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Evaluation of the Effects of Corrective Exercises on the Posture of Ballet Dancers Using the Photogrammetric Measurement Technique

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Abstract

Objective: This study investigated the effects of individualized corrective exercises on posture based on postural assessments conducted by a physiotherapist.

Materials and Methods: The study included 47 ballet students (39 females, 8 males) aged 11–19 years. Participants underwent one photogrammetric assessment at the beginning of the study and another after completing an 8-week personalized corrective exercise program. Servidor de Apontadores Portugueses Online (SAPO) postural assessment software was used for postural evaluation.

Results: In the anterior view, when pre- and post-intervention measurements were compared to reference values, statistically significant improvements were observed in the horizontal alignment of the head, acromions, and anterior superior iliac spines, tibial tuberosities ($p<0.05$). Significant improvement was noted in the horizontal asymmetry of the scapula relative to the T3 vertebra. Lateral views and vertical alignment of the head improved significantly. To the best of our knowledge, no studies have assessed the effects of corrective exercises on posture using SAPO software.

Conclusion: This study quantitatively showed that individualized corrective exercise programs by physiotherapists improve posture in ballet students, potentially reducing injury rates and enhancing physical performance. It lays the groundwork for future research on the efficacy of corrective exercises.

Keywords Posture · Corrective exercise · Ballet · Physiotherapist · Injury prevention · Physical performance

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INTRODUCTION

The American Academy of Orthopaedic Surgeons defines posture as a state of balance in standing, sitting, and lying positions, where muscles and bones have sufficient capacity to protect other body structures from injury (1).

From a biomechanical and physiological perspective, good posture minimizes stress on ligaments, muscles, tendons, and bones (2, 3). Proper posture facilitates bodily functions and reduces the energy expenditure of muscles required to maintain an upright position. In contrast, improper, forced, asymmetric, prolonged, and sustained postures result in excessive loads on tissues, surpassing the tolerable stress threshold, leading to strain or injury, and causing imbalance (4, 5). Improper posture is frequently observed in dancers, particularly ballet performers, and may increase the risk of injuries.

There is no universally accepted standard approach to posture assessment. The use of photography for measuring joint positions was first introduced by Wilson and Strasch in 1964. Compared to radiographic imaging, photography is more practical, non-invasive, and cost-effective, making its clinical and research applications highly valuable (6). Photogrammetric posture analysis provides objective data with high reliability and practical clinical utility. Therefore, its use has been recommended in clinical settings and scientific literature (7).

Various software programs have been developed for postural assessment. Servidor de Apontadores Portugueses Online (SAPO) postural assessment software was used in the present study. Although several studies in the literature have employed different methods for postural analysis, no previous research has objectively evaluated the effects of corrective exercises on posture using an advanced postural analysis technique.

The present study aimed to assess the effectiveness of personalized corrective exercises prescribed by physiotherapists through objective data collection.

MATERIALS AND METHODS

A total of 47 ballet students, including 8 males (17%) and 39 females (83%), aged between 11 and 19 years were enrolled. The study was initiated after the approval of the clinical research ethics committee of Istanbul University, Istanbul Faculty of Medicine (2019/782). For volunteers from participants' families, the consent form was obtained.

Participants underwent two photographic measurement sessions: one at the beginning of the study and another after completion of their personalized corrective exercise program for eight weeks. The photographs were captured at Mimar Sinan Fine Arts University, State Conservatory, Ballet Department. During the sessions, participants wore clothing that did not obstruct the visibility of the designated anatomical landmarks. Male students wore briefs, while female students wore ballet leotards or sports tops.

For posture assessment, 32 anatomical landmarks were marked with round, colored, and easily identifiable markers before imaging. Anatomical reference points were used as specified in the SAPO protocol. These included 32 points: the midpoint of the tragus, acromion, midpoint of the horizontal midline of the knee joint, the midpoint of the patella, tibial tuberosity, greater trochanter, anterior superior iliac spine (ASIS), C7 spinous process, inferior angle of the scapula, T12 spinous process, posterior superior iliac spine, the midpoint of the medial line of the leg, region between the malleolus and calcaneal tendon, midpoint between the second and third metatarsals of the calcaneus, lateral malleolus, and medial malleolus (Figure 1).

