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Effect of Pilates Exercise Combined with Balance Training on Lumbopelvic Stability and Shooting Accuracy in National Level Archers

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SUMMARY

Objective. Lumbopelvic stability and shooting accuracy are some of the key determinants in the performance of archers. This study aimed to investigate the effect of Pilates exercise intervention combined with balance training on lumbopelvic stability and shooting accuracy in national level archers.

Methods. A randomized control trial with pre-test and post-test control group design was conducted with thirty male professional archers between the ages of 18-30 years. The participants were randomly allocated into three groups (ten in each group: PB = Balance and Pilates exercises; B = Balance Exercises; C = No exercises). The lumbopelvic stability was determined using the Knee Lift Abdominal Test (KLAT) and Bent Knee Fall-Out Test (BKFOT) for both legs by using a pressure biofeedback unit. Shooting accuracy was measured by taking the score of two ends with 12 arrows. Baseline measurements were taken before given intervention. The training program was given for 20 minutes a day and three times per week for six weeks.

Results. One-way ANOVA showed significant difference in shooting accuracy ($F = 5.11$, $\eta p^2 = 0.159$, $p = 0.03$), KLAT (Right) ($F = 8.51$, $\eta p^2 = 0.240$, $p = 0.00$), KLAT (Left) ($F = 6.62$, $\eta p^2 = 0.187$, $p = 0.01$) and BKFOT (Left) ($F = 6.31$, $\eta p^2 = 0.195$, $p = 0.01$). Whereas no significant difference is shown in BKFOT (Right) ($F = 0.99$, $\eta p^2 = 0.035$, $p = 0.33$) among B, PB, and Control group for baseline measurement and after intervention.

Conclusions. Although balance training showed improvements in the post-test values, the most significant improvements were recorded in the Pilates plus balance training group. This information can be used to plan the training protocols for archers.

KEY WORDS

Accuracy lumbopelvic; stability; Pilates exercises; balance exercises; pre-test-post-test.

INTRODUCTION

Archery is a non-contact, static sport that demands precision, control, focus, physical ability, and determination. Archers must have a high level of physical fitness and motor competence to win national and international level competitions. Improving physical fitness and motor skill factors like core body strength, upper body strength, handgrip, leg power, and static balance can positively impact performance of the

archers (1, 2). In archery, upper limb and shoulder muscles' endurance and shooting accuracy are the most important factors to achieve the best performance in the sport. The endurance component of the upper limb muscles is much warranted, reflecting the quantity of pull and push forces that these muscles exert continuously. The major muscles of the upper limbs are activated during the shooting process (3). Accuracy is a principal skill that the archer should acquire. A good shot accuracy will be produced if the technique is good and consistent. It will be difficult for an archer to win a competition if the shooting accuracy is poor (4).

Pilates are low impact exercises that concentrate on the smaller and deeper muscles, which help in improving flexibility, abdominal, lumbopelvic stability and muscular activity. Pilates method emphasizes on precision of movement with synchronization of the breathing. It's a well-structured exercise program with engagement of body core while implementing the fluidic movements. The principles of Pilates exercises include centering, focus, control, breath, precision, and fluidity (5, 6). Pilates exercises facilitate activation of transversus abdominis, diaphragm, multifidus and pelvic floor muscles and these muscles contribute to the lumbopelvic stability (7, 8). Pilates exercises can be considered an exercise intervention that increases muscle strength and improves static and dynamic balance. Emery *et al*. reported that Pilates exercises improve poor posture by strengthening the muscles and improving the balance (9). A study on Pilates exercise and balance indicated that 16-week mat Pilates exercises improved static and dynamic balance in university students (10). Bird *et al*. demonstrated that a 5-weeks Pilates training program resulted in larger benefits in static and dynamic balance (11). Jang also indicated that balance ability was improved through Pilates exercises (12). Balance is the process of maintaining the body's center of gravity (COG) vertically over the base of support. Balance training has been used to promote balance and sports-related skills and prevent and rehabilitate lower extremity sports injuries (13). It has been proven as an effective intervention to improve static postural sway and dynamic balance in athletes and non-athletes (8). It is also seen that an improved balance is linked to good lumbopelvic stability (14). Kim found that 12 weeks of balance training in the Sprinter/Skater pattern affects a high school archer's static and dynamic stability (15). According to Brill, posture stability and static balance skills increased after the Pilates exercise program (16).

