Karim Salehzadeh, Assistant Professor of Sports Physiology of Azarbaijan Shahid Madani University, Tabriz, Iran. TEL. +98 9143194653, Email: salehzadeh@azaruniv.edu

However, the nature and manner of neuromuscular coordination and compatibility induced by strength programs is not very well understood. Moreover, results from various studies are contradictory (Wulkow, et al. 2011). Studies have reported that developments in neural system occur in primary stages of training and structural formation of muscles (hypertrophy) follows this stage. Furthermore, lack of enough understanding about the nature of neural conductivity, whether it is hereditary or adaptability, poses a question that neural compatibilities do not occur or are not significant in trained athletes (Bompa, 2008).

Considering the contradictory results and increasing attention to strength trainings to improve physical fitness, proposing novel solutions for succeeding in international events of different sports including emerging individual and team sports seems to be crucial. Therefore, this question arises that whether strength training increase neuromuscular coordination and compatibility in pool players and improves target tracking and shot control. Thus, the present study investigates the effects of strength training on neuromuscular coordination in pool players.

MATERIALS AND METHODS

This is an applied quasi-experimental study with pre-test post-test design. The study population included all 30 pool players in the city of Mianeh with at least three years' experience in the year 2014. The statistical sample was decided to be all the subjects present in the statistical population. Subjects (mean age: 20.8± 1.24 yrs, mean height: 178± 3.92 cm and mean weight: 81± 3.95 kg) were randomly assigned into control (n=15) and experimental (n=15) groups. Following an orientation session at the beginning of the study, the experimental group performed 12-week strength training program. The exercise regimen included 90 minutes strength training 3 session/week. To apply appropriate overload, exercise intensity was set based on the n1RM assessed at the end of each period. Each session consisted of Bench press, biceps barbell curl, triceps barbell curl, lat pull, barbell Lift. Larger muscles were before smaller ones and multiarticular trainings were conducted before monoarticular ones. Trainings had four stages including warm up with 50% maximum strength and the following stages with 70, 80 and 85% maximum strength with 12, 8 and 6 repetitions respectively. The control group attended pool training exclusively. The tests for collecting data were conducted in two stages of pre and posttests including maximum strength (1RM) for five exercises including bench press, biceps barbell curl, triceps barbell curl, let pull and barbell lift. the exercises were performed on the Techno Jim machines which recommended exercises for each individual using their information such as weight, height, gender and level of the exercise and the following formula, (Bompa, 2011).

$$1RM= weight/ 1.0278- repetition*0.0278$$

Neslosn's reaction test was also conducted to measure action and reaction time of hands, dart test for measuring muscular coordination, electromyography test of muscles for measuring neuromuscular coordination and pool ball shooting test to measure target tracking. The electromyography test for measuring neuromuscular coordination has been used in several studies and has been validated. The reliability of the test of targeting pool ball is reported to be 0.78 (Agred, 2002 and Orbe, 2005). The reliability coefficient of Nelson's Reaction test for measuring the action and reaction time of hands was reported by Arazi (2011), Hemayat Talab (2012) and Hamare (2013) to be 0.855, 0.864 and 0.89 respectively. Moreover, the validity coefficient of dart test to measure neuromuscular coordination was also reported by Arazi (2011) and Hamare (2013) to be 0.76 and 0.83 respectively. In other words, these tests are of decent validity.

Data Collection

After careful preparation of skin (shaving it, clearing and disinfecting it with alcohol) two surface electrodes for muscular electromyography were put on biceps and triceps with two centimeter distance from each other. The reference electrode was put on the tendon of biceps and triceps, the active electrode was put on distal point of biceps and triceps and finally the ground electrode was put on the forearm muscle. Subjects were asked to contract biceps and triceps isometric ally. Neural activity of the muscle was recorded at the maximal voluntary isometric contraction. The neural activity was recorded and the EMG amplitude was analyzed by E B Neuro System device made in Italy.

