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Trunk endurance exercise and the effect on instrumental performance: a preliminary study comparing Pilates exercise and a trunk and proximal upper extremity endurance exercise program

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ABSTRACT: Instrumental musicians are at risk for upper extremity performance related musculoskeletal disorders (PRMD). Increased trunk muscle endurance and neuromuscular control may allow the musician more effective management of the upper extremity workload. The purpose of this preliminary study was to investigate and compare the efficacy of two therapeutic exercise approaches directed toward increasing trunk and proximal upper extremity muscle endurance and neuromuscular control, and to determine if these changes affect instrumental performance. This study was an interrupted time-series, two-group, pre-post-test experimental design. Participants included 14 university-level instrumental musicians who were assigned either to a Pilates mat exercise program, or a conventional trunk endurance exercise program. Trunk endurance and seven selected aspects of instrumental playing were measured at the beginning of the study, after the six-week baseline (no intervention) period, and after the two concurrent six-week exercise interventions. Following both interventions, there was a significant increase in trunk extensor and lateral muscle endurance. The participants reported a significant decrease in pain, fatigue, and perceived level of exertion while playing an instrument. There was no significant difference in trunk endurance when comparing the two exercise groups; therefore, the Pilates method was equally as effective as the conventional trunk and proximal upper extremity endurance exercise program. Musician education and wellness programs should include exercise programs that improve trunk muscular endurance and neuromuscular kinesthetic control, thereby allowing the musician to improve the physical aspects of their performance and achieve their highest level of musicality.

KEY WORDS: Musician injuries, musician wellness, therapeutic exercise, instrumentalists' exercise

The rate of occurrence of musculoskeletal injuries for musicians ranges from 39 per cent to 87 per cent, which is similar to work related musculoskeletal injuries in the general population (Wu, 2007; Zaza, 1998). More specifically, 76 per cent of the 4,025 members of the International Conference of Symphony and Opera Musicians (ICSOM) reported having at least one injury severe enough to affect performance (Fishbein, Middlestadt, Ottati, Strauss, & Ellis, 1988). For professional musicians, even a minor musculoskeletal injury, which may not be disabling to the general population, may significantly affect their ability to perform. The musculoskeletal injuries incurred by musicians in the course of their work are described as Performance Related Musculoskeletal Disorders (PRMD) and are defined by Zaza (1998) as neuromuscular disorders that develop from playing an instrument, rather than problems that may interfere with playing. Even if PRMD do not prevent the musician from playing, they may affect the musicality (defined by Fink, 2002, as a balance of esoteric and practical) of his or her playing (Lister-Sink, 2002). Identifying and addressing PRMD are therefore essential for the musician.

The necessity for successful prevention and treatment of musculoskeletal problems in musicians has led to greater awareness of PRMD among musicians, music educators, and healthcare providers and to the development of performing arts medicine. This has grown a great deal over the last three decades. One of its primary goals is education for the prevention and treatment of PRMD (Storm, 2006).

Within performing arts medicine, identifying and managing both the physical and psychological stress encountered by the artist is described as an important component in maintaining the wellness of the musician. When investigating the physical requirements and effects of musical performance there are several factors to consider. The musician must often achieve high speed control of repetitive complex upper extremity movement patterns which can lead to muscular fatigue (de Lisle, Speedy, Thompson, & Maurice, 2006). Some instruments also require static, awkward positioning of the joints and muscles of the spine and upper extremities, which may add to muscular fatigue (Quarrier, 1997). In occupational medicine research, undesirable functional changes have been found to occur in skeletal muscle during sustained exertion, resulting in decreased precise motor control and skeletal muscle overuse injuries including tendonitis, muscular pain, entrapment neuropathies, and focal dystonia (Bejjani, Kaye, & Beham, 1996; Brandfonbrener, 2006; Chaffin, 1973; Hansen & Reed, 2006; Lederman, 2003; Lederman, 2006; Lie-Nemeth, 2006; Quarrier, 1997; Zaza, Charles, & Muszynski, 1998). These requirements of upper extremity speed, coordination, control, and muscular endurance, along with stressful postural positions maintained for long time periods, place the musician at an increased risk for PRMD.

Risk of PRMD is also increased by the psychological stress the musician may experience as a result of general anxiety, performance anxiety (stage fright), and depression (Steptoe, 2001). He or she may experience discomfort while playing resulting from increased physiological arousal leading to increased muscular tension that can cause injuries to the upper extremity musculature. Musicians may experience these significant psychological and physical stresses without realizing their extent and the effect on their health, and the negative impact on their musicality.