Previous research has shown the significance of postural stability in archery performance, especially in the last second before string release and during the release itself (17-19). Limited postural sway and postural consistency across shots are other important predictors of archery efficiency (20, 21). The performance characteristics are needed in the pelvic region, trunk, shoulder girdle, and arms to ensure shooting accuracy. In addition to strength and endurance, postural stability is an important factor in determining the success of each shot.

In order to have better performance, archers require proper strength, balanced pose and stability of respiratory function (22). Consistency and stability are vital in archery; quite often archers have to maintain an asymmetric posture, which could be a reason for their poor performance (23). Hence, their shooting accuracy and stability need to be improved to increase their performance, which is thought to be done through balance training and Pilates exercises. Therefore, this study aimed to investigate the effect of Pilates exercise intervention combined with balance training on lumbopelvic stability and shooting accuracy in national level archers.

MATERIALS AND METHODS

Study design and setting

A randomized control trial with pre-test and post-test control group design was selected to conduct this study. The participants were selected from an International Stadium in, New Delhi and the study was conducted in the shooting range of JLN stadium.

Ethical approval

The Institutional ethics committee of Jamia Hamdard approved the study (reference no. 02/19 – date of approval: February 13, 2019). Written informed consent was taken from every participant. This study was conducted as per the principles of Helsinki.

Sample size calculation

The sample size was calculated by G*Power software (3.1.94) with the combination as statistical test-means: differences between matched pairs, types of power analysis – *A priori*: compute require sample size – given α = 0.05, Power (1-ß err prob) = 0.80, and effect size dz = 0.5. the calculated sample size is 27. The 10% samples were increased to conduct this study.

Participant

Thirty male archers with an average age of 20.33 years and an average participation experience of 2.9 years at the national level, who were in regular practice, were recruited for this study. The participants were randomly allocated into three groups (ten in each group: PB = Balance and Pilates exercises; B = Balance Exercises; C = No exercises) by an independent researcher who was not part of the current study. The consort diagram of participant flow is available

as **figure 1**. The participants who had a recent history of musculoskeletal injury or neurological impairment, biomechanical abnormalities, and history of any medication or vertigo that directly or indirectly impairs the performance were excluded.

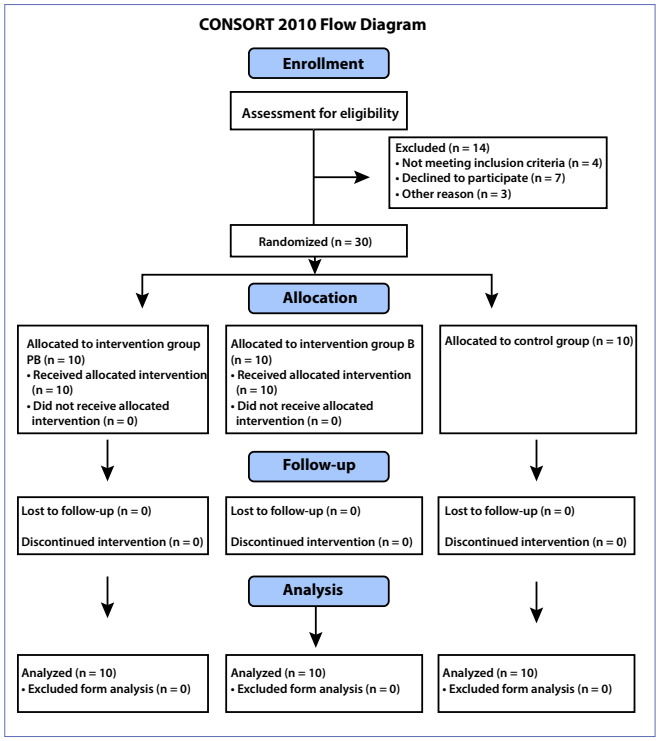

Figure 1. Flowchart of the study.

Outcome measures

Lumbopelvic stability

The lumbopelvic stability was determined using the Knee Lift Abdominal Test (KLAT) (24) and Bent Knee Fall-Out Test (BKFOT) (25) (**figures 2,3**) for both legs by using a pressure bio-feedback unit (Stabilizer®, Chattanooga Group Inc., Hixson, TN, USA., SKU-9296-5338276 USA). This device provides a measuring range of 0-200 mmHg pressure with an accuracy of ± 3 mmHg. This unit consists of a combined gauge and inflation bulb connected to a pressure cell. The highest absolute mmHg variation from the pre-set baseline pressure (40 mmHg) was recorded.

Shooting accuracy

Shooting accuracy was measured by taking the score of two ends with 12 arrows (each end containing 6 arrows). The position of the shaft on the target determines the

Figure 2. Participant performing Knee Lift Abdominal Test.