Program Development

The most critical factor in designing a corrective exercise program is individualization, in which the exercise prescriptions should be tailored to each person's specific needs. The exercises must be appropriately designed and correctly taught. Initially, the exercises should be performed under the supervision of a physiotherapist. The program should be flexible and progressive. It should be organized in a way that is functional according to the person's lifestyle, occupation, recreational activities, and sports participation, considering the results of the evaluation. The sustainability of the program is essential.

The primary goal of corrective exercise training is to eliminate muscle imbalances. If the program begins before optimal muscle balance is achieved, the exercises may further exacerbate imbalances.

In summary, the four fundamental objectives in the sequence should be:

1. Muscle balance
2. Stability
3. Functional strength
4. Functional power

Selecting the most beneficial exercises for the individual, modifying them when necessary, and properly adjusting the load, repetitions, and rest intervals enhance the effectiveness of the program (8).

The exercise program was individually designed based on the initial postural assessment measurements of each participant. In the development of the program, lateral trunk muscle flexibility was evaluated using side reach tests, core strength was assessed through pre-core exercises, and the functional capacity of the hip abductors was examined using modified side plank tests. The exercises were prescribed to be performed in a symmetrical and correct posture, ensuring postural balance.

Figure 1. Postural assessment according to photogrammetric measurement method.

The program was designed with beginner-level core strength, stability, functional strength, and mobility exercises. Strength exercises were performed using body weight and resistance bands. After four weeks, the difficulty of exercises using resistance bands was increased by transitioning to a higher-resistance band. The exercises were performed three times per week for eight weeks.

Statistical Analyses

Data analysis was conducted using SPSS v21 software, with statistical significance set at $p<0.05$. Pre- and post-exercise data were analyzed using the paired sample t-test.

RESULTS

Demographic data of 47 ballet students who participated in the study are given in the Table 1 (Table 1). A total of 47 ballet students, including 8 males (17%) and 39 females (83%). Pre and post-test results are shown in the Table 2. Postural assessments conducted before and after the exercise program revealed significant improvements across anterior, lateral, and posterior views. In the second measurements taken following the intervention, most parameters showed a notable shift toward the reference value of 0. This indicates a reduction in postural asymmetry and an overall improvement in body alignment. In the anterior view, changes in the horizontal alignment of the head, acromions, ASIS, the angle between bilateral acromions and ASIS, and the tibial tuberosity angles were all statistically significant ($p<0.05$). These results suggest that the body's frontal symmetry improved, approaching the ideal postural alignment. In both right and left lateral views, significant improvements were observed in head alignment, trunk verticality, pelvic positioning, hip and knee angles ($p<0.05$). While the ankle angle did not show a statistically significant change in some comparisons ($p>0.05$), other parameters indicated a clear postural correction. This suggests that the ankle may respond differently or more slowly to the applied exercise program. In the posterior view, the scapular alignment relative to the T3 vertebra showed a statistically significant improvement toward symmetry ($p<0.05$). Additionally, changes in both right and left rear foot angles were also found to be significant ($p<0.05$), further supporting the positive impact of the exercise regimen. Overall, the findings demonstrate that the exercise program led to improvements in postural alignment by moving measured values closer to their ideal reference points. This indicates a beneficial effect on body symmetry and postural control.

Table 1. Demographic data

	Mean ± SD	Min	Max
Age (years)	13.72 ± 2.23	11	19
Height (cm)	152.55 ± 13.20	129.5	178
Weight (kg)	39.73 ± 11.05	24.3	62.5
BMI	16.72 ± 2.13	13.37	22.17

SD: Standard Deviation; BMI: Body Mass Index

DISCUSSION

The present study objectively and quantitatively demonstrated, for the first time, the effectiveness of individualized corrective exercise programs designed by physiotherapists in improving posture. This study will serve as a foundation for future research on the effectiveness of corrective exercises.

