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Original Article

Physiotherapy Section

Effect of Plyometrics and Pilates Training on Dynamic Balance and Core Strength of Karate Players

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ABSTRACT

Introduction: The success of the karate player mainly depends on the balance and core strength. Improvement in these physical variables depends upon the type of exercise training used by the athletes. In the Indian context, there is lack of literature that supports the use of Pilates and Plyometric Training (PT) programme in training of Karate players. Therefore, to achieve success in the sport, best training method should be chosen by athletes or coaches.

Aim: To compare and evaluate the effectiveness of two training programs Pilates and Plyometric on balance and core strength of National level male Karate athletes.

Materials and Methods: The design of this study was experimental and sampling technique was simple random sampling. This study was conducted on a sample of 120 with 40 subjects in each group i.e., Experimental group A (Plyometric, N=40), Experimental group B (Pilates, N=40) and Control group C (N=40). The data was collected during 20th May 2018 to 10th February 2020. The national level male karate players in the age group of 18 to 24 years with playing experience of five years were included in the study. The plyometric and pilates training were carried out in experimental groups for three days per week for eight weeks and no training method was implemented in the control group. Three reading were recorded, at the baseline, at the end of 4th and 8th week. Dynamic balance and core strength were the outcome measurements which were measured by modified Star Excursion Balance Test (mSEBT) and isometric core strength tests respectively. All the data was analysed by SPSS version 2.0 and the descriptive stats noted as mean±SD. ANOVA post-hoc analysis were calculated with p-value significance set at <0.05.

Results: After eight weeks of intervention, both experimental groups showed significant improvement in dynamic balance and core strength comparisons between the groups. When the pre-test and post-test values of the experimental groups have been compared at the 4th week and 8th week of the study showed significant improvement (p-value <0.001) in the mSEBT and Core strength of the plyometric group compared to pilates and control group.

Conclusion: The findings of the present study revealed that plyometrics and pilates both can improve balance and core strength of karate players but the PT method had more positive and statistically better effects on core strength and dynamic balance than pilates group in the view of sports performance.

Keywords: Isometric core strength test, Martial arts, Modified star excursion balance test, Physical fitness

INTRODUCTION

In the present world, the sports experts seek to use scientific findings to prepare more professional athletes for the successful performance in sports competitions like national, international and Olympic competitions, so it is essential for various championships and tournaments to take benefit of the best exercise methods chosen by knowledgeable and well experienced coaches for professional athletes [1]. Karate is a type of combat sport and now it is one of the most widely practiced system of Japanese martial arts in the world [2]. The literal meaning of karate is "empty hands" that means freedom to use hands without using weapons against an opponent [3]. The dynamic structure of kumite involves overcoming the competitor with use of various movements, defensive and offensive technique [4]. Karate is a sport that requires skills, good agility, speed, balance and core strength. In sports, every competition requires better and maximum performance, to improve the efficacy of specific kinetic patterns and techniques demanded for success [5]. Previous studies found that in skill related sports the muscle strength, balance, flexibility, endurance, coordination, and efficiency of the athlete play a crucial role in performance of a sports athlete to achieve success [6-8]. An effective strength and conditioning program is one of the most important elements for sustained high performance of these athletes to develop overall fitness [9]. Improvement in the sports performance and balance depends on core muscles strength and its stabilisation during jumping, running and throwing [10,11].

Pilates and PT improve posture, balance, increase core strength and are helpful for improving athletic performance and sports specific skills [12-16]. Pilates is a popular form of exercise training which consists of series of stretching and strengthening exercises with proper trunk control and breathing. This training is based on the key principles of management of the center of gravity, concentration, control, precision, flow, and breathing [17]. Pilates improves posture, balance, increase core strength, peripheral mobility, which may be helpful for improving athletic performance [12,18,19]. The other method of training is PT that is used in all types of sports. In PT, a rapid stretching of a muscle occurs immediately followed by the shortening of the same muscle again [20]. It increases strength, power, proprioception and explosiveness [21,22]. Previous evidence had reported that unilateral and bilateral PT, improve the balance in young athletes and a combination plan (plyometric, technical, balance, and strength) improved balance.Therefore, PT is widely known as a potential tool for improving balance and functional sports performance [23,24].

