EFFECTS OF A 12-WEEK CORE TRAINING PROGRAM ON PHYSICAL CHARACTERISTICS OF RHYTHMIC GYMNASTICS: A STUDY IN KUALA LUMPUR, MALAYSIA

Soheyla Nazari[1*] and Lim Boon Hooi[1]

[1]Faculty of Sport Center, University of Malaya, Kuala Lumpur, Malaysia

[*]Email address: soheylanazari@gmail.com
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Abstract

Background: Improving the physical characteristics of rhythmic gymnasts (RGs) has a significant impact on their level of performance. The enhancing of certain characteristics among RG is helpful in the early stages of RG training process. Methods: The current quasi-experimental study aimed to assess the effects of the core training program on enhancing physical characteristics including power (vertical jump test), balance (stork stand balance test), flexibility (sit and reach test), and strength and endurance (sit-up test), among Malaysian rhythmic gymnasts. Forty female rhythmic gymnasts (aged 6-9 years old) from 2 sport clubs located in Kuala Lumpur, Malaysia, were selected to participant in this study and divided randomly into intervention and control groups. Participants in the intervention group received 12 weeks of the core training program as the intervention program. Results: The results showed the core training program had positive effects on physical characteristics including power (Δmean=-2.95, $p<0.001$), balance (right leg: Δmean=-2.25, $p<0.001$ and left leg: Δmean=-0.69, $p=0.04$) and strength (Δmean=-2.70, $p<0.001$) among participants in the intervention group. However, compared to pre-test scores, no significant changes were seen in the mean scores for flexibility (sit and reach test) in the post-test ($p>0.5$). Conclusion: Overall, the results of the current study showed that the intervention program can be introduced as an effective program for improving the physical characteristics of the young female Malaysian RGs. The findings of the current study could be used by Malaysian gymnastics coaches and gymnastics trainers to design and implement a continuous core training program to improve the performance of Malaysian RGs.

Keywords: Core training, Malaysian gymnast, physical performance, rhythmic gymnastics

Introduction

Rhythmic Gymnastics (RG) is essentially a sporting procedure developed through modification of techniques and adaptations inclusive of level of competitiveness, age, and many other categories of assessment. For athletes seeking to excel in RG, passionate dedication to improve their abilities has become increasingly required in order to succeed in reaching personal goals. Improving the physical and technical characteristics among the rhythmic gymnasts has a significant impact on their level of performance (Bassett & Leach, 2011).

Gymnastics is a specifically skilled sport, demanding exceptionally high levels of athlete conditioning. As a consequence of the demands, gymnasts are among the fittest, mentally most composed, strongest and most flexible of all athletes, as presented by their capabilities of bodily movement and control over a large variety of positions (Bassett & Leach, 2011).

The lumbo-pelvic muscles (core) provide an essential platform in order to assist in control of these movements (Willson, Dougherty, Ireland, & Davis, 2005). Well trained core muscles ensure a solid foundation to the limbs for torque generation (Behm, Wahl, Button, Power, & Anderson, 2005). Just about all movements begin in the core region of the body. The core muscles are activated to play a role as a stabilizer to ensure that body maintains an upright position even before movement in the limbs is initiated. A strong core musculature stabilizes the pelvis dynamically during functional movements (Becker, Fröhlich, Kelm, & Ludwig, 2018).

Many health professionals focus on core training in a variety of environments. Strength and conditioning coaches realize the benefits of obtaining a strong core in enhancing sport performance. For a high number of strength and conditioning professionals, core stability is understood as a true key component in training individuals for improving sport performance (De Blaiser et al., 2017). Although it has been identified that focused core training has positive effects in numerous sports, far less is understood about the effect on gymnasts.

Numerous studies have provided information on the physical and technical characteristics and successful performances in multiple types of sports, but few studies have been completed on RG. Not many studies explain a good proposal to determine a useful model of training for successful performance. Durall et al. (2009) concluded that the 10-week core training program provided confident information that stimulation increase in trunk muscular capacity has a direct positive effect on gymnastic performances (Alves et al., 2015).

Studies highlighted the importance of core training for gymnasts, due to the various components of spin and rotation required in many gymnastic movements (Bisel, Kramer, & Banas, 2017). Durall et al. (2009) studied the effects of a pre-season trunk muscle training programs on the occurrence of low-back pain in Division III female collegiate gymnasts. Although further research is required to evaluate the effects of core training and

whether it should be an inclusion to all gymnasts' conditioning programs (Durall et al., 2009; Rutkauskaitė & Skarbalius, 2011; Thompson, Cobb, & Blackwell, 2007).

