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MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Effectiveness of catching and throwing ball exercise in the treatment of patients with non-structural scoliosis

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Abstract: Introduction: Scoliosis is a condition that affects spinal curvature of the spine resulting in turning from side to side. Mostly, these changes in affecting a person's overall posture and trunk alignment. Roughly, its affect 3% of the population and occurrences in women more than often than in men. The cases vary from mild to severe, meaning that the treatment for the condition vary widely. Exercises therapy considered the primary plan of treatment of these cases. The purpose: of the study to investigate the impact of adding throwing and catching ball exercises in the program of exercises provided to patients with Non-Structural scoliosis. Study Design: The study design was a randomized, single-blind 1:1 parallel-group study. Material and Methods: 32 patients, male and female, aged from 18 to 45 years and diagnosed with non-structural scoliosis were involved. They were divided into two equal groups with 16 patients each. Patients in group (A) were treated using physical therapy scoliosis-specific exercises (PSSEs) based on specific form of auto-correction exercises in form of spinal elongation, isometric exercises contraction, and stabilizing exercises. Patients in group (B) were treated as patient in group (A) regarding the type of exercises, frequency per week and the duration of exercises, in addition to 5 sets of 10 repetitions each of ball throwing and catching exercises. The treatment will continue for 6 weeks and carried on a frequency 2 sessions per week. Changes and progressions were analyzed using paired t-test before, after 12 sessions and as a follow up after 6months. Conclusion: 12 sessions of core exercise protocols would decreased Cobb's angle and improved back muscle activities with functional scoliosis in adults. Thus, the results of current study suggest that both core strengthening exercise protocol may be used to minimize the degree of scoliosis and improve back muscle strength in patients with functional scoliosis. However, adding catching and throwing exercises might help in decreasing the low back pain and accordingly the quality of life.
[Akram F. Abdelhamid and Hanan Al-Qhatani **Effectiveness of catching and throwing ball exercise in the treatment of patients with non-structural scoliosis.** Life Sci J 2023;20(7):1-7]. ISSN 1097-8135 (print); ISSN 2372-613X (online). http://www.lifesciencesite.com.01.doi:10.7537/marslsj200723.01.

Keywords: Catching, electromyography, standing, trunk, pain, Cobb's angle.

1. Introduction:

Scoliosis is defined as a lateral curvature of the spine greater than 10 degree the Cobb angle accompanied by vertebral rotation (1, 2). The causes of scoliosis vary and often categorized by the shape of the curve to idiopathic (structural), and postural (non-structural) (2, 3). The non-structural scoliosis mainly refers to a temporary curvature in the spine without rotation of the vertebrae (2). It is considered the most common type in adults and accompanied usually with a back pain (5).

68% of cases of scoliosis could be progressed by time leading to physical impairments, including muscle imbalance and its related back pain, cosmetic deformities, affecting the quality of life (5, 6). To reduce the progression of curves and decreasing their possible secondary risks, serval studies have recommended Physiotherapy Scoliosis Specific Exercises (PSSE) (4). These interventions have three standard features including 3-dimension self-correction, Stabilization of the corrected posture, and Training activities of daily living (ADL). The active 3D self-correction is accomplished by increasing the patient's awareness of the deformity and the required changes to correct it by stimulating a reaction against the deviation. Then, through a variety of exercises the spinal stabilization and posture could be achieved subconsciously through the mechanisms of neurosensory stimulation to maintain the posture. Such self-correction could be replicated with "distracting" situations using different exercises that place demand on neuromuscular system to increase stability during movements, exercises and daily actions, such as ascending and descending stairs, sit-to-stand, balancing on one limb or reaching with the arm, thereby could "strengthening" the neuromuscular connections included in postural correction programs.

PSSE focus on muscular endurance and strengthening of the postural correction, balance reactions development, and integration of neuro motor system (4). Strengthening the muscular endurance is aiming to develop the abdominal, paravertebral, scapulo-humeral girdle and lower limbs muscles through isometric contractions to stabilize the scoliotic spine (4). The enhancement of balance reactions aims to improve axial, static, and dynamic balance of the trunk that is important in postural rehabilitation (4). Additionally, using the internal high intensity forces created by the isometric tensions, the global postural alignment are applied (4). This results in a corrected posture where the concavities are expanded and open while the convexities are contained. All these 3D postural correction could be achieved through translation of movements, rotation and mixed (sagittal expansions) (4).