In order to investigate the effects of strength training on reaction time, neuromuscular coordination and compatibility and target tracking, before and 48 after experimental period measurements were performed. Before beginning the pretest the subjects were introduced to all devices and stages of the experiment and a pilot test was conducted. The subjects were asked to attend training sessions regularly and avoid consuming any supplement or medicine during the test. They were also asked to have enough sleep. They were advised to have a one-day rest before pre and posttests. Participants were provided a detailed study overview and a written consent was filled in by participants at the beginning of the study. Subjects had been ensured to be able to cut-off cooperation at any time without any particular reason. Before taking records, the subjects performed stretching exercises for 5-10 minutes. After a 5 minutes of rest, each subject conducted reaction tests, electromyography and throwing dart test alternatively. In order to record the reaction time, the Nelson's ruler test was used. In this test, the records from both hands and each hand separately were recorded by a ruler three times. In order to record the neuromuscular coordination, dart-throwing test was applied. In this test, a target board with 10 scored circles was used. The furthest circle from the centre was scored 10 and the nearest one to the centre was scored 100. Subjects throw darts from a three-meter distance to the board installed at 2 meter and 15 centimeters height. Each subject had three throws. They were not allowed to bend forward or lift their foot. Their records were calculated by two professional testers. The subjects were advised not to do any specific activity one day before the tests. Nelson's reaction time, dart throwing and measuring height, weight, and arm perimeter and arm length were conducted in the pool salon.

Data were analyzed using SPSS for Windows version 21. Distribution of data was assessed for normality using Kolmogorov–Smirnov. Paired *t*-test was used to compare the pre-test (week 0) and post-test (week 12) values in each group. Relationships between the variables were examined by Pearson's correlation test (r). Statistical significance was set at $P<0.05$

RESULTS

The normal distribution of the data, presented in table 1, was examined and confirmed by Kolmogorov–Smirnov statistical test.

Table 1. Single sample Kolmogorov–Smirnov test (K-S)

group	test	control		experimental	
		pretest	posttest	pretest	posttest
reaction time	Z	0.18	0.15	0.2	0.14
	P	0.83	0.41	0.13	0.51
dart throwing	Z	0.47	0.58	0.41	0.28
	P	0.17	0.15	0.14	0.15
EMG	Z	0.43	0.14	0.44	0.57
	P	0.14	0.17	0.14	0.16
Target tracking	Z	0.52	0.48	0.18	0.28
	P	0.12	0.14	0.17	0.14

The reports of Pearson's correlation test (r) for relationship between variables is presented in table 2.

Table 2. The relationship between strength training and reaction time, neural-neuromuscular coordination and neuromuscular compatibility of dominant and non-dominant hands

strength training	variable	reaction time of dominant hand
	Pierson coefficient	0.297
	P	0.002
	Number	15
Strength training		reaction time of non-dominant hand
	Pierson coefficient	0.541
	P	0.04
	Number	15
strength training		Neuromuscular coordination of dominant hand
	Pierson coefficient	0.341
	P	0.039
	Number	15
Strength training		Neuromuscular coordination of non-dominant hand
	Pierson coefficient	0.425
	P	0.033
	Number	15
Strength training		Neuromuscular compatibility of dominant hand
	Pierson coefficient	0.317
	P	0.04
	Number	15
Strength training		Neuromuscular compatibility of non-dominant hand
	Pierson coefficient	0.167
	P	0.337
	Number	15

Results of the study demonstrated that there was a significant and positive relationship between strength training and reaction time of dominant hand (r=0.297, P= 0.002), neuromuscular coordination of dominants hand (r=0.341, P= 0.039), neuromuscular coordination of non-dominant hand (r=0.425, P=0.033) and neuromuscular compatibility of dominant hand (r=0.317, P=0.04). Moreover, the relationship between strength training and reaction time of non-dominant hand (r=-0541, P=0.04) was negative and significant. Furthermore, the relationship between strength training and neuromuscular compatibility of non-dominant hands of pool players in this study was insignificant (r=0.167, P=0.337).

Table 3. Average scores recorded in performing reaction time, neuromuscular coordination and neuromuscular compatibility of pool players in pre and posttests

Considering table 3, the difference between mean scores obtained in reaction time, neuromuscular coordination and neuromuscular compatibility of pool players in pre and posttests was significant ($P<0.05$) which proves the significant effect of strength training on reaction time, neuromuscular coordination and neuromuscular compatibility in pool players. The difference between post-test and pre-test scores in experimental group was significant which shows that strength training had significant effect on reaction time and neuromuscular coordination and compatibility.

Table 3. Average scores recorded in performing reaction time, neuromuscular coordination and neuromuscular compatibility of pool players in pre and posttests

		assignment score						
group		**pretest**		**posttest**		**dependent t test**		
		mean	**standard**	**mean**	**standard**	**degree of f**	**amount of t**	**significance**
reaction time	experimental	16	2.5	9	2.65	13	-9.78	0.02
	control	17	2.49	16	2.00	13	-5.38	0.255
neuromuscular coordination	Experimental	50	8.50	70	14.85	13	-12.45	0.04
	Control	50	8.50	40	14.180	13	-10.33	0.285
neuromuscular compatibility	Experimental	277.32	80.94	393.65	83.35	13	-42.58	0.04
	Control	237.65	42.38	252.3	45.87	13	-33.16	0.375