With advancements in technology, posture assessment through photographic analysis has become possible. Although there are studies evaluating posture using technological tools, research focusing on the assessment of whole-body posture remains limited. Studies that simultaneously evaluate all body segments are essential for accurately defining an ideal posture model.

Research examining whole-body posture in healthy individuals is necessary to establish reference values for normal posture. Quantifiable data play a critical role in physical therapy (9). In a study conducted by Robertson et al., symmetrical postural alignment was defined as the standard posture (8). Robertson et al. used reference values recommended by physiotherapy and rehabilitation departments (8). However, some researchers have debated this topic, suggesting that an individual's ideal posture does not necessarily have to conform to the "normal" posture. These researchers emphasize that future studies involving a larger sample of individuals without musculoskeletal disorders and evaluating all body segments could contribute to the ongoing discussion on standardizing reference values for normal posture (10). In the present study, the SAPO postural assessment software was used to evaluate posture through photographic analysis. From the anterior view, the horizontal alignment of the head and acromions and the angle between the two acromions and two ASIS were analyzed. From the posterior view, the reference angle for scapular horizontal asymmetry relative to T3 was set at "0" (11, 12).

There is no universally accepted standard approach for posture assessment (13), and the methods used vary (13). In a study by Roggio et al., which assessed the posture of 200 healthy adult men and women using photogrammetric analysis, a significant difference in shoulder adduction angles

Table 2. Pre- and post-test results

Angles and Distances	Measurement First	Measurement Second	t	p value
ANTERIOR VIEW				
Head Horizontal Alignment (°)	2.30 ± 1.45	0.81 ± 0.66	7.26	*0.001
Horizontal Alignment of Acromions (°)	1.60 ± 0.98	0.72 ± 0.67	7.87	*0.001
Horizontal Alignment of (ASIS) (°)	1.80 ± 1.04	0.80 ± 0.69	6.42	*0.001
Angle Between the Two Acromions and Two ASIS (°)	2.00 ± 1.25	0.87 ± 0.74	7.84	*0.001
Right Upper Extremity Anteversion Angle (°)	−2.56 ± 2.76	−2.045 ± 2.25	−2.27	*0.027
Left Upper Extremity Anteversion Angle (°)	−3.13 ± 3.04	−2.52 ± 2.27	−1.78	0.081
Tibial Tuberosity Horizontal Angle (°)	2.11 ± 1.19	1.11 ± 0.88	5.06	*0.001
Right Q Angle (°)	15.37 ± 6.15	14.46 ± 4.19	0.95	0.347
Left Q Angle (°)	12.42 ± 5.58	12.66 ± 3.21	−0.29	0.768
LATERAL VIEW (RIGHT)				
Head Horizontal Alignment (Side View) (°)	59.59 ± 5.34	57.91 ± 3.48	2.38	*0.021
Head Vertical Alignment (°)	10.76 ± 5.48	6.91 ± 4.38	5.27	*0.001
Trunk Vertical Alignment (°)	−1.48 ± 0.41	−0.76 ± 0.27	−2.53	*0.015
Hip Angle (°)	−10.78 ± 0.83	−8.21 ± 0.86	−3.56	*0.001
Body Vertical Alignment (°)	3.12 ± 0.97	2.38 ± 1.03	5.19	*0.001
Pelvis Horizontal Alignment (°)	−13.60 ± 0.51	−5.33 ± 0.49	−13.38	*0.001
Knee Angle (°)	−8.73 ± 0.68	−5.94 ± 0.61	−4.90	*0.001
Ankle Angle (°)	75.27 ± 45.26	87.48 ± 5.41	−1.81	0.075
LATERAL VIEW (LEFT)				
Head Horizontal Alignment (Side View) (°)	58.30 ± 18.89	58.18 ± 3.36	0.048	0.962
Head Vertical Alignment (°)	11.86 ± 5.70	7.97 ± 5.49	6.44	*0.001
Trunk Vertical Alignment (°)	−0.68 ± 0.48	−0.65 ± 0.26	−0.72	*0.943
Hip Angle (°)	−10.78 ± 0.83	−8.21 ± 0.86	−3.56	*0.001
Body Vertical Alignment (°)	3.12 ± 0.97	2.38 ± 1.03	5.19	*0.001
Pelvis Horizontal Alignment (°)	−13.60 ± 0.51	−5.33 ± 0.49	−13.36	*0.001
Knee Angle (°)	−8.73 ± 0.68	−5.94 ± 0.61	−4.90	*0.001
Ankle Angle (°)	80.59 ± 8.24	89.42 ± 2.28	−1.55	0.127
POSTERIOR VIEW				
Scapular Horizontal Asymmetry Relative to T3 (cm)	17.78 ± 11.89	8.54 ± 7.45	6.83	*0.000
Right Posterior Foot Angle (°)	0.83 ± 3.80	4.18 ± 10.5	−2.13	*0.038
Left Posterior Foot Angle (°)	4.18 ± 1.59	0.65 ± 0.57	2.31	*0.025