As in the recent years, importance has been increased in karate sport in India with occurrence of many injuries [25,26] so, it is necessary to study the effective training protocols in this sport to prevent injuries [27]. Very little work has been done in the field of physical fitness pertaining to karate. There are limited investigations about the effects of plyometric and pilates training on balance and core strength of karate players.Thus, the present study was conducted with the aim to evaluate and

compare the effectiveness of two training programs Pilates and Plyometric on dynamic balance and core strength of National level Karate players.

MATERIALS AND METHODS

This was an experimental study conducted on 120 karate athletes of NCR region from various karate academies - ShitoRyu Seiko Karate Do India, Dwarka, Nathu Ram Convent Senior Secondary School, Nangloi, New Delhi, XMA Academy, Dwarka, Warrior's Fighting Center, Gurugram, Sai Karate Academy, Gurugram. A sample of 120 pairs (40 in each group: Plyometric group, Pilates group and control group) was calculated using G. Power software version 2.0, considering 95% power, 5% significance level true difference between the mean 2.3 and standard deviation of 0.83 in agility performance.

The data was collected during 20th May 2018 to 10th February 2020. The Research Proposal of the study was approved by Institutional Clinical Ethical Committee (ICEC) of SGT University, Gurugram vide letter no. ICEC SGTU/FOP/2018/171 dated 10-05-2018 (Appendix A). Informed consent was taken from all the participants. It included male players with age 18 to 24 years (21.00±1.77 years) and having experience of playing past five years. Recreational Karate players and players with recent injury in the previous six months were excluded. Outcome measures were dynamic balance and core strength. Modified mSEBT for dynamic balance and core strength tests were conducted. Group A underwent PT programme, Group B underwent Pilates training programme and Group C acted as control. The training program was limited to three days per week for eight weeks. The dependent variables selected for the study were-dynamic balance and core strength and all the subjects were tested prior to and after 4th and 8th week of the experimental period on the selected dependent variables.

Dynamic Balance

Balance was measured by mStar Excursion Balance Test. It was measured at Baseline, 4th week and at the end of 8th week.

Procedure: The mStar Excursion Balance Test was used for dynamic stability. It consists of 3 tape measures attached to the ground at 135 degrees between the posterior-lateral and posterio-medial compared to the anterior and 90 degrees between the posterior lateral and posterior medial reach distances. Subjects should perform a single leg stance in the middle of the grid, their stance leg on the anterio-posterior reach direct lines. The subject then asked to reach with their non-weight bearing leg as far as they could along a reach direction. For this study this included the anterio-medial, posterio-lateral and posterior-medial reach directions. The subject reached as far as they could while maintaining their balance, touching down lightly with the most distal part of their foot and then returned to the starting position. The subject then performed 4 practice reaches in each reach direction. After a two minute rest, 3 reach trials were performed in each direction with a 30 second rest between attempts and 1 minute rest between reach directions. If the subject touched down with the whole non-weight bearing foot, moved the stance leg from starting position or was unable to regain starting position after touching down the subject had to perform the trial again. The leg length of the stance leg was measured with the subject on a plinth from the Anterior Superior Iliac Spine (ASIS) down to the base of the medial malleolus [28].

Core Strength

The core strength was measured by McGill protocol at the baseline, at the end of 4th week and at the end of 8th week. This protocol consisted of four tests that measured all aspects of the torso via isometric muscle endurance: Trunk flexor test, Trunk extensor test, Right and left lateral musculature test.

1. **Trunk Flexor test:** It began with the person in a sit-up position with the back resting against a jig angled at 60 degree from the floor. Both knees and hips should be flexed 90 degree, the arms are folded across the chest and the feet are secured. Then the jig was pulled back 10 cm and the person holds isometric posture as long as possible. When any part of the person's back touches the jig, it means failure.
2. **Trunk Extensor test:** In this test the upper body cantilevered out over the end of the bench and pelvis, knees, and hips should be positioned neutral and secured with the arms helding across the chest. If the upper body drops below the horizontal position, it means failure.
3. **Lateral Musculature test:** In this test, the person lie down in the full side-bridge position. Both legs should be extended and the top foot placed in front of the lower foot for support. Subjects supported themselves on one elbow and on their feet while lifting their hips off the floor to create a straight line from head to toe. The uninvolved arm was held across the chest with the hand placed on the opposite shoulder. When subjects lost the straight-back posture or the hip touches the ground, indicated failure [29].

Training Programs

The detailed training protocols are explained in [Table/Fig-1,2] [30,31]. The control group (Group C) was asked to do their conventional training for 60 minutes and routine exercises including warm-up for ten minutes and cool down for five minutes.