DISCUSSIONS AND CONCLUSION

The present study demonstrated that there is a relationship between strength training and reaction time of dominant hand ($r=0.297$, $P= 0.002$) and non-dominant hand ($r=0.541$, $P=0.04$) in pool players (Table 2). This finding is consistent with Enoka (2012), Saez, et al. (2012), Arazi, et al. (2011) and Kavei, et al. (2014). Saez, et al. (2012) showed that a combined plyometric and strength training relatively improved power, action and reaction time, fast running and neuromuscular compatibility compared to mere plyometric or strength training. Markovic and Mikulic (2010) demonstrated that strength training affects reaction time and neuromuscular coordination. To justify, we speculate that strength training increases neuromuscular coordination which may be originated from neural adaptations probably due to further motor units recruitment and faster neural discharge

However, our results are inconsistent with Sheikh Al Eslami Vatani (2006) and Hamare (2013). They found that indices of motor fitness (reaction time and neuromuscular coordination) in groups do not change significantly after 6 weeks of plyometric training compared to the pretest. Exception for this was the dynamic balance in plyometric group. The difference between the results of our study and Sheikh Al Eslami Vatani (2006) and Hamare (2013) may be due to differences in exercise protocol or subjects characteristics.

Furthermore, this study demonstrated that there is a relationship between strength training and neuromuscular coordination of dominant hand ($r=0.341$, $P=0.039$) and non-dominant hand ($r=0.425$, $p=0.033$) in pool players (Table 2). This finding is consistent with findings of Valipoor Dehno, et al. (2010), Arazi, et al. (2011), Kavei, et al. (2014), Zarei, et al. (2013), Saez, et al. (2012) and Menz, et al. (2013). Enoka (2012) believes that the most important factor in increasing strength and neuromuscular coordination lies in neural system. Saez, et al. (2012) demonstrated that a combined protocol of plyometric and strength training relatively improve power, moving speed, swift running and neuromuscular coordination compared to plyometric or strength training alone. Besides, Tine-Alkjear, et al. (2013) observed that four weeks of drop jumping with low intensity significantly increased V wave in Soleus muscle and improved jumping. This may be due to increased stimulation to a motor neuron after training. Accordingly, results from studies by Kavei, et al. (2014) showed that mechanism of the effects of strength and plyometric training are the same and therefore, plyometric training or a combination of plyometric and swift running exercises improve performance in a similar way. Thus, these adaptations is likely to stem from neural adaptations probably due to further motor units recruitment and faster neural discharge Moreover, our findings revealed that there is a relationship between strength training and neuromuscular coordination of dominant hand ($r=0.317$, $P= 0.04$) in pool players (table 2). This finding is compatible with those of Shavandi, et al. (2006), Valipoor Dehno, et al. (2010), Kavei, et al. (2014), Markovic & Mikulic (2010), Theilen (2013) and Tine Alkjear, et al. (2013). Shavandi, et al. (2006) showed that there is a significant increase in potential range of training group and a significant decrease in delay time parameter of electric stimulation group comparing pre and posttests. Yet, Valipoor Dehno, et al. (2010) observed significant changes in electromyography only in the combined group. Kavei, et al. (2014) approved of their previous findings and showed that a combined plyometric and strength training significantly increased the activity of the leg extensor in a maximum isometric contraction. However, findings of studies conducted by Sheikh Aleslami Vatani, et al. (2006) and Astrid, et al. (2010) are inconsistent with this study. One of the reasons for this contradiction is the difference in statistical sample, research methodology, exercise protocol and sports in which subjects are involved.

Furthermore, the results of the study revealed that there is no significant relationship ($r=0.167$, $P=0.337$) between strength training and neuromuscular coordination of non-dominant hand (table 2). These are inconsistent with findings of Sheikh Aleslami Vatani, et al. (2006), Aagaard, et al. (2002) and Astrid, et al. (2010). Shekh Aleslami Vatani, et al. (2006) observed that six months weight training does not induce changes in neuromuscular coordination and the time of occurring these coordination's in body builders. They reported that integral EMG levels, nerve conduction velocity, signal latency and wave amplitude do not significantly change in body builders trainings. Aagaard, et al. (2002) investigated the effects resistance training on neural adaptations and observed no significant changes in M wave in the Soleus muscle. Accordingly, results for Astrid et.al. (2010) studies demonstrated that balance trainings might improve control over neuromuscular coordination. Nevertheless, findings of studies conducted by Enoka (2012), Saez, et al. (2012), Tine-Alkjear, et al. (2013), Zarei, et al. (2013), Makovic & Mikulic (2010), Valipoor Dehno, et al. (2010) and Kavei, et al. (2014) contradict with findings of the present study. Damirchi, et al. (2007) on the other hand, demonstrated that M wave amplitude, maximal voluntary contraction, and nerve conduction velocity significantly increased and M wave latency decreased in the experimental group. They showed that when an athlete begins a new exercise program, neural adaptations like nerve conduction velocity, increase in motor units recruitment and the rate of discharge in these units improves which results in improved power generation in muscles.