Given the demands encountered during performance, the musician might benefit from a trunk stabilization exercise program that would assist in efficient management of the upper extremity workload. This program would include trunk muscle endurance and neuromuscular control training as they facilitate trunk stabilization. Panjabi (1992) defines stabilization as the coordination of spinal muscle control, allowing the individual to maintain the neutral spinal position dynamically while performing activities of daily living. According to Hodges (2004) it is necessary for management of the upper extremity workload and is achieved by contracting the stabilizing trunk muscles prior to moving the arm. Such control of the trunk musculature is critical for the efficient transfer of energy from the torso to the smaller extremities during many activities. It involves muscle and kinesthetic lumbopelvic control whereby the ribcage and pelvis remain connected during torsional activities of the trunk. In addition, scapular stabilization is a necessary component of trunk control and when present, may assist in decreasing the workload transferred to the upper extremities during functional activities such as instrument playing (Tse, McManus, & Masters, 2005). Therefore, trunk muscular endurance exercise and postural kinesthetic training are important components in a program for prevention and management of PRMD (Ackermann, Adams, & Marshall, 2002; Hodges, 2004; Palac & Grimshaw, 2006).

Even though exercise is considered an important component in injury prevention and rehabilitation for PRMD, there are very few research studies examining the effectiveness of exercise programs for musicians with randomized controlled trials. In a review article, Shafer-Crane (2006) described the use of trunk and shoulder stabilization exercises in the treatment of repetitive strain upper extremity injuries in the musician. These were found effective in increasing trunk muscle endurance and postural kinesthetic awareness. In another review it was reported that many of the musculoskeletal pain and postural disorders in musicians could be prevented by a regular conditioning and comprehensive postural program (Dommerholt, Norris, & Shaheen, 1997). This program included exercises to restore trunk and pelvic stability, motion control, flexibility, muscle balance, strength, endurance, and efficient breathing patterns.

In a single participant case study, Palac and Grimshaw (2006) detailed a case history involving a female violinist with left upper extremity pain on palpation over the lateral and dorsal forearm, insertion of the levator scapulae, and the upper trapezius. This patient's treatment plan included diaphragmatic breathing exercises, trunk strengthening, endurance, and kinesthetic training, flexibility exercises for the cervical spine and upper extremities, and manual therapy. The patient responded with decreased pain and increased functional ability and remained pain free through three years of post-intervention follow-up. In Palac and Grimshaw's opinion, the most important aspect of treatment for this violinist was her acquisition of the kinesthetic awareness of posture and position that allowed her to continue as a performer (Palac & Grimshaw, 2006).

Ackermann et al. (2002) compared strength versus endurance training, specifically, for the undergraduate music major. Nineteen undergraduate music majors participated in a study using a test-retest control design. They were assigned either to a strength or an endurance training group exercise regimen, meeting two times weekly for six weeks. The exercise training in each group was directed at the trunk and proximal upper extremity musculature. Endurance training was found to be more effective as the endurance participants reported a significant decrease in perceived level of exertion during playing. Based on this literature review, increasing trunk muscle endurance and neuromuscular control is indicated in the prevention and treatment of PRMD (Brandfonbrener, 1998).

Having evaluated the physical demands placed on the musician and determined the most effective treatment programs for PRMD, we now consider Pilates exercise as an intervention to meet the needs of the musician. Pilates exercise training, based on the teachings of Joseph Pilates (1880-1967), claims to increase trunk muscle endurance, strength, flexibility and neuromuscular control. Its goal is to improve general body flexibility and health by emphasizing ‘core’ (truncal) strength, endurance, posture, and coordination of breathing with movement. It was originally used almost exclusively by athletes and dancers, but has recently become more common in rehabilitation and fitness programs. More than five million people practise Pilates in the USA (Chang, 2000). The exercises can be adapted either to provide gentle endurance and strength training for rehabilitation, or to challenge skilled athletes with a vigorous workout (Segal, Hein, & Basford, 2004). In Stott Pilates, used in the present study, the original program has been modified (Merrithew, 2001) so as to incorporate more preparatory exercises, improve safety and permit the maintenance of a neutral spine position.

Pilates training, often referred to as ‘core’ strengthening, focuses on extensor, flexor, lateral trunk and scapular musculature. The goal of increasing trunk muscle strength and endurance without straining peripheral joints is achieved through coordinating breathing with movement; stabilization of the scapula, pelvis, and rib cage regions; and neutral head and cervical spine placement. Pilates instructors provide tactile cues and verbal feedback with visualization to maximize movement accuracy and safety during exercise. Pilates exercises initially use a minimal level of force on the trunk musculature. As the individual progresses and develops improved trunk strength, endurance, and kinesthetic postural control, the level of force placed on the musculature increases so as to retrain proprioceptive mechanisms while fostering more efficient movement patterns (Segal et al., 2004).

Research-based evidence to validate the claims of Pilates practitioners is just beginning to appear in the literature. Forty-seven participants attending a Pilates mat class once a week for six months, were assessed for composite flexibility, body composition, and self assessment of health, including posture. The participants demonstrated improved flexibility, but no changes in body composition or assessment of health and posture (Segal et al., 2004). In comparison of Pilates training with and without equipment (an oblong-shaped exercise ring) to exercise using conventional weight-lifting equipment, Pilates training was shown to be more effective for muscular endurance while weight-lifting was more effective for muscular strength (Petrofsky, Morris, Bonacci, Hanson, Jorritsma, & Hill, 2005). A randomized control trial study investigated the efficacy of Pilates-based therapeutic exercise treatment as compared to standard care (physician consultation without any specific exercise intervention) of chronic low back pain and functional disability. The Pilates method was statistically significantly more effective in decreasing chronic non-specific low back pain and functional disability (Rydeard, Leger, & Smith, 2006).