Weeks	Plyometric training program	Sets	Reps
1st	Side to side ankle hops	15	2
	Standing jump and reach	15	2
	Front cone hops	6	5
2nd	Side to side ankle hops	15	2
	Standing long jump	6	5
	Lateral jump over barrier	15	2
	Double leg hops	6	5
3rd	Side to side ankle hops	12	2
	Standing long jump	6	4
	Lateral jump over barrier	12	2
	Double leg hops	8	3
	Lateral cone hops	12	2
4th	Diagonal cone hops	8	4
	Standing long jump with lateral sprint	8	4
	Lateral cone hops	12	2
	Single leg bounding	7	4
	Lateral jump single leg	6	4
5th	Diagonal cone hops	7	2
	Standing long jump with lateral sprint	7	4
	Lateral cone hops	7	4
	Cone hops with 180 degree turn	7	4
	Single leg bounding	7	4
	Lateral jump single leg	7	2
6th	Diagonal cone hops	8	4
	Hexagon drill	8	4
	Cone hops with change of direction sprint	12	2
	Double leg hops	7	4
	Lateral jump single leg	6	4
7th	Diagonal cone hops	7	2
	Standing long jump with lateral sprint	7	4
	Cone hops with 180 degree turn	7	4
	Single leg bounding	7	4
	Lateral jump single leg	7	4

8th	Side to side ankle hops	12	2
	Standing long jump	6	4
	Lateral jump over barrier	12	2
	Double leg hops	8	3
	Lateral cone hops	12	2

[Table/Fig-1]: Eight week Plyometric Training Program (Group A).

Weeks	Exercises	Repetitions
1st	Hundreds	5
2nd	One leg stretch 1, Double leg stretch 1/2, Clam	6
3rd	One leg stretch 2 Shoulder bridge 2	7
4th	Shoulder bridge 2 Hip twist	7
5th	Scissors 1, One leg kick	8
6th	Scissors 2, Side kick 1	10
7th	Side kick 2, One leg circle ½	10
8th	Side kick 2, One leg circle ½	10

[Table/Fig-2]: Eight week Pilates Training Program (Group B).

STATISTICAL ANALYSIS

Data was statistically analysed in SPSS software version 20. The normality distribution of all variables was verified by using Shapiro-Wilk test. Variables that were found to be non-normal distribution were log transformed for further analysis. Repeated measures ANOVA (Analysis of Variance) test was used for time and frequency domain measures to find out the main effect (time effect and group effect) and time×group interaction followed by the post-hoc analysis. All data are presented as mean±SD. The significance level was set at p<0.05.

RESULTS

[Table/Fig-3] showed the comparison of demographics of age, height, weight and Body Mass Index (BMI) of plyometric, pilates and control group. All groups were similar at the beginning (before) of the study.

Variables	Plyometric Group A Mean±SD	Pilates Group B Mean±SD	Control Group C Mean±SD	f-value	p-value
Age (years)	21.10±1.48	21.00±1.77	21.10±1.87	0.05	0.96
Height (cm)	174.23±3.21	174.50±3.42	174.50±3.84	0.08	0.92
Weight (kg)	65.2±3.49	65.25±3.06	65.85±3.80	0.33	0.72
BMI (kg/m²)	21.65±0.80	21.43±0.83	21.61±0.78	0.83	0.44

[Table/Fig-3]: Comparison of demographic variables between the groups at baseline. Post-hoc Anova test used. p-value <0.05 to be considered significant

The outcome variables of the two experimental groups and control group on selected physical variables (dynamic balance and core strength) were analysed at the baseline at the 4th week and at the 8th week and the details of analysis of each variable is shown in [Table/Fig-4,5].

The results of the present study showed that there was a significant difference between the post-test means of PT group and Pilates Training group, PT group and Control group, Pilates Training group and Control group. From [Table/Fig-4,5] it was revealed that PT group (Group A) had shown better performance than Pilates Training group and Control in Dynamic Balance and core strength. There is a significant group effect, time effect as well as group × time interaction respectively for dynamic balance and core strength