Values are presented as mean ± standard deviation. Comparisons were performed using the paired sample t-test. *: $p < 0.05$ was considered statistically significant in all analyses.

was observed between males and females (14). Elpeze et al. investigated the effects of corrective exercises on balance and kyphosis in adolescents diagnosed with kyphosis and concluded that a corrective exercise program resulted in a reduction in kyphotic curvature and improvements in balance (15). Similarly, Kouchi et al. reported that an 8-week corrective dance exercise program in adolescent girls led to a decrease in thoracic hyper-kyphosis and an improvement in scapular positioning (16). Another study examining the impact of corrective and stabilization exercise programs on fundamental movement patterns in dance students reported that these programs led to improvements in basic movement skills, balance, and motor control (17).

In a study involving dancers aged 18–24 years, exercise interventions targeting forward head posture and rounded shoulders resulted in significant postural improvements (18). A systematic review investigated the effects of exercise on postural alignment and categorized studies based on conditions such as forward head and shoulder dysfunction, hyper-kyphosis, and scoliosis. The review concluded that interventions designed to stretch tight muscles and

strengthen weak muscles could effectively improve postural dysfunction (19).

In most studies, posture assessment has been limited to single-segment evaluations, such as the position of the head relative to the shoulders in the sagittal plane (20). The average angular values of each segment have typically been determined using different methods (21). Due to methodological differences among studies and the isolated evaluation of individual segments, comparisons between results have become challenging.

In the present study, post-exercise measurements of parameters with reference values defined by the SAPO software showed a statistically significant improvement toward the reference values. Furthermore, for parameters without predefined reference values, intra-group comparisons revealed statistically significant differences.

In the photogrammetric method used for posture assessment in this study, the accurate localization of anatomical landmarks depends on the examiner's anatomical knowledge and is subject to potential error. Despite the use of the anatomical landmark feature in the SAPO software, markings on the photographs still have a margin of error, which can introduce measurement errors. Moreover, a lack of familiarity with the software may complicate the assessment process. To minimize the likelihood of error, all pre- and post-exercise measurements in the present study, including determination of anatomical landmarks by palpation, marking on photographs, and posture assessment using the software, were conducted by a single physiotherapist with expertise in this area.

Minimizing error is crucial for obtaining objective data in posture assessment, which has clinical significance, as it allows for the evaluation of load distribution across the musculoskeletal system. Our primary goal during corrective exercises was to identify and correct imbalances in load distribution through targeted interventions.

Although previous studies have used the SAPO software for posture assessment, no study has evaluated the effects of corrective exercises on posture using photogrammetric measurement with SAPO.

In conclusion, the data obtained in the present study indicate that individualized corrective exercise programs designed by physiotherapists have positive effects on posture, potentially leading to reduced injury rates and improved performance.

Ethics Committee Approval: The study was initiated after the approval of the clinical research ethics committee of Istanbul University, Istanbul Faculty of Medicine (2019/782).

Informed Consent: For volunteers from participants' families, the consent form was obtained.

Peer Review: Externally peer-reviewed.

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