Thus, existing research investigating Pilates exercise has shown that this method increases trunk muscle endurance and decreases pain. In order to manage upper extremity workloads, it is necessary to achieve neuromuscular control of the scapula, pelvis and spine. This requires trunk muscular endurance to maintain stable positions during functional activities. An exercise program aimed at prevention and management of PRMD may include Pilates exercise as an additional exercise method for the instrumental musician.

The purposes of this study were to: 1) investigate the effectiveness of endurance and neuromuscular control exercise programs directed at improving trunk and proximal upper extremity muscle endurance and lumbopelvic control; 2) determine if changes in trunk muscle endurance and lumbopelvic control affect instrumental performance; 3) compare the effectiveness of two types of endurance and neuromuscular control exercise programs: a Pilates mat program and a conventional trunk and proximal upper extremity endurance exercise program.

METHOD

Participants

Fourteen instrumental musicians (five men, nine women) with a mean age of 20.93 ± 2.84 years (range = 18 - 29 years) enrolled in a university music program volunteered to take part in this study. The participants played the following instruments: flute (n = 5), trumpet (n = 2), oboe (n = 1), clarinet (n = 1), trombone (n = 2), bass trombone (n = 1), harp (n = 1), and percussion (n = 1). They were recruited using purposive sampling and sampling of convenience through the university band program, following approval of the project from the Institutional Review Board of the sponsoring university. Written notices were displayed and verbal announcements were made requesting volunteers for this study. Each participant read and signed an informed consent form detailing the purpose, procedure, possible risks, and time commitment involved with participation in the study. At the time of this study, the participants were not involved in any other regular exercise program and had no prior experience of Pilates exercise. Also, at the onset of the study, 13 of the 14 participants described pain in the upper back, neck, or upper extremities when they played their instrument. Any individuals with a diagnosed medical condition such as cervical disc disease with pain radiating into the upper extremity, neurological symptoms, upper extremity tendonitis, upper extremity nerve entrapment, any condition exacerbated with exercise, or any condition in which exercise was contraindicated, were excluded from the study.

Study design and procedures

This study utilized an interrupted time-series, two-group, pre-post-test experimental design (Figure 1). The research project lasted 13 weeks and was conducted within one semester to control attrition of the participants due to schedule changes. Three data collection sessions were conducted: 1) initial; 2) pre-test (after six weeks without intervention); 3) post-test (after six weeks of exercise). In each data collection session a questionnaire was administered and trunk muscle endurance and lumbopelvic control measures were collected. Random assignment of the participants was attempted, but due to required weekly school rehearsal for some of the participants, the assignment was based on convenience. After assignment to one of the two exercise groups, the participants completed either six weeks of Pilates exercises or conventional trunk and proximal upper extremity endurance exercises. After the exercise intervention, a third and final data collection session took place. For the convenience of the participants, the exercise classes were conducted during the evening in the physical therapy department of the sponsoring university. Equipment used included exercise balls, mats, light weights (1-3 pounds), Theraband and exercise rings.

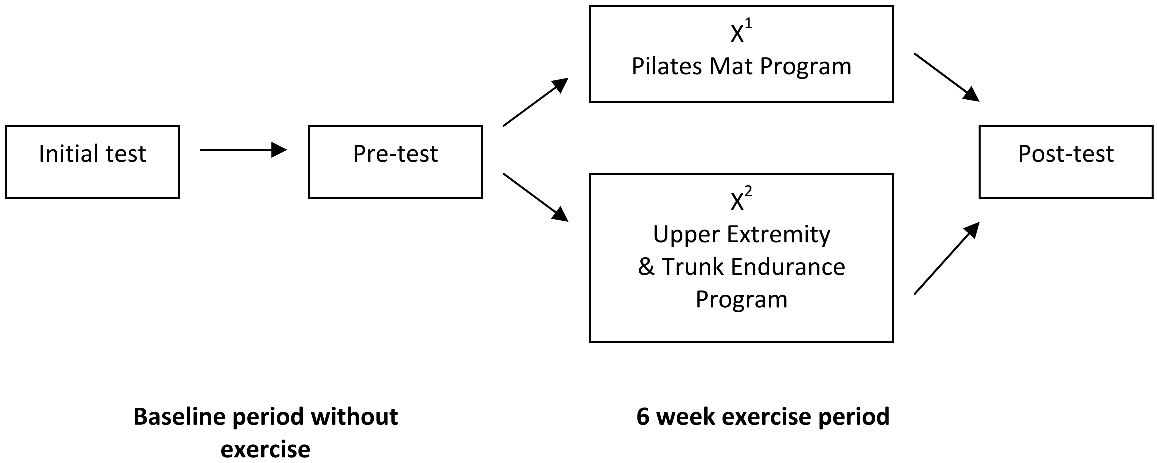

FIGURE 1. Interrupted time-series, two group, pre-test-post-test experimental design.