Figure 3. Participant performing Bent Knee Fall-Out Test.

scores. Mostly the targets have ten concentric circles with different color codes. The whole target is divided into 10 scoring zones ranging from 10 to 1 depending upon the proximity from the pinhole in the center. Hitting the innermost circle will fetch an archer 10 points and hitting the outermost circle will fetch 1 point. For an end of 6 arrows, the archer gets a time limit of 4 minutes. Arrows shot outside the time limit are not counted. If an arrow's

shaft crosses two colors or any separating lines between two scoring zones, the arrow will score the greater value of the two zones (2).

Interventions

Pilates exercise training

Pilates exercise training was given to the participants as per the Park *et al.* protocol (23). The warmup included breathing, rolling back, coccyx curl and hundred breathing. The main workout included exercises like single leg stretch, straight leg raises, basic bridge, bridging variation, quadruped, clap with seal motion, mermaid twist, swimming, double leg stretch, shoulder bridge, swan dive and leg full front. Rest position, cat with arm/leg extension and breathing were given as cool down activities. The whole protocol took around 50 minutes in administration. The above article may be referred for the details of the protocol (23).

Balance training

Balance training was given to the participants as per the recommendation of the present literature. The training was done in double limb stance, single leg stance and tandem stance for a period of six weeks with three training sessions per week. The progression was done in terms of progression from double limb stance to single limb stance to tandem stance; from eyes open to eyes closed and from a firm stable surface to an unstable surface like foam mat. The double limb eyes open stance on the firm surface was skipped for all the subjects. Each session lasted for a period of 20 minutes (26, 27).

Procedure

Upon their arrival at the shooting range, all the necessary information, relative risk, and study benefits were imparted to all the participants. The participants were screened according to the inclusion and exclusion criteria, and demographic and anthropometric measurements were taken. A baseline measurement of lumbopelvic stability and shooting accuracy was taken for all the three groups. Lumbopelvic stability was tested with Pressure Biofeedback Unit with the help of two tests, *i.e.*, KLAT and BKFOT as follows. The participants were in a crook lying position for the KLAT.

The pressure biofeedback unit was placed horizontally under their spines. The lower edge was kept at the level of the posterior superior iliac spines. The biofeedback unit's basal pressure was set to 40 mmHg (baseline pressure). Participants were instructed to lift one foot to 90° hip and knee flexion and hold for 4-6 seconds while maintaining the lumbar spine in neutral position. The maximum pressure deviation was recorded and used for further investigation (26). The participants were supine for the BKFO test, with the pressure biofeedback unit inserted vertically under the lumbar spine and the lower edge two centimeters caudal of the posterior superior iliac spines on the lower edge the opposing side of the flexed knee. In addition, a folded towel was placed near the pressure biofeedback unit to maintain the same height on both sides of the lumbar spine. The pressure biofeedback unit's basal pressure was increased to 40 mmHg (baseline pressure). After that, one hip was flexed, and the knee was also flexed to 120 degrees, with the foot lying on the examination couch's surface. Participants were instructed to return to the beginning position by carefully bending their hip to about 45 degrees of abduction/lateral rotation while keeping their foot supported alongside their straight knee. The maximum pressure deviation was measured and analyzed further (26). A simple long arm goniometer with a 360° angle was used to control the starting positions of the hips and knees during KLAT and BKFO. The participants were tested for their shooting accuracy as well. Accuracy was tested by taking the scores of 2 ends, *i.e.*, 12 arrows. The position of the shaft on the surface of the target determines the score.

After taking the baseline (pre-test) measurements, the PB group (Pilates + Balance training) was given a Pilates exercise program of 50 minutes with 10 minutes warm-up and 10 minutes cool down period for six weeks with a frequency of three times per week. Also, balance training was given in this group for 20 minutes 3 times per week for six weeks. The exercises were breathing, rolling back, coccyx curl, and a hundred for warm-up. In the workout session, the exercises were single leg stretch, straight leg raise, basic bridge, bridging variation, quadruped, clap with seal motion, mermaid twist, swimming, double leg stretch, shoulder bridge, swan dive, leg full front. The cooldown period consisted of rest, cat with arm/leg extension and breathing.

The balance training (B) group received a balance training program for 20 minutes and three times per week for six weeks. The training was adjusted and progressed according to the capability of the athletes. At first, the training was performed on the floor and then the same exercises were performed on foam. Exercises started with double limb eyes open progressing to double limb eyes close progressing to single-limb eyes open to single-limb eyes close and then progressing to tandem stance with eyes open and then closed. Group C (control) did not receive any type of training.