There are differing reports covering the effects of core training programs on various sports performance. The majority of studies were carried out on athletes, and a certain variety of sport training accompanied the core training program on elite athletes (Gorostiaga et al., 2004; Moore, Hickey, & RAOUL F REISER, 2005). In view of this differentiation of reports, the importance of core training on the gymnasts' performance, as well as absence of published study in Malaysia covering this specific area, current study particularly refers to the rhythmic gymnastics (RG) novices, characterized by an enormous amount of skills that they are expected to attain.

The current study aimed to assess the effects of the core training program on enhancing the physical characteristics of the young female Malaysian Rhythmic Gymnasts. Adopting a core training program based on requirements of Malaysian RG has significant effect on improving physical abilities and technical performance. The program used in current study focuses on Malaysian novice RG based on their requirements on successful performance as well as using the experience and knowledge of experts in this area.

Methodology

Study Design

The current study is quasi-experimental with one pre- and two post-tests, in which participants were randomly selected to receive the intervention programme (intervention group). The pre-test was conducted before starting the first session of training and post-tests 1 and 2 were conducted after session 8 and 12 respectively. Based on the study design, the participants in control group received no training.

Participants

From a total of seven sport clubs training rhythmic gymnasts in grade 1 (minimum age for this level is 6 and maximum is 9 years old), located in Kuala Lumpur, Malaysia, in 2014, only two clubs were accepted to contribute in this study. Overall, 40 female rhythmic gymnast trainees were recruited to join the interventional study from these two sport clubs (23 and 17 participants from club 1 and 2, respectively) based on the study's inclusion and exclusion criteria, which were as follows:

- ✓ Inclusion: Participants who were active in rhythmic gymnastics clubs in grade 1; Participants who had never had specific core stability training; Age: 6-9 years old.

- ✓ Exclusion: Participants who had physical disability that prevented them from participating in the study.

The participants were randomly divided to intervention (n=20) and control (n=20) groups using random sampling with a draw session. Prior to these steps, a meeting was scheduled

with participants and their parents in each club to give them some information about the study and ask them about their willingness to participate in the study. The details of the training sessions were fixed in a meeting or through phone calls with the parents. The current study was approved by the Ethics Committee of University of Malaya.

Developing and Designing the Intervention Program

The aim of the interventional program was improving participants' core region in order to enhance their physical performance in rhythmic gymnastics. The intervention plan was mainly adapted from Stanton's protocol Swiss Ball training program through a process of consultation with field experts and coaches (Stanton, Reaburn, & Humphries, 2004). Searching for the best resources and references based on the study objectives through online searching (literature review) and getting the experts recommendations through several meetings with gymnastic coaches and instructors were carried out in this stage.

Putting all the sources, references and data together, five preliminary activities were adopted from some available core training activity guidelines including Stanton's protocol Swiss Ball training program (Stanton et al., 2004). To use the documents, the required permissions were obtained from the publishers or organizations. Study objectives, the skill level of the participants, and time limitations were some of the important considerations for designing the activities.

In the last step, based on the research goals and objectives, the duration of the project, study limitations (Mohammadzadeh, Awang, K.S, & Ismail, 2017) and after some major changes, the 5 activities were rewritten for intervention sessions. These activities were gathered in a single set as the intervention protocols "Trainer Guideline" and some related pictures were attached. Content and face validity as well as reliability of the activities were checked to finalize the activities. In order to assess the content validity of the interventional program, the initial version was reviewed by nine fitness and gymnastic trainers.

The first session included introducing the program and benefits of core training sessions. Intervention sessions were held twice weekly (Monday-Saturday) for core muscle strength. Each participant was given a Swiss ball suitable to the participant's height. The size of the Swiss balls was conducive to accomplishing >90° angle at both the hip and knee while sitting on the Swiss ball (Norris, 1999). The training plan included the following:

Abdominal Crunch

Crunches or abdominal crunches work the rectus abdominal muscle in the midsection of body. Abdominal curls may also engage the external or internal oblique muscles, especially when rotation is added to the movement. Abdominal crunches are an effective way to strengthen the front of the torso and the core region.

Swiss Ball Wall Squat

The quadriceps or front of thigh is the targeted muscle during this exercise, but many other muscles get a workout as well. The butt, hip, calf, back of thigh, low back, abs, and side abs are all used during this exercise. The Major muscle groups utilized during this leg exercise are: Gluteus maximus, Gluteus medius, Gluteus Minimus, Quadriceps, and Hamstrings. Special emphasis is placed on the quadriceps muscles, as they control motion both eccentrically and concentrically.

Superman on an Exercise Ball

The Superman exercise is one of the best exercises to strengthen upper and lower back muscles. If done regularly, the Superman exercise may help alleviate back pain that is related to weak back muscles. In addition to strengthening back muscles, the Superman works gluteus and hamstring muscles. This Exercise is a great bodyweight core move that works to stabilizing muscles of back as well as gluteus, hamstrings and shoulders.

Kneeling Ball Roll

This kneeling ball roll starts with the hands on the ball and ends in a push up position.