Trunk muscle endurance and lumbopelvic control measurement

Trunk muscle endurance and lumbopelvic control outcome measure data were collected by a licensed physical therapist blinded to the group assignment. Three trials of endurance (measured in seconds) were recorded for the trunk flexors, extensors, and bilateral lateral trunk musculature (Figures 2, 3 and 4). The muscle endurance testing was performed in a rotating order of muscle groups, allowing a three-minute rest period between each muscle group, then repeating the protocol three times. Lumbopelvic control was tested once during each session as described by McGill (2006) (Figure 5).

FIGURE 2. *Trunk flexor endurance test*. The participant assumes a supine position with 90 degrees of flexion at the hip and knee joints. The cervical spine and upper trunk are flexed as far as possible while maintaining a neutral pelvis position. Endurance is measured in seconds and the test is terminated when the participant moves out of the original position (Ito, Shirado, Suzuki, Takahashi, Kaneda, & Strax, 1996).

FIGURE 3. *Trunk extensor endurance test.* The participant assumes a prone position while lifting the sternum off the floor and maintaining the thoracic spine and pelvis in a neutral position. A small pillow is placed under the abdomen and the participant maintains slight cervical flexion. Endurance is measured in seconds and the test is terminated when the participant moves out of the original position (Ito et al., 1996).

FIGURE 4. *Lateral trunk endurance test.* The participant assumes a full side-bridge position with the legs extended and the top foot placed in front of the lower foot. The participant supports the trunk on one elbow and their feet while lifting their hips off the floor to create a straight line over their entire body length. The uninvolved arm is held across the chest with the hand placed on the opposite shoulder. Endurance is measured in seconds and the test is terminated when the participant moves out of the original position (McGill, 2006).

A B C

D

FIGURE 5. *Lumbopelvic control test*. The participant assumes the full push up position (A and D). The trunk is held in plank position with the pelvis and ribs level. A yardstick is placed perpendicular to the spine over the pelvis at the L5 level, parallel with the floor. The participant lifts one hand and places it over the other. Lumbopelvic control is tested bilaterally and is present when the pelvis remains level and the yardstick remains parallel with the floor (B). Lumbopelvic control is not present when elevation of the pelvis occurs and the yardstick does not remain parallel with the floor when the hand is moved (C) (McGill, 2006).

Questionnaire

The questionnaire comprised seven items concerning the presence, frequency and intensity of pain, fatigue, muscular tension, perceived level of exertion, and perceived level of musicality during instrumental performance (Appendix A). Pain experienced by the participants while playing was considered a symptom associated with performance-related musculoskeletal disorder (PRMD) as defined by Zaza et al. (1998). Though this questionnaire was not piloted, this definition of PRMD has been found to be reliable when used by musicians (Ackermann et al., 2002; Zaza & Farewell, 1997). Participants were instructed to mark responses using visual analog scales (VAS) consisting of a 10 cm line for each item below which descriptors were provided representing the full range of possible responses (Yoshimura, Paul, Aerts, & Chesky, 2006).

Four additional narrative questions administered at post-test addressed perceived changes in functional activities, response to the experience of undertaking the exercise class, and its effect on personal wellness goals (Appendix B).

Evaluation sessions

Initial (Week 1): Trunk muscular endurance and lumbopelvic control data were collected (Figures 1-5). The questionnaire was administered to the participants. The participants then continued with their normal activities for six weeks with no intervention.

Pre-test (Week 7): The same physical therapist collected identical outcome measurement data for each participant, as in the initial session (Figures 1-5). Next, the 14 individuals were assigned to either the Pilates exercise group (X1) (n = 7; seven women, no men) or the conventional proximal upper extremity and trunk endurance exercise group (X2) (n = 7; two women, five men). A required weekly flute choir rehearsal was scheduled during the same time the conventional endurance exercise class had already been scheduled. As a result, these flute students had to be assigned to the Pilates class. Most flute players in the choir were women and therefore the Pilates class participants were women.

Post-test (Week 13): For 13 participants, the same physical therapist collected the same outcome measurement data as in the initial and pre-test data collection sessions, while remaining blinded to group assignment. One participant was tested by a different examiner due to a scheduling conflict. During this last data collection session, the participants completed four additional narrative questions on the self-report questionnaire (Appendix B).