Despite that the Exercises therapy considered the primary plan of treatment for the scoliosis, no exercise is more effective on other in scoliosis rehabilitation (2, 3). However, recent clinical and motor learning studies have recommended that rehabilitation procedures should be task-specific (9, 10, and 11). These studies have suggested that functional tasks involving upper limb movements could challenge trunk stability and activate trunk muscles to levels comparable to traditional exercises. Consequently, task-specific exercises are favored in trunk rehabilitation (4, 12). Task-specific training combines the practice of ADL with objectives to enhance the best motor-control strategies and functional recovery of the involved muscles (13).

As 'reaching tasks 'is one of the basic components of ADL, physiotherapists often incorporate reaching in dynamic trunk rehabilitation (13). According to Jeannerod (1984), 'reaching 'is moving the hand quickly toward an object to grasp it. Forward reaching to targets during standing is a common action that perturbs stability and enhances trunk muscle activity as it involves interactions between the arm, trunk and base of support, which is provided by the feet on the floor (14, 15, and 16). One such therapeutic exercise offering a goal-directed reaching task that is motivating and familiar, yet challenging, is catching and throwing a ball (17). Consequently, clinicians have included self-paced ball catching and throwing while standing into their scoliosis rehabilitation programs as it covers most of the PSSE principles (15, 17).

Despite the popularity of catching and throwing a ball in scoliosis rehabilitation programs, studies investigating its efficacy on adult patients with non-structural scoliosis are scares. Therefore, the purpose of this study was to evaluate the effect of catching and throwing a ball while standing on the non-structural scoliosis. These data can be used by physiotherapists to make an accurate evidence-based decision to develop an efficient non-structural scoliosis rehabilitation programme tailored to their patients' needs.

Methods

Participants

32 participants were recruited from physical therapy clinic using a convenience sampling method. Participants in this study were adults diagnosed with non-structural scoliosis and referred to rehabilitation treatment at the School of Physical Therapy and Rehabilitation of Cairo University. The inclusion criteria were as follows: aged between 20-60 years, male or female, a Cobb angle of ≤18 °, history of thoracic and low back pain. Participants with a history of neuromuscular, cardiovascular, pulmonary, vestibular, or rheumatologically diseases were excluded. Patients were also excluded if they had been prescribed brace treatment, had idiopathic scoliosis, had received any previous surgical or conservative treatment of the spine, were unable to participate, Pregnant or were Allergy to adhesives.

Experimental procedure

All experimental participants attended a three data-collection sessions (i.e. initial, after 6 sessions, 12 sessions) in during which they were required to complete three trials of the ball-catching and throwing exercises while standing. Prior to data collection, each subject was given a familiarization period of two trials to ensure the ability to perform all exercises safely and correctly.

Equipment

The sEMG signals were obtained is though a wireless EMG sensor system (Noraxon USA Inc., Scottsdale, AZ, USA), that transmits data from the electrodes to a receiver, to obtain EMG signals in dynamic conditions. This sensor system has a 4000Hz EMG sampling rate, real time synchronizations, and low baseline noise. The myoMUSCLE software (Noraxon USA Inc. Scottsdale, AZ, USA) was used for EMG data analysis.

Additionally, participants were videotaped using (a Microsoft LifeCam Studio (Full HD 1080p Sensor) on a tripod. The video was synchronized with (Video-Theater system) ensure that the period of the ball-catching and throwing exercise (i.e. from when the examiner threw the ball until the participant caught and threw it back) was flagged and analyzed correctly.

Electrode placement

The participant was placed in the standing position to prepare the reflectors placement for the scapula (Superior Angle, Inferior Angle, and

Acromion Process), Thoracic/lumber spine (spine Process of T7, T12, and L5)

Afterwards, the skin area was prepared by shaving excess body hair where required. Then, 70% isopropyl alcohol swabs were used to gently abrade and clean the skin over each muscle belly for electrode placement. These preparation steps were used to optimize the quality of data collection and reduce skin impedance.

Pre-gelled disposable bipolar Ag/AgCL disc surface electrodes (White Sensor 4535M, Ambu, Denmark) with a conductive area of 10 mm² were placed to standardized locations on the body. The diameter of the electrodes was 18 mm, and the interelectrode distance was 30 mm. In line with (name of anatomy reference book of locating the places of reflects)

On electrode placement, wires and sensors were thoroughly secured with 3M Transpore™ medical tape (Micropore Plus, St Paul, MN, USA) to minimize movement and 'noise'.