Hamstring Curl

The ball hamstring curl exercise is a leg curl variation used to build and strengthen the muscles of the hamstring complex. The ball hamstring curl exercise provides several unique challenges. For example, it challenges the core to stabilize the spine as you contract your hamstrings to bring the exercise ball towards the body.

The Swiss balls were either 55 or 65 cm in height. The volume of the exercise program gradually increased by incrementing the repetitions and duration of the activities. Before each session, participants performed a 6-8 minute warm-up following by stretching. The rest interval between the sets and circuits was approximately 30 seconds. Exercise session lasted 30 minutes for week 1 and gradually increased up to 45 minutes in progress of the time. In each session and movement, participants were reminded to focus on the specific muscles activated while performing movement (for example, abdominal muscles during Abdominal Crunch).

Measuring Details of the Study Variables

A high level of physical abilities is needed to succeed in women's competitive gymnastics. Strength, endurance, agility, flexibility, balance and power are some of the most important physical skills that play a vital role in the success of a competitive gymnast (Bradshaw & Rossignol, 2004). These physical characteristics are mentioned by the USAG Talent Opportunity Programs (TOPs) test, a multi-test battery designed to measure gymnasts'

abilities (Sleeper, Kenyon, & Casey, 2012). Details of the physical characteristics are provided below.

Power (Vertical Jump Test)

The Vertex Vertical Jump Meter was used as a variant of the traditional sergeant jump. It comprises plastic swivel vanes arranged in half-inch increments attached to a telescopic metal pole adjusted for each subjects' reach height (Buckthorpe, Morris, & Folland, 2012).

The test requires subjects to use their dominant hand to displace the highest possible plastic vane with an overhead arm swinging motion at the apex of their jump. Jump height was determined as the number of vanes displaced above the metal pole and converted from inches to centimeters. All jumps were performed from a standardized position, with the participant standing facing the vanes at a distance of 10 cm from the vertex, with their dominant shoulder aligned with the end of the vanes (Buckthorpe et al., 2012). The test was repeated three times.

Scoring

The highest displaced horizontal swivel vane determines maximum jump height (cm). To calculate vertical jump height, the difference between standing reach measurement and the highest displaced horizontal swivel vane is measured. According to the norm (Sheerin, Williams, Hume, Whatman, & Gleave, 2012) a score with the range of <6.4 cm is very poor; (6.4 - 11.8) poor; (11.9 - 17.2) below average; (17.3 - 28.2) average; (28.3 - 33.7) above average; (33.8 - 39.1) good; and > 39.1 excellent (Table 1).

Balance (Stork Stand Balance Test)

The equipment of this test was flat, non-slip surface and stopwatch. The subjects were asked to remove their shoes and place the hands on the hips, then position the non-supporting foot against the inside knee of the supporting leg. The subjects were given one minute to practice the balance. The subject raised their heel with the examiner signal to balance on the ball of the foot. The stop watch was started as the heel was raised from the floor. The stopwatch was stopped if any of the following occurred:

- ✓ The hands come off the hips;
- ✓ The supporting foot swivels or moves (hops) in any direction;
- ✓ The non-supporting foot loses contact with the knee;
- ✓ The heel of the supporting foot touches the floor;
- ✓ The participants were first instructed to familiarize themselves with the balance position, and they were advised to stand as long and as quietly as possible. Three trials were allowed, and the best was recorded.

Scoring

The maximum time which participants hold the body in the right position recorded in seconds and the best of three attempts was the final score. According to the norm (Sheerin

et al., 2012), scores with a range of <1.56 (s) are very poor balance, (1.56 - 1.68) (s) poor; (1.69 - 2.32) (s) below average; (2.33 - 6.11) (s) average; (6.12 - 9.93) (s) above average; (9.94 - 12.78) (s) good; and >12.78 excellent balance (Table 1).

Flexibility (Sit and Reach Test)

The equipment of this test was a Sit and Reach Box. The subjects were asked to sit on the floor with legs stretched out straight ahead. Shoes should be removed. The soles of the feet are placed flat against the box. Both knees should be locked and pressed flat to the floor. The tester assisted by holding them down, with the palms facing downwards, and the hands on top of each other or side by side. The subject reached forward along the measuring line as far as possible. After some practice reaches, the subject reached out and held that position for at two seconds while the distance was recorded (Davis, 2004).