Besides, this contradiction may lie with different training programs. In other words, insignificant changes in non-dominant hand may be due to insufficient motor unit's recruitment. The changes in EMG amplitude observed in dominant hand in our study may be due to the stimulation of central neuron system or related muscular factors which eventually increases the stimulation of muscle (Ramezan Poor, et al. 2012).

The results of the present study revealed that strength trainings significantly affected reaction time (P=0.02), neuromuscular coordination (P=0.04) and neuromuscular compatibility (P=0.04) in pool players (Table 3). This finding is compatible with findings of Enoka (2012), Saez, et al. (2012), Yamauch (2012), Tine-Alkjear, et al. (2013), Laciuga, et al. (2014), Conciecau, et al. (2014), Arazi, et al. (2011) and Kavei, et al. (2014). Many researchers believe that strength training increases motor units recruitment, hypertrophy and muscular power; these adaptations result in improved coordination and compatibility between neural and muscular systems ending in optimum performance.

Conclusion

Findings of this study revealed that strength training significantly improves neuromuscular coordination and compatibility in male pool players. This adaptation has probably neural base and may recruit more motor units and increase neural discharge rate. Therefore, strength training program in pool players may have positive outcomes.

Suggestions

Considering the significant effect of strength training on neuromuscular coordination, reaction time and neuromuscular compatibility of dominant and non-dominant hands it is suggested that pool players and other athletes who rely on their hands consider strength training to improve their skills and achieve optimal performance.

REFERENCES

Aagaard, P., E.B. Sinonsen, J.L. Andersen, P.D. Poulsen, (2002). Neural adaptation to resistance training: Changes in evoked V-wace and H-reflex responses. J. Appl Physiol., 92(6): 2309-2318.

Arazi, H., A. Asadi, K. Hussaini, S. K. Mohammad Zade, & Kh. Piri Kord, (2011). The effects of thirty hours of sleeplessness on reaction time, neural-muscular coordination and aerobic capacity of male non-athlete students. Ofoghe Danesh., 2: 14- 21.

Astrid. Z, H.U. Markus, Bscher, L. V. Winfried, B. F. H. Nsel, & P. Klaus, (2010). Balance training for neuromuscular control and performance enhancement: A systematic review. J of Athlet Train., 45(4): 392–403.

Banaeifar A, A. Gorzi, M. Hedayati, Z. Nabiollahi, N. Rahmani Moghaddam, (2011). Effect of an 8-week resistance training program on acetyl cholinesterase activity in rat muscle. KAUMS J (FEYZ)., 15(4): 6-16.

Bompa, T. O, (2008). Theory and methodology of training .The key to athletic performance: (Third ed). Dubuque: Kendall /Hunt Publishing Company, PP: 86-91.

Bompa, T. O, (2011). Strength exercises for athletes: designing exercising program. Translated by: Ali Heidarian pour& Ali Gorzi. Tehran, the j of sport, PP: 180-220.

Conceicau, M., L.E. cadore, M. Gonzalez-Izal, M. Izquierdo, & et al, (2014). Strength training prior to endurance exercise: impact on the neuromuscular system, endurance performance and cardiorespiratory responses. J of Hum Kinet., 44: 171-181.

Damirchi, A., H. Mohebi, Ali. Hussaini, (2007). The effects of isotropic strength trainings on electronographic parameters and maximum intentioanl contraction in athletes. Olympic J., 153: 23- 34.

Enoka, R.M., S. Bandry, T. Rudroff, D. Farina, M. Klass, & J. Duchateau, (2012). Unraveling the neurophysiology of muscle fatigue. J Electro Kine., 21: 208-219.

Hamareh, H., (2013). Study on the effects of six weeks of plyometric exercises on static and dynamic balance, reaction speed and neural-muscular coordination of Taekwondo players of Abdanan. Chamran University of Ahwaz. Faculty of sports science. M.Sc. Thesis.

Hemayat Talab, R., (2012). Measuring and gauging in sports sciences. Tehran: Elmo Harekat Publications. PP: 76.