In line with Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) guidelines and recent studies (Hermens et al. 2000; Marshall and Murphy 2005; O'Sullivan et al. 2012; Youdas et al. 2018), the locations of the RA and ES were identified. For the RA, both electrodes were placed vertically, 3 cm lateral from the centre of the umbilicus (O'Sullivan et al. 2012). Electrodes for both the ES were positioned vertically to the spine. The ES electrodes were placed 3 cm lateral to the spinous process above and below the L1 level (O'Sullivan et al. 2012).

Exercises

Control group exercice

Exercises program that given to the control group follow the protocol of PSSEs treatment exercises. The exercises program includes:

Type	**Name**	**Description**
Stretching Exercises	Lateral side stretch Exercises	Standing upright and shift the upper trunk to opposite side of the scoliosis curve
	Prayer stretch exercises	Patient on hand and knees. Drop hips back toward feet, lifting tailbone and press the hands forward to elongate the spine then take side movement against scoliotic curve
	Wag The Tail exercises	Begin on hand and knees with a neutral spine, then make C Curve , bringing shoulder and Hips closer together on the concave side
	Cat Camel Exercises	From Kneeling position, round back Up Then drop back toward the ground
	Lower lateral side stretch	Standing Upright with Hips feet width apart. Grip the wrist on the side will be elongated and pull laterally

All the exercises were performed for 2 sets and each with 10 repetitions on a daily base.

Strengthening exercises:

Type	**Name**	**Description**
Strengthening Exercises	Open Book Exercises	From Kneeling position, One hand behind head rotate away from stationary arm then rotate in to close the elbow together
	Bird Dog Exercises	From Kneeling position, maintain neutral spine, tighten abdominal muscles and slowly raise one arm with opposite leg slowly
	Standing Oblique Crunch Exercises	Standing upright, bending from trunk lower the hand toward thigh on the same side. Squeeze oblique muscles and come back to upright position
	Side Plank exercises	Laying on one side tighten abdominal muscle and left hip off the table maintain a neutral spine

All strengthening exercises were performed 2 sets with 10 repetitions each

Experimental Group:

All the patients in this group were do the same exercises program of Control group in addition catching and throwing ball exercises.

Starting positions

Prior to catching and throwing a ball, the participant was positioned in accordance with the standards of published studies.

Participants were instructed to keep their shoulder blades slightly retracted, thoracolumbar spine extended, and feet flat on the floor and positioned shoulder-width apart, with hands resting. In addition, to exclude any influence of differences in shoes (height of heels), all participants were barefoot (De Bruyne et al. 2016).

Measured from a side view using a universal goniometer (Chattanooga©) with a plastic 360° goniometer face and 10-inch movable arms, which has shown excellent reliability.

Catching a ball

After adjusting the starting position, the ball-catching and throwing task was performed. While sustaining the starting position, each participant was asked to grab onto and hold a soft rubber medicine ball and threw it back to the searcher, filled with water and weighing 1 kg (LEDRAGOMMA Pezzi, compact medicine ball, Italy). The ball was thrown towards the participant by the researcher at the level of the xiphoid process (i.e. chest) (Scariot et al. 2016).

Participants performed a series of three isolated medicine ball catches and throws with one-minute rests between repetitions to avoid muscle fatigue. Before each trial, the participants were required to attain the starting posture.

The thrower (i.e. researcher) was the same for all participants and conditions, remained positioned at a 2.5-m distance, and threw the ball in a similar direction and level for all situations and participants. To ensure this distance between the researcher and all participants, a 2.5-m tape was placed on the floor. This tape had a standardized space between the researcher's feet, and a line for the participants to position their feet.

Signal processing

A pre-amplifier with an overall gain of 500, input impedance >100 Mohm and common mode rejection ratio >100 dB was used. sEMG signals were collected at a sampling frequency of 1000 Hz and bandpass filtered at 10–500 Hz. All raw EMG signals were visually inspected for artefacts. To quantify the data and increase the reliability and validity of findings, all raw EMG signals were full-wave rectified and smoothed using a root mean square with a window of 250 ms using Noraxon myoRESEARCH 3.10 software.

The beginning and end of each trial were determined and flagged by the researcher according to the corresponding time-synchronized videos. The start of the ball-catching exercise was defined by the moment when the ball left the researcher's hand, while the end was defined by the moment when the participant grabbed onto and held the ball [7]. Between each trial, a clear resting period was ensured to achieve a zero-baseline level of activity.