Table 1: Norms of Performance on Each Physical Test for Gymnasts Aged 6-9 Years Adopted from the study by Sheerin et al. (2012)

Performance	Vertical jump (cm)	Stork Stand Balance (s)	Sit and Reach(cm)	Sit-up(s)
Very Poor	<6.4	<1.56	<15.5	<10
Poor	6.4 - 11.8	1.56 - 1.68	15.5 - 20.5	10 - 14
Below Average	11.9 - 17.2	1.69 - 2.32	21.0 - 25.5	16 - 22
Average	17.3 - 28.2	2.33 - 6.11	26.0 - 37.0	24 - 36
Above Average	28.3 - 33.7	6.12 - 9.93	37.5 - 42.5	38 - 44
Good	33.8 - 39.1	9.94-12.78	43.0 - 47	46 - 50
Excellent	>39.1	>12.78	>47.5	>50

Scoring

The sliding ruler centered on the top of the box was used to obtain the SR scores. The markings on the ruler were positioned so that the 35-cm mark represented the point at which the subjects' fingertips were in line with their toes. This device permitted a scoring range from 0 cm to 50 cm. According to the norm of Sheerin et al. (2012), scores with <15.5 are very poor; (15.5 - 20.5) poor; (21.0 - 25.5) below average; (26.0 - 37.0) average; (37.5 - 42.5) above average; (43.0 - 47.5) good; and >47.5 excellent flexibility (Table 1).

Strength and Endurance (60 Second Maximum Sit-Up Test)

Stop watch, a partner to hold subject's ankles, and Mat or towel to lie on (optional) were the test equipment. The subject had to flex the trunk up until the elbows touched the thighs and then lower the trunk back until the scapulae came into contact with the floor for a successful sit-up (Dendas, 2010).

Scoring

The test was scored as maximal number of correct sit-ups within the 60-second time period. The completion of one complete curl up (up and back) counts as one. Sheerin et al. (2012) norm suggests the scores with <10 are very poor; (10 - 14) poor; (16 - 22) below average; (24 - 36) average; (38 - 44) above average; (46 - 50) good; and >50 excellent (Sheerin et al., 2012) (Table 1).

Assessments

The pre-test was done before starting the interventional training for all participants (control and experimental group). The first post-test was done immediately after finishing the 8th week. The second post-test was done 4 weeks after the first one. All physical tests including vertical Jump, stork stand balance test, sit and reach test, and sit up were conducted by the main researcher and two local research assistants (a top fitness trainer with more than 10 years of experience in fitness and strength training and a postgraduate student in the sport coaching field with several years' experience working in gymnasium fitness clubs). All participants had a warm up before performing tests with their gymnastic coach for about 20 minutes. The warm up contained:

- ✓ 5-min run around the spring floor with intermittent skipping and jumping.
- ✓ Walk on high toe with knees straight across floor.
- ✓ Walk on high toe with knees bent across floor.
- ✓ Walk on heels across floor.
- ✓ Static stretching on panel mats.

All participants in both clubs did the physical tests in a single day (morning and evening). RAs were responsible for performing specific tests for all the participants. Main researcher conducted 2 tests for all participants. In each club the participants (n=20) divided into 3 groups for performing physical tests: group 1, vertical jump test with 7 participants and one assistant; group 2, sit and reach test with 7 participants and one assistant; and group 3, sit up test and stork stand balance test with 6 participants and the main researcher. After performing each test, participants were led to another group to perform next tests. Each Assistant wrote the name of participants in each test to make sure all 20 participants performed all the tests. All processes were performed in the other club with the same assistants with the remainder of the participants.

The participants in the control group received only the routine exercises for the duration of the study. The pre- and post-tests were done for the participants in both the intervention and control groups similarly and in the same days.

Validity and Reliability Tests

The content validity of the study's selected tests was checked and approved by a panel of experts including university lectures and judges and coaches in the related area. In order to check the reliability of the study's tests, a test-retest reliability coefficient was done among 10 female rhythmic gymnasts (aged 6-9). The results showed that the Pearson Correlation was higher than 0.7 for all tests (vertical jump=0.84; right leg balance=0.76; left leg balance=0.72; sit and reach=0.88; sit up=0.86).

Data analysis

Data analysis was done using SPSS software (version 21). The skewness ratio and its standard error were taken to check the normality (between -2 and 2) (Bai & Ng, 2005).

Confidence interval and the level of significant alpha were set at 95% and 0.05, respectively.

A mix of between-within subject ANOVA was done to investigate the differences in the mean of the continuous variables among the 3 stages of pre- and post-tests in the intervention and control groups. The normality (Skewness and Kurtosis) and homogeneity of variance (Levene's test) of variables were assessed before doing the main test. Partial eta square was used as a value of effect size. According to Cohen (1988), 0.01, 0.06 and 0.14 represent small, moderate and large effect sizes, respectively (Bakeman, 2005).

Results

Age, height and weight of the participants

Table 2 represented the mean score of age, height and weight of the participants in the study. According to the results, the mean age of participants was 7.55±1.01. Furthermore, the mean scores of participant height and weight were 126.45±12.83 and 25.55±7.43, respectively.