Post-test measurements for lumbopelvic stability and shooting accuracy were taken of all the three groups after completion of the six weeks training program.

Statistical analysis

Statistical analysis was computed using IBM SPSS software version 23. Data were screened for missing data, outliers, typo

error, and normality of data was confirmed with the Shapiro-Wilk test. The descriptive statistics of the anthropometric data were used to calculate the mean and standard deviation. The inferential statistics were used to determine the variance in the anthropometric data. One way analysis of variance (ANOVA) was used to determine the variance between groups for lumbopelvic stability and shooting accuracy of national-level archers. The least significant differences (LSD) *post-hoc* test was used to find the significant difference within groups. Partial Eta squared (ηp^2) was used to determine the effect size as the $\eta p^2 = 0.01$ considered as small effect; $\eta p^2 = 0.06$ considered as medium effect; and $\eta p^2 = 0.14$ considered as large effect (28). The statistical results were considered statistically significant if the P-value was less than 0.05.

RESULTS

One-way ANOVA showed significant difference in shooting accuracy ($F = 5.11$, $\eta p^2 = 0.159$, $p = 0.03$), KLAT (Right) ($F = 8.51$, $\eta p^2 = 0.240$, $p = 0.00$) KLAT (Left) ($F = 6.62$, $\eta p^2 = 0.187$, $p = 0.01$) and BKFOT (Left) ($F = 6.31$, $\eta p^2 = 0.195$, $p = 0.01$). Whereas no significant difference showed in BKFOT (Right) ($F = 0.99$, $\eta p^2 = 0.035$, $p = 0.33$) among B, PB, and Control group for baseline measurement and after intervention.

Post-hoc (LSD) test showed a significant difference in shooting accuracy ($p = 0.03$) for Pilates plus balance training group only when compared to the control and the balance training group. For KLAT (Left and Right) there were statistically significant differences between the balance only and the control group ($p = 0.03$ and 0.02). Pilates plus

Table I. Descriptive and inferential statistics for their anthropometric characteristics between the different groups.

Anthropometric Characteristics	Balance training (Mean ± SD)	Pilates+Balance training (Mean ± SD)	Control (Mean ± SD)	F-value	Significance
Age (years)	19.40 ± 2.06	19.40 ± 2.11	22.20 ± 4.46	1.73	0.16
Height (cm)	64.74 ± 9.54	65.54 ± 11.64	62.89 ± 10.37	2.34	0.67
Weight (kg)	164.76 ± 5.40	168.57 ± 4.37	165.28 ± 6.21	1.63	0.83
BMI (kg/m^2)	20.78 ± 2.07	22.70 ± 2.45	22.30 ± 1.64	2.36	0.11

*Significant at 0.05 level; BMI: Body Mass Index.

Table II. Descriptive and inferential statistics (ANOVA) between the groups for their pre-test and post-test.

	Group	Baseline Mean ± SD	Post-training Mean ± SD	F-value	Partial Eta Squared	Significance
Shooting Accuracy (Score)	B	108.50 ± 9.05	111.40 ± 6.31	5.11	0.159	0.032*
	PB	96.10 ± 12.65	103.30 ± 12.65			
	Control	107.60 ± 6.43	106.20 ± 10.16			
KLAT (Right) mmHg	B	60.70 ± 7.67	55.10 ± 9.98	8.51	0.240	0.007*
	PB	50.80 ± 6.39	45.30 ± 3.02			
	Control	56.80 ± 8.40	51.60 ± 10.56			
KLAT (Left) mmHg	B	63.60 ± 12.24	54.80 ± 6.87	6.62	0.187	0.016*
	PB	51.80 ± 8.85	44.40 ± 4.92			
	Control	56.00 ± 12.68	61.00 ± 10.11			
BKFOT (Right) mmHg	B	50.10 ± 5.60	48.20 ± 6.44	0.99	0.035	0.328
	PB	47.20 ± 2.57	46.60 ± 3.37			
	Control	49.20 ± 5.69	48.70 ± 6.41			
BKFOT (Left) mmHg	B	44.50 ± 4.40	46.50 ± 3.40	6.31	0.195	0.018*
	PB	46.90 ± 4.67	43.30 ± 2.98			
	Control	46.30 ± 3.80	49.50 ± 5.38			

*Significant at 0.05 level.

Table III. Inferential statistics (*post-hoc* [LSD]) within groups for different intervention.