Variables	Plyometric Group A Mean±SD	Pilates Group B Mean±SD	Control Group C Mean±SD	Group (G) effect (p-value)	Time (T) effect	G×T inter-action
Right anterior						
Baseline	70.53±2.76	69.48±2.40	70.16±2.88	**<0.001**	0.925	0.831
4th week	75.70±2.80	73.10±2.44	70.97±2.93	0.402		
8th week	82.14±3.17	77.77±2.64	71.14±2.89			
Left anterior						
Baseline	67.26±2.38	66.87±2.04	66.72±2.17	**<0.001**	0.957	0.913
4th week	73.81±2.82	71.15±1.77	67.31±2.26	0.606		
8th week	80.91±3.11	75.96±2.27	67.48±2.41			
Right postero-medial						
Baseline	99.04±3.19	99.46±4.26	99.13±3.63	**<0.001**	0.904	0.820
4th week	107.44±3.74	103.91±4.55	99.37±3.04	0.514		
8th week	118.13±3.88	113.17±4.81	99.68±2.55			
Left postero-medial						
Baseline	97.27±3.49	97.48±4.71	97.59±3.81	**<0.001**	0.928	0.820
4th week	104.30±3.97	102.15±4.74	97.59±3.81	0.390		
8th week	113.91±4.15	110.91±4.55	97.68±3.66			
Right postero-lateral						
Baseline	98.18±2.89	98.18±4.78	98.93±3.71	**<0.001**	0.913	0.840
4th week	106.06±3.10	104.06±4.98	98.97±3.07	0.431		
8th week	115.05±4.23	113.37±4.57	99.00±3.50			
Left postero-lateral						
Baseline	96.10±3.17	96.64±4.50	96.86±3.77	**<0.001**	0.906	0.799
4th week	103.00±3.34	101.81±4.53	97.48±3.69	0.319		
8th week	112.47±3.91	107.17±4.90	98.26±3.56			

[Table/Fig-4]: Comparison of dynamic balance of experimental and control group.

Variables	Plyometric Group A Mean±SD	Pilates Group B Mean±SD	Control Group C Mean±SD	Group (G) effect (p-value)	Time (T) effect	G×T inter-action
Trunk flexor test						
Baseline	137.93±1.70	137.41±1.56	137.76±1.43	**<0.001**	0.959	0.911
4th week	147.19±2.15	144.59±1.87	138.20±1.44	0.842		
8th week	155.58±2.55	153.19±2.37	138.55±1.85			
Trunk extensor test						
Baseline	161.14±1.48	161.39±1.87	160.96±1.68	**<0.001**	0.958	0.916
4th week	169.11±1.41	167.00±1.85	161.15±1.75	0.810		
8th week	175.84±1.69	173.50±2.13	161.29±2.00			
Right mus. test						
Baseline	97.88±2.56	97.76±3.04	97.77±2.54	**<0.001**	0.944	0.896
4th week	111.41±4.06	108.62±2.82	97.82±2.59	0.823		
8th week	123.33±4.20	118.59±2.71	97.85±2.60			
Left mus. test						
Baseline	99.99±3.42	99.01±2.94	98.63±3.71	**<0.001**	0.942	0.895
4th week	117.74±4.21	109.62±2.67	98.65±3.46	0.838		
8th week	127.43±3.87	120.20±2.04	98.76±3.52			

[Table/Fig-5]: Comparison of core strength of experimental and control groups. mus.: Musculature

in Group A. [Table/Fig-6] represents group wise comparison (mean difference) of all groups with significant p-value at level <0.05.

[Table/Fig-7] represents ANOVA post-hoc analysis (p<0.001) of dynamic balance of groups A, B and C between baseline, 4th week and 8th week. Significant differences were observed between baseline to 4th week, 4th week to 8th week and baseline to 8th week in group A and B. Both experimental groups showed significant improvement in the mSEBT and core strength.

DISCUSSION

The present study aimed to find out the effectiveness of two training programs on dynamic balance and core strength of karate athletes. The players had similar baseline values for age, height, weight and BMI. The result of the present study showed that there was a significant improvement in both the experimental groups than the control group in terms of dynamic balance and core strength. Statistically group A i.e., plyometric was found superior compared to pilates and control group. In karate training, balance is the key element for athletes and improved by the training of core