Table 2: The mean score of age, height and weight of the participants (n=40)

Characteristics	Mean	SD
Age	7.55	1.01
Height	126.45	12.83
Weight	25.55	7.43

The results of repeated measure ANOVA on the physical variables showed that there was a significant difference in terms of: 1) vertical jump between two groups ($F=56.66$, $P<0.001$, $\eta2=0.50$) and among 3 stages of time ($F=36.97$, $P<0.001$, $\eta2=0.49$); 2) right leg balance between two groups ($F=15.93$, $P<0.001$, $\eta2=0.30$) and among 3 stages of time ($F=52.26$, $P<0.001$, $\eta2=0.58$); 3) left leg balance between two groups ($F=4.75$, $P=0.03$, $\eta2=0.11$) and among 3 stages of time ($F=2.95$, $P=0.05$, $\eta2=0.07$). There were no significant differences in the mean values of sit and reach between two groups ($F=0.17$, $P=0.67$) and among 3 stages of time ($F=2.85$, $P=0.06$) (table 3).

Table 3: Result of ANOVA within – between subject effects for physical characteristics

Variable		df	Mean Square	F-Value	P-Value.	Partial Eta Squared
Vertical Jump	Time	2	60.32	36.97	<0.001*	0.49
	Group	1	343.41	7.13	0.01*	0.16
	Time * Group	2	62.25	26.36	<0.001*	0.41
Stork Stand Balance (right leg)	Time	1.41	30.12	52.26	<0.001*	0.58
	Group	1	108.01	15.93	<0.001*	0.30
	Time * Group	1.41	26.47	54.92	<0.001*	0.55
Stork Stand Balance (left leg)	Time	2	1.37	2.95	0.05*	0.07
	Group	1	24.89	4.75	0.03*	0.11
	Time * Group	2	4.40	8.21	0.001*	0.18
Sit and Reach	Time	1.60	3.41	2.85	0.06	0.07
	Group	1	9.07	0.17	0.68	0.00
	Time * Group	1.60	1.16	0.77	0.44	0.02
Sit-up	Time	1.51	45.03	27.70	<0.001*	0.43
	Group	1	795.67	10.15	0.003*	0.21
	Time * Group	1.51	33.42	15.50	<0.001*	0.30

*Significant at level p<0.05

Furthermore, analyzing data showed the core training program as the interventional program had a positive effect on participants' physical characteristics, including power (Δmean=-2.95, p<0.001), balance (right leg: Δmean=-2.25, p<0.001 and left leg:Δmean=-0.69, p=0.04), and strength (Δmean=-2.70, p<0.001) in the intervention group. Compared to the pre-test scores, no significant changes were seen in the mean score of flexibility (sit and reach test) in the first post-test (p>0.5). Results of the second post-test also showed that performing exercises in mid-time continually improved the participants' performance (Table 4).

The differences between intervention and control groups was significant for the physical characteristics including vertical jump (post-test1 :Δmean=3.90, p<0.001, post-test 2: Δmean=5.15, p<0.001); right leg balance (post-test1: Δmean=2.57, p<0.001, post-test 2: Δmean=2.80, p<0.001); left leg balance (post-test1: Δmean=1.15, p=0.01, post-test 2: Δmean=1.42, p=0.003); and sit-up (post-test: Δmean=5.57, P<0.001, post-test 2: Δmean=6.35, p<0.001) (Table 5). In summary, the mean score of jumping ability in intervention group at the pre-test was 23.75±3.77, which significantly (p<0.0001, η^2=85) increased to 26.70±4.00 and 28.20±5.00 in the first and second post-tests, respectively. The mean score of right leg balance in intervention group at the pre-test was 5.59±1.45, which significantly (p<0.0001, η^2=76) increased to 7.85±1.77 in the first post-test.

Table 4: Holistic mean difference between intervention and control groups in pre-test, post-tests for physical characteristics

Variable	time	Intervention group (I)	Control group (J)	Mean Difference (I-J)	S.E	p. value	95% CI		Partial η^2
							Lower Bound	Upper Bound	
Vertical Jump	1	23.75	22.65	1.10	1.23	0.38	-1.39	3.59	0.1
	2	26.70	22.80	3.90	1.26	<0.001*	1.34	6.45	0.20
	3	28.20	23.08	5.15	1.43	<0.001*	2.26	8.04	0.25
Stork Stand Balance (right leg)	1	5.59	5.27	0.32	0.47	0.50	-0.63	1.28	0.1
	2	7.85	5.28	2.57	0.53	<0.001*	1.50	3.36	0.39
	3	8.19	5.39	2.80	0.51	<0.001*	1.76	3.83	0.44
Stork Stand Balance (left leg)	1	6.70	6.61	0.16	0.51	0.75	-0.87	1.19	0.003
	2	7.46	6.30	1.15	0.41	<0.001*	0.32	1.98	0.17
	3	7.77	6.35	1.42	0.45	<0.001*	0.50	2.33	0.20
it and Reach	1	35.95	36.15	-0.20	1.29	0.88	-2.81	2.41	0.001
	2	35.10	35.85	-0.75	1.39	0.59	-3.56	2.06	0.01
	3	35.50	36.20	-0.70	1.36	0.61	-3.46	2.06	0.01
Sit-up	1	35.95	32.60	3.35	1.53	0.06	-0.16	6.86	0.05
	2	38.65	32.90	5.75	1.61	<0.001*	2.49	9.01	0.25
	3	39.50	33.15	6.35	1.60	<0.001*	3.11	9.59	0.29