The analysis of the identified sEMG signals resulted in a mean sEMG amplitude per muscle per trial. Then, the average mean sEMG amplitude of three correctly performed trials on each seating surface was calculated and normalized to %MVIC for each muscle to assess the muscle activity. All data were inputted into a Microsoft Excel spreadsheet and imported to SPSS for statistical analysis.

Statistical analysis

All statistical analysis was performed using SPSS version 25 (SPSS Inc., Chicago, IL, USA), and the level of significance was set at p = .05.

Descriptive analysis (mean and standard deviation [SD]) was performed for the demographic data. In the current study, as the sEMG data were not normally distributed, the assumptions for carrying out paired t test were not met. Therefore, the non-parametric alternative to the pried t test, the Wilcoxon-Whitney test, was adopted.

Results:

Table 1. General Characteristics of the subjects

Age (years)	31.44	**8.23**
Height (m)	1.75	0.07
Weight (kg)	81.41	9.56
BMI (kg/m^2)	26.6	1.57

N=number of participtants, Kg= Kilograms, m=metres BMI=Body Mass index, SD= Standard deviation

Table 2. Paires test results for trunk muscle activity (%MVIC) of the participants.

Muscles	Before	After 12 sessions	After 6 weeks
RT RA	.215	.234	.215
LT RA	.134	.605	.179
RT ES	.352	.196	.301
LT ES	.877	.326	.877

Table 3. Mean and SD of the pain score visual analogue scale (VAS) **?**

Pain	**Paired test results**		
	Before	**After 12 sessions**	**After 6 weeks**
	.622	.622	.622

Mean ± SD, * significant difference from between the 2 group, p< 0.05

Table 4. Mean and SD of Cobb's angle Score (°)

Pain	Paired test results		
	Before	**After 12 sessions**	**After 6 weeks**
Mean (SD)	.098	.204	*<.001

Mean ± SD,* significant difference from between the 2 group, p< 0.05

Discussion:

The scoliosis curves could be progressed over time, leading to physical impairments, including muscle imbalance, related back pain, and cosmetic deformities affecting the quality of life. To reduce the progression of curves and decrease their possible secondary risks, rehabilitation exercises are recommended. Although opinions differ about the most effective exercises, the aim of trunk strengthening exercises to enhance spinal functional stability though strengthening the abdominal and lumbar muscles. One such therapeutic exercise offering a goal-directed reaching task that is motivating and familiar, yet challenging, is catching and throwing a ball (17). Consequently, clinicians have included self-paced ball catching and throwing while standing into their scoliosis rehabilitation programs as it covers most of the PSSE principles (15, 17). Despite the popularity of this exercise, studies investigating its effect on scoliosis are scarce. Thus, in this study, the trunk muscle activation, cobb's angle of lumber spine and pain were assessed while side throws and catches of medicine-ball towards the convexity side.

In the current study, the activity of all trunk muscles increased while catching and throwing a ball during standing, however, the activity of bilateral ES and RA were not significant between the two treatment programs. This trunk muscle activity could be explained by the biomechanical demands of catching a ball task (Horsak et al. 2017). When the arms are lifted to reach a ball while standing, the centre of mass (COM) moves forward and the trunk moment acts backward; this shift in the COM and the reaction force result in postural sway (Jung et al. 2016). Thus, the key trunk muscles increase contraction to counteract postural perturbation and maintain the COM on the base of support (Scariot et al. 2016). According to Marshall and Murphy (2006), the activity of trunk muscles increases when the COM moves away from the midline of the body and in theory, when the COM moving forwards the back muscles ES should activate more than the abdominal muscles RA.

Additionally, the sEMG activity for the bilateral RA, and ES ranged from median %MVIC of Youdas et al. (2018) categorized these values as medium levels of muscle activity during the exercise. This indicates that catching a ball might be sufficient for enhancing trunk stability. According to McGill (2015), exercises that produce trunk muscle activity of around 10% of MVIC are sufficient for trunk stability and endurance purposes, especially for activities of daily living. However, if the goal of rehabilitation is to enhance the strength of trunk muscles, trunk exercises that activate muscles to more than 50% of MVIC might be needed (Horsak et al. 2017). The results of the current study also suggest that catching and throwing a ball on standing could recruit trunk muscles at magnitudes comparable to traditional exercises such as bridging (Imai et al. 2010; Youdas et al. 2018). This could be explained by the previous studies that the intra-abdominal pressure and muscle activity increased immediately prior, and the rectus abdominis (RA) were highly activated [5]. During the throwing, there is co-contraction of all abdominal muscles that is influenced by the ground reaction force [6].