Variables	Group	Mean difference	Std. Error	p-value
mSEBT (Right anterior)	Group A vs Group B	0.01488	0.00852	0.250
	Group B vs Group C	-0.00954	0.00852	0.795
	Group C vs Group A	-0.00534	0.00852	1
mSEBT (Left anterior)	Group A vs Group B	0.3907500	0.4918463	1
	Group B vs Group C	0.1420000	0.4918463	1
	Group C vs Group A	-0.5327500	0.4918463	0.843
mSEBT (Right postero-medial)	Group A vs Group B	-0.00388	0.00855	1
	Group B vs Group C	0.00316	0.00855	1
	Group C vs Group A	0.00072	0.00855	1
mSEBT (Left postero-medial)	Group A vs Group B	-0.00158	0.00946	1
	Group B vs Group C	-0.00157	0.00946	1
	Group C vs Group A	0.00315	0.00946	1
mSEBT (Right postero-lateral)	Group A vs Group B	0.00068	0.00886	1
	Group B vs Group C	-0.00803	0.00886	1
	Group C vs Group A	0.00735	0.00886	1
mSEBT (Left postero-lateral)	Group A vs Group B	-0.00508	0.00903	1
	Group B vs Group C	-0.00266	0.00903	1
	Group C vs Group A	0.00774	0.00903	1
Core strength (Trunk Flexor test)	Group A vs Group B	0.00380	0.00254	0.410
	Group B vs Group C	-0.00255	0.00254	0.949
	Group C vs Group A	-0.00125	0.00254	1
Core strength (Trunk Extensor test)	Group A vs Group B	-0.00156	0.00234	1
	Group B vs Group C	0.00268	0.00234	0.767
	Group C vs Group A	-0.00112	0.00234	1
Core strength (Right Lateral Musculature test)	Group A vs Group B	0.00133	0.00616	1
	Group B vs Group C	-0.00022	0.00616	1
	Group C vs Group A	-0.00111	0.00616	1
Core strength (Left Lateral Musculature test)	Group A vs Group B	0.00975	0.00753	0.594
	Group B vs Group C	0.00414	0.00753	1
	Group C vs Group A	-0.01389	0.00753	0.203

[Table/Fig-6]: Group wise comparison of variables in groups.
p-value <0.05 to be considered significant

Variables	Week	Group A (p-value)	Group B (p-value)	Group C (p-value)
mSEBT (Right anterior)	Baseline vs 4th week	<0.001	<0.001	<0.001
	4th week vs 8th week	<0.001	<0.001	0.848
	8th week vs Baseline	<0.001	<0.001	<0.001
mSEBT (Left anterior)	Baseline vs 4th week	<0.001	<0.001	<0.001
	4th week vs 8th week	<0.001	<0.001	0.672
	8th week vs Baseline	<0.001	<0.001	<0.001
mSEBT (Right postero-medial)	Baseline vs 4th week	<0.001	<0.001	1
	4th week vs 8th week	<0.001	<0.001	1
	8th week vs Baseline	<0.001	<0.001	0.760
mSEBT (Left postero-medial)	Baseline vs 4th week	<0.001	<0.001	1
	4th week vs 8th week	<0.001	<0.001	1
	8th week vs Baseline	<0.001	<0.001	1
mSEBT (Right postero-lateral)	Baseline vs 4th week	<0.001	<0.001	1
	4th week vs 8th week	<0.001	<0.001	1
	8th week vs Baseline	<0.001	<0.001	1
mSEBT (Left postero-lateral)	Baseline vs 4th week	<0.001	<0.001	0.033
	4th week vs 8th week	<0.001	<0.001	0.100
	8th week vs Baseline	<0.001	<0.001	0.004
Core strength (Trunk Flexor test)	Baseline vs 4th week	<0.001	<0.001	0.102
	4th week vs 8th week	<0.001	<0.001	0.416
	8th week vs Baseline	<0.001	<0.001	<0.001
Core strength (Trunk Extensor test)	Baseline vs 4th week	<0.001	<0.001	0.253
	4th week vs 8th week	<0.001	<0.001	1
	8th week vs Baseline	<0.001	<0.001	0.094
Core strength (Right Lateral Musculature test)	Baseline vs 4th week	<0.001	<0.001	1
	4th week vs 8th week	<0.001	<0.001	0.493
	8th week vs Baseline	<0.001	<0.001	0.189
Core strength (Left Lateral Musculature test)	Baseline vs 4th week	<0.001	<0.001	1
	4th week vs 8th week	<0.001	<0.001	0.493
	8th week vs Baseline	<0.001	<0.001	0.189