*Significant at level $p<0.05$

The results of the second post-test in the intervention group showed the continuity of improving the balance ability (8.19±1.82). Additionally, the mean score of left leg balance in the intervention group at the pre-test was 6.77±1.72, which significantly ($p=0.04$, $\eta^2=32$) increased to 7.45±1.36 in the first post-test. The mean score of left leg balance also showed improvement in the second post-test (7.77±1.59) compared to the first one.

The mean score of sit and reach in the intervention group at the pre-test was 35.95±0.91, which changed to 35.10±0.98 in the first post-test and 35.50±0.96 in the second post-test, with no significant difference among three stages of time ($F=2.85$, $p=0.06$). Meanwhile, the mean score of sit-up test in intervention group at the pre-test was 35.95±5.01, which significantly ($p<0.0001$, $\eta^2=85$) increased to 38.65±3.87 in the first post-test.

Table 5: The difference of physical characteristics means scores between tests in Intervention and control groups

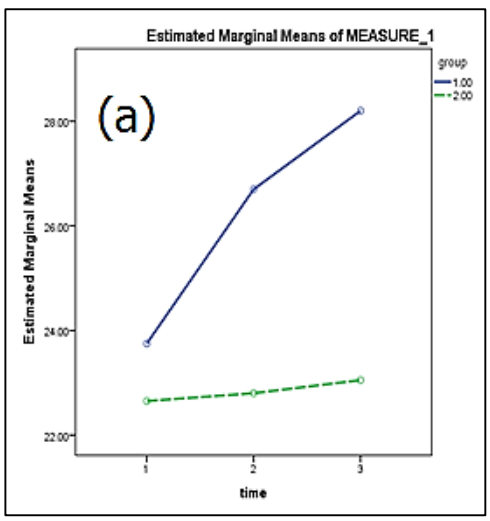
Variable	intervention position	(I) time	(J) time	Mean Difference (I-J)	S.E	p. value	95% CI		Partial η^2
							Lower Bound	Upper Bound	
Vertical Jump	intervention	Pre-test	post - test1	-2.95*	0.23	<0.001	-3.53	-2.36	0.85
		Pre-test	post - test2	-4.45*	0.46	<0.001	-5.59	-3.31	
		Post-test	post - test2	-1.50*	0.47	0.01	-2.69	0.31	

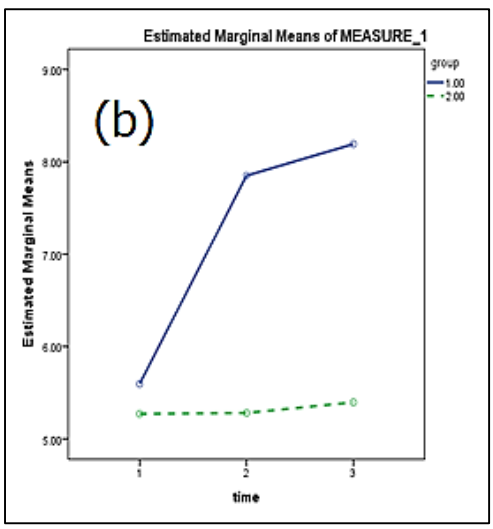
		Pre-test	post - test1	-0.51	0.24	1	-0.73	0.45	0.03
	control	Pre-test	post - test2	-0.37	0.45	1	-1.54	0.74	
		Post-test	post - test2	0.14	0.47	1	-1.44	0.94	
Stroke Stand Balance (right leg)		Pre-test	post - test1	-2.25*	0.21	<0.001	-2.80	-1.72	0.75
	intervention	Pre-test	post - test2	-2.60*	0.25	<0.001	-3.21	-1.98	
		Post-test	post - test2	-0.34*	0.13	0.03	-0.66	-0.03	
		Pre-test	post - test1	-0.10	0.21	1	-0.55	0.53	0.02
	control	Pre-test	post - test2	-0.12	0.24	1	-0.74	0.50	
		Post-test	post - test2	-0.11	0.13	1	-0.43	0.47	
Stroke Stand Balance (left leg)		Pre-test	post - test1	-0.69*	0.27	0.04	-1.37	-0.01	0.32
	intervention	Pre-test	post - test2	-1.00*	0.28	<0.001	-1.69	-0.30	
		Post-test	post - test2	-0.31*	0.10	0.01	-0.60	-0.06	
		Pre-test	post - test1	0.30	0.27	0.80	-0.37	0.98	0.03
	control	Pre-test	post - test2	0.26	0.28	1	-0.43	0.95	
		Post-test	post - test2	-0.04	0.10	1	-0.30	0.21	
Sit and reach		Pre-test	post - test1	0.85	0.35	0.06	-0.o01	1.17	0.17
	intervention	Pre-test	post - test2	0.45	0.41	0.85	-0.58	1.48	
		Post-test	post - test2	0.40	0.26	0.39	-1.05	0.25	