The study findings can be compared to studies that have assessed the effect of standing, reaching and throwing tasks (Gregory et al. 2006; O'Sullivan et al. 2006; O'Sullivan et al. 2012; De Bruyne et al. 2016). This comparison was made due to the biomechanical similarities between these tasks and catching a ball when lifting the arms and move them away from trunk to reach an object, which similarly challenges trunk stability (Jeannerod 1984; Dean et al. 1999; Jung et al. 2016).

Accordingly, the results of the present study were consistent with the studies of Gregory et al. (2006) and Holmes et al. (2015) that demonstrate the activation of all trunk muscles during these tasks. However, in the current study, the level of trunk muscle activity of the bilateral RA and ES was higher than the reported magnitude of trunk muscle activity in previous studies. In a study conducted by Holmes et al. (2015), trunk muscle activity ranged between 4.9% and % MVIC. Conversely, Gregory et al. (2006) reported that trunk muscle activity ranged from 1% to 3% MVIC. However, the results of these studies and the current study cannot be compared directly, due to the differences in the type of tasks. Both Gregory et al. (2006) and Holmes et al. (2015) evaluated office tasks that involved a slow and controlled movement, whereas the current study assessed catching and throwing a ball, a task that is fast and unpredictable (Scariot et al. 2016).

The influence of the task type on trunk-muscle activation was noticed in several studies (Van Dieen et al. 2001; Gregory et al. 2006; Holmes et al. 2015). Therefore, the level of trunk-muscle activation reported in the current study might be attributed to the fact that, during catching a ball exercise, the trunk works to counteract postural perturbations induced by a self-initiated reaching movement and the force of the ball (Scariot et al. 2016). Based on perturbation characteristics such as magnitude and type of task, the central nervous system modifies motor responses (Scariot et al. 2016). As such, higher trunk muscle activity would be elicited to meet the demands of catching and throwing actions characterizing by a backward-forward motion that activate the musculature throughout the stretch-shortening cycle. At the end of the backward phase, the antagonistic muscles generates forces in the opposite direction of the movement through the eccentric activation, storing elastic energy and breaking the motion which is partially reprocessed during the forward phase (Vera-Garcia et al. 2014).

On the other hand in this study, there is no significant difference between the two groups at the first and after the 12 sessions in the Cobbs angle, whereas a significant difference were noticed after 6 months. These results were consistent with study of Yun He et al, 2016 who found that the Cobb's angles were significantly lower and back muscle strength was significantly improved than baseline in both groups, but there were no statistically significant between group differences. These results could be explained by the fact that Core exercise could correct the spinal misalignment via neuromuscular control improvement, the strength and endurance of the trunk and pelvic floor that are believed to play important roles in spinal stability and arrangement.

Interestingly, the current study found a significant difference between the treatment and control group in the low back pain using VAS. These results were in line with results of recent systematic review by Xin Lia et al,(2021) that showed significantly better quality of life with core strengthening exercises. These results could be explained by the type of catching and throwing task as functional and motivating exercise which might enhance the sociological aspect of such exercise. However, further studies would help in confirming this correlation.

In conclusion, 12 weeks of both core exercise protocols programmer decreased Cobb's angle and improved back muscle activities with functional scoliosis in adults. Thus, the results of current study suggest that both core strengthening exercise protocol can be used to minimize the degree of scoliosis and improve the strength of back muscles in patients with functional scoliosis. However, adding catching and throwing exercises might help in decreasing the low back pain and accordingly the quality of life.

The results of the current study cannot be accepted without considering its limitations including the use of sEMG that is prone to electrical artefacts. However, the current study tried to minimize artefacts by following the recommendations of the SENIAM guidelines such as skin preparation, standardized electrode placement, small inter electrode distance and relatively short electrode wires [13]. Additionally, the limitation of this study was that the speed of the medicine-ball was not controlled. However, two experienced researchers visually evaluated each throw, selecting the trial performed with the best technique for each exercise and participant. Another limitation of this study was the high variability of lumbar kinematics and muscular activation between participants, which is common in trunk biomechanical studies (22, 23). In addition, although two series of MVCs were performed, we cannot exclude the possibility of not having reached the actual maximum value in some muscles, which could affect the comparison between muscle activities. Finally, a specific technique to isolate the twisting rotation of the hips or the spine was not coached.

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7/12/2023