[Table/Fig-7]: Post-hoc analysis of variables between groups.
p-value <0.05 to be considered significant

muscles [32]. PT consists of stretch-shortening cycle and is widely used as a training method in karate to improve the efficiency of the player [33,34]. Previous evidence found that it lead to an increase in muscle power and muscle activity by stimulation of neural system [35-37]. Aminaei M et al., proved the effects of PT and cluster training on explosive power and strength in karate players. It was found that explosive power and strength improved. The results indicated both cluster and PT program seems to improve physical fitness elements at the same levels [38]. Moreover, significant improvement in the strength, power and agility was reported by Davaran M et al., by using intervention of six weeks of PT [39]. Ramírez-Campillo R et al., showed a significant improvement in all directions of dynamic balance (antero-posterior and medio-lateral balance) in forty soccer players by the six weeks Plyometric Training. It was found that vertical, horizontal and combined vertical and horizontal jumps showed significant improvement in explosive actions, balance and intermittent endurance capacity of soccer players [40]. Evidences showed improvements in the balance of the players after six weeks PT [25,41] and in young athletes [25,42]. This improvement in the balance performance may be related to improvement in the co-contraction of lower-extremity muscles or due to some changes in the proprioception (joint sense and awareness in the space) and neuromuscular control [43]. Neuromuscular control plays an important role in improvement in balance. In a previous research Filipa A et al., demonstrated the effects of neuromuscular training on the SEBT composite score which improved significantly in the training group as compared to the control group [44].

The present study also reported that pilates training also improved in balance and strength by the eight weeks intervention. It was found in the previous evidence that 6-week core training improved dynamic postural control [45]. A previous study by Iacono AD et al., on football players found that four weeks (five days a week) core balance training significantly improved static and dynamic balance of players [46]. Similarly, Granacher U et al., proved that there are significant improvement in the balance values of both groups (stable and unstable surfaces) when exposed to two different training methods (six-week core programs) on football players [47]. Furthermore, Kalra S et al., found that five weeks pilates training improved dynamic balance for both lower extremities (dominant and non-dominant) in all four components (anterior, medial, posterior, lateral) as measured by SEBT showed that there was a highly significant improvement seen in experimental group as compared to control group (p<0.001) [48]. The result of our study is consistent with the findings of the study by Shavikloo J et al., who concluded that six week Pilates training programme was more effective than conventional training in improving anterior, posterio-lateral and posterio-medial components of dynamic balance as measured by Y balance test in futsal players [49].

The present study showed significant improvement in core strength of karate players in the experimental groups. This finding is supported by Schilling JF et al., who observed significant increase in three different core endurance tests (back extensor durability, flexor endurance and side muscle strength) in a six-week core force and endurance training intervention (2 times a week) on non-active individuals; however no change in sprint,

agility, and vertical jump was reported [50]. Pilates training resulted in enhanced stability of vertebral column, neuromuscular co-ordination and hence improvement in dynamic balance was seen [49]. The Pilates group had much significant improvement than control group because the regular use of Pilates exercise led to strengthening of abdominal and core muscles, flexibility of trunk muscles and increased the biological capacity efficiency by breathing control [51].

Limitation(s)

The study was conducted on male players only. Therefore, the gender specific differences were not studied.

CONCLUSION(S)

It can be concluded that the Indian karate players showed significant improvement in dynamic balance and core strength after eight weeks of PT which was very encouraging and demonstrated the better response on performance. It is recommended that coaches and trainers should incorporate this training protocol with conventional training to improve sports performance of karate athletes. A longitudinal study can be done on a large sample size and long term effects of plyometric and pilates training can be studied. Furthermore, the effects of PT on cardiopulmonary fitness of karate athletes can be studied.