	control	Pre-test	post - test1	0.30	0.35	1	-0.56	1.16	0.06
		Pre-test	post - test2	-0.05	0.41	1	-1.08	0.98	
		Post-test	post - test2	-0.35	0.26	0.56	-0.30	1	
Sit-up	intervention	Pre-test	post - test1	-2.70*	0.44	<0.001	-3.80	-1.60	0.60
		Pre-test	post - test2	-3.55*	0.47	<0.001	-4.73	-2.37	
		Post-test	post - test2	-0.85*	0.27	0.01	-1.52	-0.18	
	control	Pre-test	post - test1	-0.30	0.43	1	-1.40	0.79	0.04
		Pre-test	post - test2	-0.55	0.46	0.76	-1.73	0.63	
		Post-test	post - test2	0.25	0.27	1	-0.92	0.42	

*Significant at level p<0.05

Furthermore, the results of the second post-test showed the continuity of improving the sit-up in intervention group (39.50±3.83). Figure 1 represents the mean plot of the study variables in the intervention and control groups across the three stages of time.





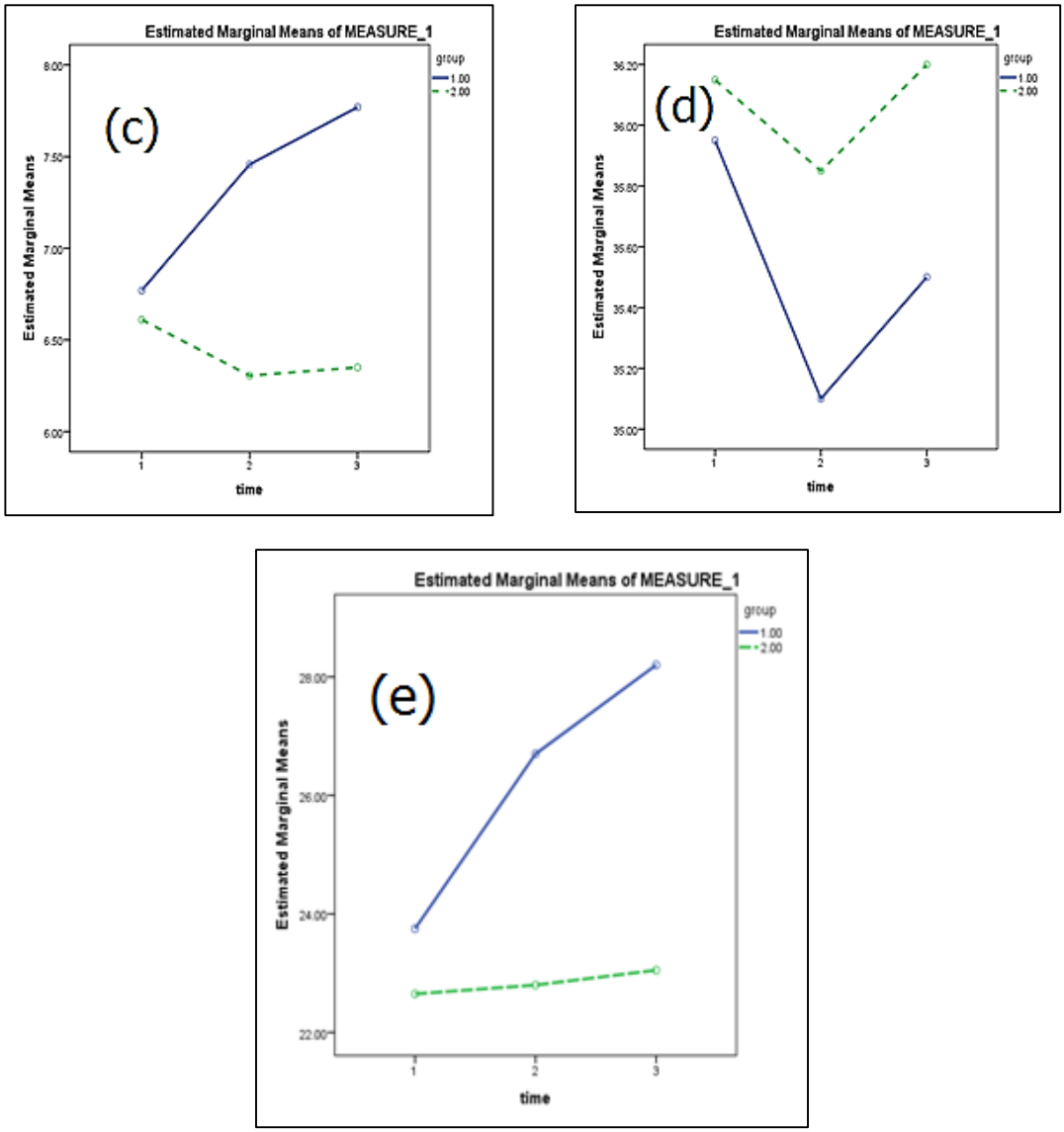


Figure 1: The mean plot of the (a) vertical jump; (b) right leg stork stand balance; (c) left leg stork stand balance; (d) sit and reach; and (e) sit-up in intervention and control groups across the 3 stages of time

The results of the current study showed that the core training program had a significant positive effect on power, balance and endurance among participants in the intervention group. Meanwhile, no significant differences were seen in the participants' flexibility before and after the core training program.

The findings of the current study are supported by outcomes of previous research. According to a study by Sheerin et al. (2012), at the end of training sessions the mean score of jumping ability among participants in the intervention group was improved from the average level to the borderline value between average and above average (28.20±5.00).

Meanwhile, the mean score of right and left leg balance among participants in the intervention group were improved from average (2.33-6.11) to the above average range (6.12-9.93). As well, the mean scores of one minute sit-ups among participants in the intervention group were improved from average (24–36) to the above average range (38-44) (Sheerin et al., 2012).

The well-trained core is essential for optimal performance and injury prevention. A strong core musculature dynamically stabilizes the pelvis during functional movements. Although it has been established that focused core training has a positive effect in numerous sports, little is known about its effect among gymnasts. A study by Bassett and Leach (2011) among female junior elite gymnasts showed the core stability training is beneficial to gymnasts in terms of enhancing core endurance times up to 20 second intervals, which may be beneficial to performance (Bassett & Leach, 2011). Furthermore, in a study by Hojong et al. the core-muscle training is suitable in enhancing the basic balance ability in Korean female gymnasts on rings (Gil, Yoo, & Yoon, 2016).