Test-retest reliability of the trunk endurance measures

In previous studies trunk flexor endurance test-retest reliability (r) was found to be good to excellent (Portney & Watkins, 2000) with a correlation for healthy men of 0.95 and for healthy women of 0.89 (Ito et al., 1996). In an additional study, trunk flexor endurance test-retest reliability was excellent; the intraclass correlation coefficient (ICC) was 0.95 with $p <$ 0.01 (Ito et al., 1996). Trunk extensor endurance test-retest reliability, as determined in previous studies, was reported to be excellent with a test-retest correlation (r) for healthy men of 0.97 and for healthy women of 0.94 (Ito et al., 1996). Again, in an additional study the trunk extensor endurance test-retest reliability was excellent; the ICC was 0.97 with $p <$ 0.01 (Ito, et al., 1996).The test-retest reliability for lateral trunk endurance was previously found to be excellent with a correlation (r) of 0.98 (McGill, 2006).

Description of exercise intervention

Both exercise intervention programs used trunk muscle endurance training either through a Pilates mat exercise class or a conventional trunk and proximal upper extremity endurance exercise class. The Pilates exercise routine included a greater emphasis on kinesthetic postural awareness and intentional breathing with movement. Both exercise groups met for two one-hour sessions each week for six weeks and were taught by a licensed physical therapist also trained as a Stott Pilates instructor. The Pilates participants learned selected exercises from the Stott Pilates Mat Program (Merrithew, 2001; Appendix C, Part 1). These were chosen because they are reported to increase muscular endurance, flexibility, and kinesthetic awareness. In this class, all exercises were directed by the instructor using demonstration, visual and tactile cues, and verbal feedback. Each class began with a selected portion of the entire program, though each trunk muscle group was addressed in every session. Progression through the exercises was determined by the developing endurance and neuromuscular control abilities of the participants. As the participants became able to perform the exercises effectively, more advanced exercises were added to the class. The class participants moved through the exercises as a group.

The conventional endurance training class included exercises for the proximal upper extremity and trunk musculature (Appendix C, Part 2). These proximal exercises were chosen because endurance of the scapular and trunk muscles is necessary to support the workload of the distal upper extremity musculature (Ackermann et al., 2002; Dommerholt, 1997). The exercises used weights and involved single movements often directed to one specific muscle group with less emphasis on neuromuscular control than Pilates exercises. The weights ranged from one to three pounds and the repetitions ranged from 15 to 20 since light resistance and higher repetitions are most effective in endurance training (American College Of Sports Medicine, 1998). Participants recorded the weight they used and the number of repetitions they performed for each exercise. If they reported any pain performing an exercise with a weight, the amount of weight was decreased or the weight was eliminated altogether. Initially the instructor directed all the exercises for the group. As the participants became familiar with the exercises, they completed them independently within the group, although the instructor continued directing some of the exercises and moved about the room to make corrections as needed.

Statistical Analysis

Statistical analysis was performed using SPSS software version 13.0. Analyses of variance and t-tests were used to analyse scores representing trunk muscle endurance and the seven self-report questions while frequency of occurrence was used to analyse the lumbopelvic control data. The data collected from the four narrative questions administered during the post-test data collection session were evaluated using content analysis (Portney & Watkins, 2000).

RESULTS

Attendance

The attendance rate was 84% for the Pilates exercise class and 95% for the endurance training exercise class. The main reasons for non-attendance were illness or school required performance or rehearsal.

Trunk muscle endurance measures

Although the two exercise groups (Pilates and conventional trunk endurance exercise) were small, preliminary one-way analyses of variance were conducted to rule out differences between the two groups at initial testing and pre-testing (at the end of the baseline, no-intervention period), and then to test for differences attributable to type of exercise at post-testing (after the intervention). These revealed a significant difference between the two groups at initial testing for the left lateral trunk muscles (F [1, 12] = 6.76, p = .023), and a near-significant difference for the right lateral trunk muscles (F [1, 12] = 6.76, p = .054), such that the Pilates group had greater endurance. There were also significant differences between the two groups at pre-testing, again for the left lateral trunk muscles (F [1, 12] = 6.83, p = .023), and a near-significant difference for the right lateral trunk muscles (F [1, 12] = 4.34, p = .059), such that the Pilates group had greater endurance. There were no significant differences between the two groups at post-testing. Means and standard deviations for both groups at each time of testing are shown in Table 1.

TABLE 1. Trunk muscle endurance measured in seconds

	Mean (SD) Initial		Mean (SD) Pre-test (before exercise intervention)		Mean (SD) Post-test (after exercise intervention)	
Muscle Group	Endurance n = 7	Pilates n = 7	Endurance n = 7	Pilates n = 7	Endurance n = 7	Pilates n = 7
Flexors	71.6 (25.0)	80.0 (29.0)	68.2 (22.9)	74.2 (30.6)	76.4 (21.9)	105.6 (66.4)
Extensors	106.3 (73.8)	135.5 (70.4)	81.3 (26.1)	121.6 (79.5)	124.3 (63.9)	127.3 (51.4)
Right lateral	29.6 (7.5)	45.2 (23.9)	28.0 (9.7)	44.8 (18.1)	40.2 (13.0)	53.4 (16.7)
Left lateral	26.7 (4.3)	46.0 (19.4)	26.7 (6.0)	44.8 (19.5)	41.4 (17.1)	52.4 (19.4)

Change scores were calculated by subtracting each participant's scores at initial testing from those at pre-testing, and at pre-testing from those at post-testing. ANOVA revealed no effect of exercise type on change scores following the baseline period or intervention. For this reason, the participants were considered as one group (N = 14), and paired samples t-tests were undertaken to investigate the effect of endurance exercise, regardless of whether this consisted of Pilates or conventional trunk endurance exercises.