Kavei, Aboozar., R. Gharakhanloo, H. Rajabi, (2014). Neural and performance compatibilities with plyometric training against a combination of plyometric and swift running training in adolescent football players. Biolo and sports scie., 1: 1- 19.

Khajeh Nemat, Karar., H. Sadeghi, M. Saheb AlZamani, (2014). The effects of strength and stamina training on the quality of life related to elderly health. J of Isfahan Med Univ., 303: 1- 9.

Kraeme, W.J., and N.A. Ratamess, (2004). Fundamentals of resistance training: progression and exercise prescription. Med Sci Sports Exerc., 36(4): 674-688.

Laciuga, H.M., C.J. Rosenbek, W.P. Darenport, & C.M. Sapienza, (2014). Functional outcomes associated with expiratory muscle strength training: narrative review. JRRD., 51: 535-546.

Markovic, G., P. Mikulic, (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. Sports Med., 40(10): 859-95.

Menz, S.M., K. Hatten, & M. Grant-Beuttler, (2013). Strength training for a child with suspected developmental coordination disorder. Pedia Phys Ther., 1: 214-223.

Mc-Carthy, J.P., Wood, D.S. Bolding, M.S. Roy J.L, & G.R. Hunter, (2012). Potentiation of concentric force and acceleration only occurs early during the stretch shortening cycle. J of Streng and Condi Res., 26(9): 2345-55.

Parnow, A.H., Z. Gourgin, & E. Karaji, (2012). Effect of 10 week strength training on nicotinic acetylcholine receptor rate in fast and slow twitch skeletal muscles of rats. J of Shah Sadou Univ of Med Sci Yazd., 20(2): 201-210.

Rahimi, Z., M H. Alizadeh, R. Noori, Z. Rojhani, (2014). The effects of neural-muscular, strength and combined trainings on the ratio of hamstring to Quadriceps femoris muscle in female basketball players. J of the Univ of Med Sci of Zanjan., 95: 12- 23.

Ramezan Poor, MR., A. Moghadam, M. Zamani, Sh. Zerang, M. Shabani, A. Akaberi, (2012). Comparison of one-way strength training on electronographic parameters of cornea in the upper limb. J of the Univ of Med Sci of North Khorasan., 4: 459- 467.

Sáez, D.E., E. Villarreal, B. Requena, M. Izquierdo, & J.J. Gonzalez-Badillo, (2012). Enhancing sprint and strength performance: Combined versus maximal power, traditional heavy-resistance and plyometric training. J of Scie and Med in Sport., 705: 5-16.

Shavandi, N., H. Nikbakht, H. Sadeghi, E. Ebrahimi, S. Talebian, (2006). The effects of stamina-strength training and electric stimulation on neural conductivity speed in volleyball players suffering in fraspinatus syndrome. J of Res in Sports Sci., 10: 43- 55.

Sheikh Aleslami Vatani, D., N. Behpoor, AA. Gayini, (2006). The effects of six months of resistance training on neural parameters of professional body builders. Harekat j., 28: 87- 105.

Tine-Alkjaer, J., P.C. Meyland, J. Raffalt, J. Lundbye, & B.S. Erik, (2013). Neuromuscular adaptations to 4 weeks of intensive drop jump training in well-trained athletes. Physiol Rep., 1(5): 1002-10.

Theilen, T.N., (2013). Comparisons of acute neuromuscular fatigue and recovery after maximal effort strength training using powerlifts .University of South Florida Scholar Commons, 1-63.

Urabe, Y., R. Kobayashi, S. Sumida, K. Tanaka, N. Yoshida, & G.A. Nishiwaki, et al. (2005). Electro myographic analysis of the knee during jump landing in male and female athletes. Knee., 12(2): 129-34.

Valipoor Dehno, V., R. Gharakhanloo, F. Rahbari Zadeh, S J. Mola, (2010). A study on neural-muscular and performance compatibilities with selected plyometric exercises against combined resistance and plyometric exercises. Biolo and sports sci., 7: 91-113.

Wulkow, R., D. Anderson, T. Tharp, C. Elsberry, A. Beste, R. Barr, & B. Legg, (2011). Strength training in junior high athletes. Lowa High Sch Athle Assoc., 515: 1-9.

Yamauch, J. (2012). Aging and exercise training on the neuromuscular functions of human movements. Geviatrics., 15: 105-116.

Zearei, H., M.R. Ramezanpour, & S. Pakdelan, (2013). Comparison of the effect of plyometric and resistance training on explosive power and speed in female Taekwondo players. J. Basic. Appl. Sci. Res., 3: 339-343.