Results of the previous studies among the athletes of other sports are mostly in agreement with the current study outcomes as well. A study by Wong et al. (2010) showed that the 12-week combined strength and power training including core training for young soccer players significantly improved their explosive performance including vertical jump (Wong, Chamari, & Wisløff, 2010). Sekendiz et al. (2010) found significant effects on strength and endurance (trunk extensor, abdominal) after 12 weeks of Swiss-ball core strength training in sedentary women. Another study among collegiate baseball players found significant enhancement in flexor endurance among participants, although no significant increases reported in the Sorensen or side-bridging test (Sekendiz, Cug, & Korkusuz, 2010).

On the other hand, some studies have not found any significant effect of core training program on balance skills. For example, Lewarchick et al. (2003) reported that a seven-week core training program was not significantly effective on footballers' balance skills (Lewarchik, Bechtel, Bradley, Hughes, & Smith, 2003). Sekendiz et al. (2010) suggested that even the Swiss-ball exercise protocol (also was one of the current study's exercises) was effective on improving lower back muscle flexibility, but it was possible that the results were affected by the static stretches included in the warm-up and cool-down phases of the Swiss-ball exercise intervention (Sekendiz et al., 2010).

However, due to absence of the related studies among the Malaysia athletics including gymnasts, a precise comparison of the results of this study is difficult. Further studies in different levels and different sport clubs are suggested to reach a reliable image of the effects of core training on performance of Malaysian gymnasts.

Investigating the effects of core training program on the same characteristics among Malaysian Rhythmic Gymnasts in different and/or bigger sample sizes, as well as focus on the effect of core training program on the other performance factors among Malaysian RGs, is suggested for future studies to achieve clearer conclusion of effect of core stability on improving performance among Malaysian gymnasts.

Conclusion

Overall, the results of the current study showed an intervention program could be introduced as an effective plan for improving the physical and technical characteristics of young female Malaysian rhythmic gymnasts. The findings of the current study enhance the knowledge and information about the characteristics of rhythmic gymnastics performance and the importance of core training among gymnasts in Malaysia. Furthermore, the findings should encourage researchers, coaches and athletes to extend their plans using this protocol as an additional training which they can use to achieve the potential benefits of core training and enhance physical abilities and technical performance among Malaysian young female RGs.

Declaration of Conflicting Interests

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