There were no significant differences between participants' scores at initial testing and pre-testing. There were, however, significant differences between their scores at pre-testing and post-testing for extensors (F [1, 12] = 2.34, p = .036), right lateral (F [1, 12] = 3, p = .001) and left lateral trunk muscles (F [1, 12] = 3.1, p = .008) such that endurance was shown to have increased at the end of the exercise intervention period. There was also a trend towards increased endurance for flexors (F [1, 12] = 1.87, p = .084). These increases are illustrated in Figure 6.

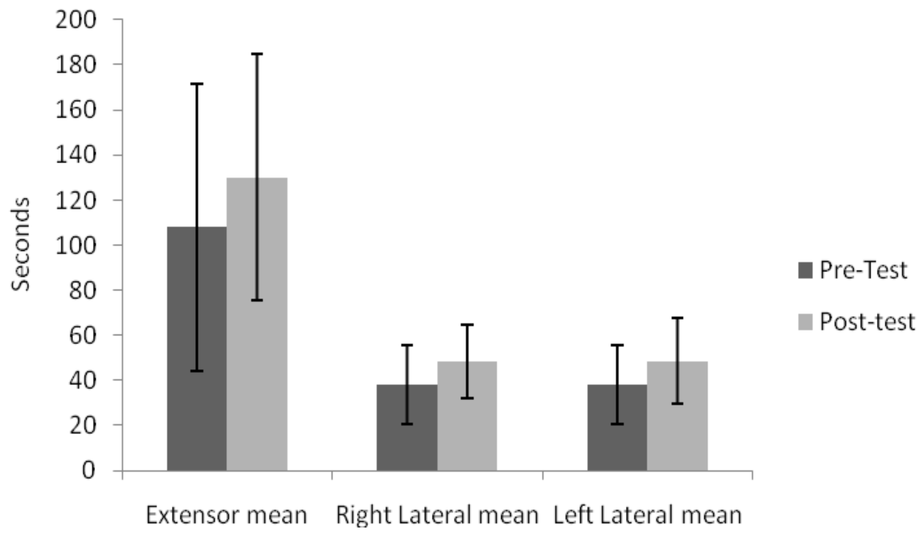

FIGURE 6. Effects of exercise on trunk muscle endurance.

Lumbopelvic control frequency of occurrence

One participant demonstrated lumbopelvic control at baseline and pre-test. Five participants including three in the Pilates and two in the conventional endurance group demonstrated lumbopelvic control at post-test.

Questionnaire

As shown in Table 2, there was a statistically significant difference between self-reported intensity of pain at the initial test and pre-test sessions reported by all 14 participants, but no other change during the baseline period. By contrast, following the intervention (regardless of exercise type), participants reported that they could play their instruments for longer periods of time before beginning to experience muscle fatigue and pain. They also reported less frequency and intensity of pain as well as lower perceived levels of exertion. The differences between their ratings at pre- and post-test were statistically significant. However, the differences between the ratings of the two exercise groups at post-test were not significant. These are illustrated in Figures 7 and 8.

TABLE 2. Questionnaire self-report data results

Question	Difference between pre-test and initial test (baseline period): paired samples t-test values (df=13)	Difference between post-test and pre- test (intervention): paired samples t-test values (df=13)	Difference between groups at post-test: independent samples t-test values (df=12)
1. I experience muscle fatigue after playing my instrument for the following length of time: (minutes)	0.09, NS	-3.38, *p* = 0.005	1.06, NS
2. My perceived level of exertion after playing my instrument 45 minutes without rest (how tired you feel in general) is: (scale = 0-100)	0.68, NS	2.25, *p* = 0.043	5.36, NS
3. I experience pain while playing my instrument when I have been performing for the following length to time: (minutes)	0.81, NS	-2.86, *p* = 0.013	0.00, NS
4. My level of musicality (being able to enjoy the process of making music and not only be concerned with the outcome) while playing my instrument is: (scale = 0-100)	0.84, NS	-2.00, NS	-0.97, NS
5. I experience muscular tension while playing my instrument after: (minutes)	1.06, NS	-1.57, NS	-0.88, NS
6. The intensity of pain that I experience while playing my instrument is: (scale = 0-100)	2.39, *p* = 0.033	3.26, *p* = 0.006	-0.15, NS
7. The frequency of pain that I experience while playing my instrument is: (scale = 0-100)	0.70, NS	3.02, *p* = 0.01	0.25, NS