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REFERENCES

[1] Kordi M. The effect of depth jump training on Electromyographic indices 16-18-year-old club athletes. Olympic Publication. 2005;21-35.
[2] Tan KS. Constructing a martial tradition: Rethinking a popular history of Karate-Dou. J Sport Social Issues. 2004;28(2):169-92.
[3] Ziaee V, Shobbar M, Lotfian S, Ahmadinejad M. Sport injuries of karate during training: an epidemiologic study in Iran. Asian J Sports Med. 2015;6(2):e26832.
[4] Doria C, Veicsteinas A, Limonta E, Maggioni MA, Aschieri P, Eusebi F, et al. Energetics of karate (kata and kumite techniques) in top-level athletes. Eur J Appl Physiol. 2009;107(5):603-10.
[5] Roschel H, Batista M, Monteiro R, Bertuzzi RC, Barosso R, Loturco I, et al. Association between Neuromuscular Tests and Kumite Performance on the Brazilian Karate National Team. J of Sport Sci and Med. 2009;8(CSSI3):20-24.
[6] Cook, G. Baseline sports-fitness testing. In: High Performance Sports Conditioning. B. Foran, ed. Champaign, IL: Human Kinetics Inc. 2001. Pp. 19-47.
[7] Okada T, Huxel KC, Nesser TW. Relationship between core stability, functional movement, and performance. J Strength Cond Res. 2011;25(1):252-61.
[8] Hibbs AE, Thompson KG, French D, Wrigley A, Spears I. Optimizing performance by improving core stability and core strength. Sports Med. 2008;38(12):995-1008.
[9] Amtmann JA, Amtmann KA, Spath WK. Lactate and rate of perceived exertion responses of athletes training for and competing in a mixed martial arts event. J Strength Cond Res. 2008;22(2):645-47.
[10] Ozmen T, Aydogmus M. Effect of core strength training on dynamic balance and agility in adolescent badminton players. Journal of Bodywork and Movement Therapies. 2016;20(3):565-70.
[11] Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports Medicine. 2006;36(3):189-98.
[12] Anderson BD, Spector A. Introduction to Pilates-based rehabilitation. Orthop Phys Ther Clin N Am. 2000;9(3):395-410.
[13] Kuo YL, Tully EA, Galea MP. Sagittal spinal posture after pilates-based exercise in healthy older adults. Spine. 2009;34(10):1046-51.
[14] Segal NA, Hein J, Basford JR. The effects of pilates training on flexibility and body composition an observational study. Arch Phys Med Rehabil. 2004;85(12):1977-81.
[15] Margaritopoulos S, Theodorou A, Methenitis S, Zaras N, Donti O, Tsolakis C. The effect of plyometric exercises on repeated strength and power performance in elite karate athletes. J Phys Edu Sport. 2015;15(2):310.
[16] de Villarreal ES, González-Badillo JJ, Izquierdo M. Low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency. J Strength Cond Res. 2008;22(3):715-25.
[17] Cruz-Ferreira A, Fernandes J, Laranjo L, Bernardo LM, Silva A. A systematic review of the effects of pilates method of exercise in healthy people. Arch Phys Med Rehabil. 2011;92(12):2071-81.
[18] Akuthata V, Nadler SF. Core strengthening. Arch Phys Med Rehabi. 2004;85(1):86-92.
[19] Niehues JR, Gonzales I, Lemos RR, Haas P. Pilates method for lung function and functional capacity in Obese Adults. Altern Ther Health Med. 2015;21(5):73-80.
[20] Baechle TR, Earle RW, editors. Essentials of strength training and conditioning. 2nd edition. Champaign, IL: National Strength and Conditioning Association. Human kinetics; 2008.
[21] Chu DA. Jumping into plyometrics. Champaign, IL: Human Kinetics (1998).
[22] Harrison AJ, Gaffney S. Motor development and gender effects on stretch-shortening cycle performance. J Sci Med Sport. 2001;4(4):406-15.
[23] Myer GD, Ford K R, Brent JL, Hewett TE. The effects of plyometric vs dynamic stabilisation and balance training on power, balance, and landing force in female athletes. J Strength Cond Res. 2006;20(2):345-53.
[24] Salehzadeh K, Karimiasl A, Borna S, Shirmohammadzadeh M. The effects of 8-week plyometric and combinational trainings on dynamic balance of teenage handball players. J Basic Appl Sci Res. 2011;1(12):3316-21.
[25] Pal S, Yadav J, Kalra S, Sindhu B. Injury profile in karate athletes- A literature review. J Critic Rev. 2020;7(9):1150-55. doi:10.31838/jcr.07.09.211
[26] Pal S, Yadav J, Kalra S, Sindhu B. Prevalence of injury pattern among karate players in Delhi-National capital region-A cross-sectional survey. J ClinDiag Res. 2020;14(8):10-12.
[27] Pal S. Preventive methods for karate injuries- A review. J ClinDiag Res. 2020;14(10):9-12.
[28] Van Lieshout R, Reijneveld EA, Van Den Berg SM, Haerkens GM, Koenders NH, De Leeuw AJ, et al. Reproducibility of the modified star excursion balance test composite and specific reach direction scores. International J of Sports PhynTher. 2016;11(3):356-65.