	Shooting accuracy	KLAT (Right)	KLAT (Left)	BNFOT (Right)	BNFOT (Left)
PB *vs* Control	0.03*	1	0.05	1	0.02*
B *vs* Control	0.54	0.03*	0.02*	1	1
PB *vs* B	0.54	1	1	1	0.07

balance training demonstrated a close to significant difference compared to control (p = 0.05). For BKFOT (Left), only the PB group demonstrated any significant difference (p = 0.02) compared to the other two groups.

DISCUSSION

This study was aimed to determine the effect of Pilates exercise combined with a balanced training program on lumbopelvic stability and shooting accuracy in national level archers. After six-week training, it was found that KLAT (Right) showed improvements in all the three groups, but the between-group comparison showed no significant difference between PB *vs* Control and PB *vs* B. Both PB and B groups improved their scores for KLAT (Left). A significant difference was also found between the B and C groups; also, there was a very close to the significant difference between PB and C groups. For BKFOT (Right), it was seen that all the groups showed improvement in their values, but there was no significant difference between any of the three groups. For BKFOT (Left), only the PB group showed improvement, and there was a significant change between the group PB and group C only. On comparing the results of shooting accuracy, it was found that although there was an improvement in both the groups (PB and B), a significant difference in the shooting accuracy was only present between the PB and C groups.

It is important to see if static or dynamic balance training may help archers improve their shooting ability. Mason and Pelgrim investigated the relationship between balance ability and shooting accuracy in junior and adult archers. They found that junior archers have a significant relationship between balance ability and shooting accuracy – the adult archers showed a higher level of balance ability than junior archers (18). Mononen *et al.* reported that shooters who control their postural balance have a steadier platform in aiming, enhancing the shooting accuracy (29). Norton *et al.* revealed that balance training enhances stability and minimizes the body's shaking, which can help in improvement in scores (30). Conversely, Kim concluded that balance training helped improve balance ability for archers, but it did not have any direct effect on shooting accuracy (15).

The Pilates exercises focus on core engagement and breath control; activation of transversus abdominis, diaphragm, multifidus and pelvic floor muscles is facilitated. These muscles contribute to the stability of the lumbopelvic region (7). This is an important finding when considering the training design for archers, as incorporating Pilates exercises in their program can significantly change their stability and performance. The specificity of Pilates exercises and the principles on which it is based might have resulted in improved accuracy of performance and stability. In addition to this, there are some obvious relationships between some of the measured variables found in previous studies (11, 12, 23, 24). Park *et al.* conducted a study on 20 high school archers and showed attentive improvements in the static balance of the right and left side on comparing with the baseline score. Some of the components of the dynamic balance score improved in the exercise group compared with the control group (23). Panhan *et al.* reported that Pilates exercises are effective in training the internal oblique muscle to improve the neuromuscular efficiency in women engaged in Pilates exercises 2 times a week (31). Phrompaet *et al.* conducted a single-blinded controlled design study on 40 subjects to determine the effects of Pilates exercises on flexibility and lumbopelvic control. The exercise group participants showed improvements in flexibility and lumbopelvic movement control (32). Hyun *et al.* also found significant effects on the static and dynamic balance of older women suggesting that these exercises effectively enhance the balance ability of older women (33). Perrott *et al.* conducted a study to determine the relationship between balance and lumbopelvic stability and reported that athletes with poor lumbopelvic stability have poorer balance than athletes with more optimal lumbopelvic stability (14). These studies offer an insight to everyone that can take such information to the level of practical application. The Pilates exercise program can and should be given as an adjunct to the training protocols of archers.

There are a few limitations to this study. Firstly, the volunteers were chosen by draw – due to that, some of the participants did not participate happily. Secondly, the

time interval, *i.e.*, six weeks, was sufficient but not fair enough to bring about large improvements. However, more improvements could have been observed if the time interval had been longer. Last, it is a single-blinded study; a double-blinded study would have increased the validity of the research.

CONCLUSIONS

Pilates exercises appear to be an effective way to improve archers' lumbopelvic stability and shooting accuracy when combined with balance exercises. However, balance training also showed improvements in comparing the pre-test and post-test values of the balance training group, but the most significant improvements were recorded in only the Pilates plus balance training group. Archery coaches could use this information to plan a training protocol for archers.

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None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

SK, DM, MD, MA, SN, MAB: conceptualization. SK, DM: data extraction. SK, DM: writing - original draft. DM, MD, MA, SN, MAB: data analysis. DM, MD, MA, SN, MAB: writing - review & editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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