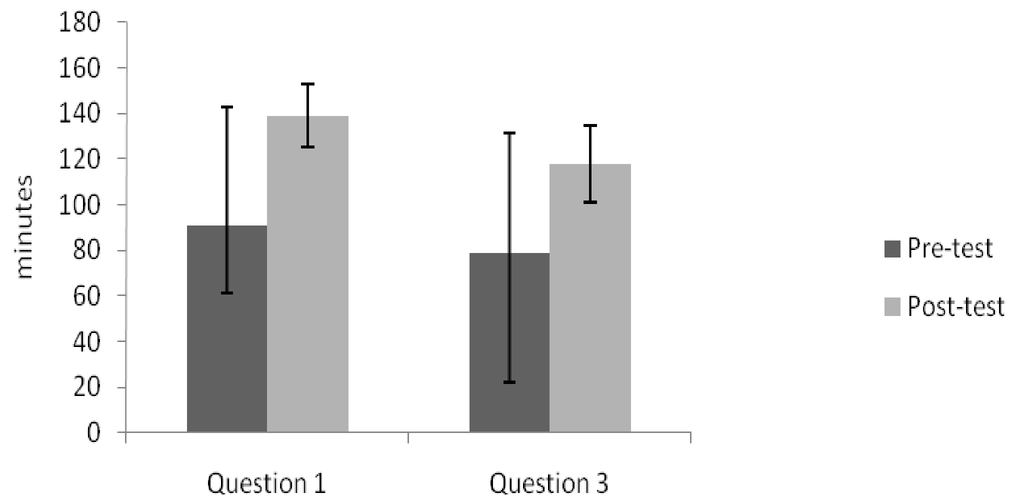

FIGURE 7. Playing time before onset of fatigue (Q1) and pain (Q3).

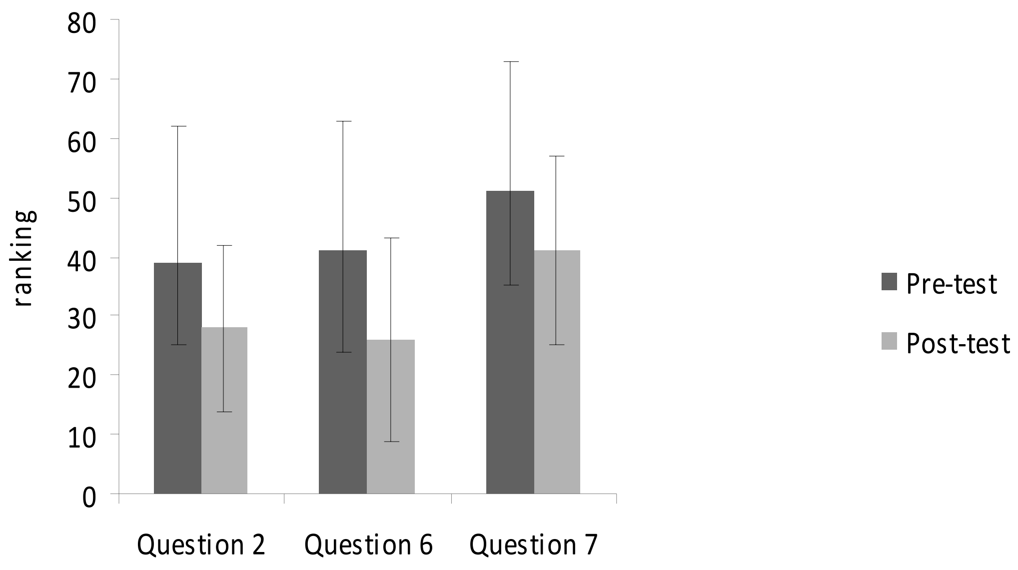

FIGURE 8. Perceived levels of exertion at 45 minutes of playing (Q2), intensity of pain (Q6) and frequency of pain (Q7) during playing.

Participants responded as follows to the narrative questions administered at post-test:

Do you notice any change with playing your instrument? Some examples might be: is there any change in pain level, breathing pattern or breath control while playing your instrument, changing endurance while playing your instrument, or more neutral posture while playing your instrument?

- *Breath control* – Four participants in the endurance exercise group and five participants in the Pilates group reported improved breath control. One Pilates participant also described improved tone production and quality and improved volume control while another stated "my breath support while playing has improved vastly and I am better able to take a good breath."
- *Pain* – Three participants in the endurance exercise group and three participants in the Pilates group reported decreased frequency and intensity of pain while playing, of these one stated "it takes longer to experience pain during band rehearsals."
- *Posture* – Six participants in the endurance exercise group and six participants in the Pilates group reported improved posture. Several participants in both groups described their posture as "improved greatly," with one endurance group participant stating "I feel straighter with a more neutral posture."
- *Playing endurance* – Two participants in the endurance exercise group and four participants in the Pilates group reported increased endurance during playing; of these one reported "I can play my instrument for longer periods without getting tired" while another stated "My shoulders don't get so tired as quickly."
- *Muscle tension* – Two participants in the endurance exercise group and three participants in the Pilates group reported decreased muscular tension of the shoulders and more relaxation. One Pilates participant reported "less tension in my shoulders" while an endurance participant stated "I feel more relaxed."