[29] Mcgill SM. Low back disorders. evidence-based prevention and rehabilitation. Champaign, IL: Human Kinetics. 2002.
[30] Irandoust K, Taheri M. Effects of 8-Week plyometric and strengthening programs on selected physical fitness factors of elite kabbadi players. IndJ Fundament Appl Life Sci. 2014;4(S4):3942-48.
[31] Kumar R. Effect of 8 Week pilates exercise training program on balance of untrained male youth boys. Int J of Behavioral Social Mov Sci. 2013;2(4):01-08.
[32] Fabio C. Function training for sports, Human Kinetics: Champaign IL, England. 2004.
[33] Chamari K, Chaouachi A, Hambli M, Kaouech F, Wisløff U, Castagna C. The five-jump test for distance as a field test to assess lower limb explosive power in soccer players. J Strength Condition Res. 2008;22(3):944-50.
[34] Markovic G, Jukic I, Milanovic D, Metikos D. Effects of sprint and plyometric training on muscle function and athletic performance. J Strength Cond Res. 2007;21(2):543.
[35] Hilfiker R, Hübner K, Lorenz T, Marti B. Effects of drop jumps added to the warm-up of elite sport athletes with a high capacity for explosive force development. J Strength Cond Res. 2007;21(2):550-55.
[36] Masamoto N, Larson R, Gates T, Faigenbaum A. Acute effects of plyometric exercise on maximum squat performance in male athletes. J Strength Cond Res. 2003;17(1):68-71.
[37] Mcbride JM, Nimphius S, Erickson TM. The acute effects of heavy-load squats and loaded countermovement jumps on sprint performance. J Strength Cond Res. 2005;19(4):893-97.
[38] Aminaei M, Yazdani S, Amirseifadini M. Effects of plyometric and cluster resistance training on explosive power and maximum strength in karate players. Int J Appl Exerc Physiol. 2017;6(2):34-44.
[39] Davaran M, Elmieh A, Arazi H. The effect of a combined plyometric-sprint training program on strength, speed, power and agility of karate-ka male athletes. Res J of Sport Sci. 2014;2(2):38-44.
[40] Ramírez-Campillo R, Gallardo F, Henriquez-Olguín C, Meylan CM, Martínez C, Álvarez C, et al. Effect of vertical, horizontal, and combined plyometric training on explosive, balance, and endurance performance of young soccer players. J Strength Condition Res. 2015;29(7):1784-95.
[41] Zech A, Hübscher M, Vogt L, Banzer W, Hänsel F, Pfeifer K. Balance training for neuromuscular control and performance enhancement: A systematic review. J Athlet Train. 2010;45(4):392-403.
[42] Chaouachi A, Othman AB, Hammami R, Drinkwater EJ, Behm DG. The combination of plyometric and balance training improves sprint and shuttle run performances more often than plyometric-only training with children. J Strength Condition Res. 2014;28(2):401-12.
[43] Hewett TE, Paterno MV, Myer GD. Strategies for enhancing proprioception and neuromuscular control of the knee. Clin Orthop Relate Res. 2002;402:76-94. doi: 10.1097/00003086-200209000-00008.
[44] Filipa A, Byrnes R, Paterno MV, Myer GD, Hewett TE. Neuromuscular training improves performance on the star excursion balance test in young female athletes. J Orthop Sports Phys Ther. 2010;40(9):551-58.
[45] Kahle NL, Gribble PA. Core stability training in dynamic balance testing among young, healthy adults. Athle Train Sports Health Care. 2009;1(2):65-73.
[46] Iacono AD, Martone D, Alfieri A, Ayalon M, Buono P. Core Stability Training Program (CSTP) effects on static and dynamic balance abilities. Gazzetta Medica Italiana Archivio per le Sci Med. 2014;173(4):197-206.
[47] Granacher U, Schellbach J, Klein K, Prieske O, Baeyens JP, Muehlbauer T. Effects of core strength training using stable versus unstable surfaces on physical fitness

in adolescents: A randomized controlled trial. BMC Sports Sci Med Rehabil. 2014;6(1):40-48.
[48] Kalra S, Yadav J, Pawaria S. Effect of pilates on lower limb strength, dynamic balance, agility and coordination skills in aspiring state level badminton players. J Clin Diagnos Res. 2019;13(7):01-06.
[49] Shavikloo J, Samami N, Norasteh A. Comparing the effects of TRX and Pilates training programs on the balance of Futsal players. Int J Sports Sci Med. 2018;2(2):42-46.
[50] Schilling JF, Murphy JC, Bonney JR, Thich JL. Effect of core strength and endurance training on performance in college students: Randomized pilot study. J Bodywork Movement Ther. 2013;17(3):278-90.
[51] Gallagher S, Kryzanowska R. The Joseph H. Pilates Archive Collection. Philadelphia: Bainbridge Books. 2000.

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