Is there anything different in your functional activities of daily living (i.e. sitting at the computer, posture, other activities, sports activities or other examples you can give)?

- *Changes in activities of daily living (ADL)* – Most participants (12 of 14) reported improved posture in the following ADL: walking, sitting, driving, using the computer, running, and playing hockey. One endurance participant described an increased ability to self correct posture and a Pilates participant reported improved posture evident to a non-participating person. Participants from both groups described decreased pain while driving and during sitting activities, better trunk control and increased strength and endurance in all ADL. One endurance participant reported ADL being more relaxed and natural, and occurring with less effort.

How would you describe this class experience in terms of the class exercises and motivation for future goals regarding wellness?

- *Response to class experience* – All participants reported that the class motivated them to continue an exercise program after the end of the exercise intervention. Several participants requested to continue the exercise class after the end of the project. One participant reported "I just feel like a better musician."

All 14 participants described a combination of at least three or more benefits after the exercise program.

DISCUSSION

The purposes of this study were threefold, to: 1) investigate the effectiveness of endurance and neuromuscular control exercise programs in improving trunk muscle endurance and lumbopelvic control for the trunk and proximal upper extremity muscles; 2) determine if changes in trunk muscle endurance and lumbopelvic control affect instrumental performance; 3) compare the effectiveness of two types of endurance and neuromuscular exercise programs: a Pilates mat program and a more conventional trunk and proximal upper extremity endurance exercise program. The main finding of this study was that both types of endurance exercise were effective in increasing trunk muscle endurance, the frequency of lumbopelvic control, and enhancing several aspects of instrumental performance.

The results of this study support the previously mentioned reviews of Lederman (2003) and Dommerholt et al. (1997) who reported that trunk endurance exercise directed at increasing endurance and stability was effective in the prevention and rehabilitation of PRMD in musicians. It has been reported that trunk muscle endurance and lumbopelvic control are necessary for trunk stabilization, which allows for more efficient management of upper extremity workloads (Hodges, 2004; Leetun, Ireland, Willson, Ballantyne, & Davis, 2004; Van, Hides, & Richardson, 2006). This is especially important for the musician when rapid, highly coordinated, repetitive upper extremity movements are executed during instrumental performance. After the exercise intervention, effective management of the upper extremity workload may have been more present in the participants as they reported decreased presence, frequency and intensity of pain, fatigue and perceived level of exertion during playing.

At the beginning of the baseline period of this study, 13 of the 14 participants reported upper back, mid-scapular, and distal upper extremity pain during instrumental performance. The musicians did consider themselves to be healthy, but were experiencing muscular pain in the upper extremities and upper trunk during playing. The questionnaire was designed to evaluate the aspects of pain (presence, frequency, intensity) that would indicate improvement or worsening of symptoms, as pain is considered a symptom of PRMD. After the exercise intervention, both types of endurance exercise groups reported a significant decrease in presence, frequency, and intensity of pain while playing their instrument. The participants also reported improved posture, regardless of exercise group, and this can contribute to a decrease in musculoskeletal pain as less stress is placed on muscular structures in the shoulder and upper back region.

In several previously mentioned reviews and studies, trunk muscle endurance exercise and neuromuscular control training were effective in reducing pain (Dommerholt et al., 1997; Lederman, 2003; Ortiz, Olson, & Libby, 2006; Palac & Grimshaw, 2006; Rydeard et al., 2006). For the musician, it is beneficial to have support for the upper extremities with trunk stabilization and muscular endurance to decrease the stress or physical demands on the upper extremities during instrumental performance. In the current study, nearly half of the participants reported decreased presence of pain during instrumental performance which supports the hypothesis that endurance training has a positive effect on performance, allowing the musician to focus on the task of making music without the distraction of physical discomfort.

In addition to decreasing pain, this study found that trunk endurance exercise training (both exercise groups) decreased fatigue and the perceived level of exertion while playing an instrument. These findings are in agreement with Ackermann et al. (2002) who found that endurance training was more effective than strength training in significantly decreasing the perceived level of exertion while playing an instrument. After the exercise intervention in the current study, nearly half of the participants reported increased endurance while playing their instrument. These findings support the hypothesis that trunk endurance exercise positively affects performance and may allow the musician to play a longer repertoire with less fatigue.

Posture, breath control, muscle tension, and playing endurance were reported to be improved after both types of exercise intervention. Each of these attributes is crucial for the musician and each is interrelated as a change in one attribute can have an impact on another. A majority of participants reported improved posture when playing their instrument as well as when performing other activities. This improved posture likely resulted from greater muscle endurance and kinesthetic body awareness. Improved posture allows the musician more efficient ergonomic use of the trunk and upper extremities, thereby contributing to the reports of decreased pain and fatigue and improved playing endurance and breath control. In addition, a majority of the participants reported improved breath control after the exercise intervention. Breath control is essential to the wind instrumentalist as it is the basis of sound production, control, and tone quality. The intentional breathing with movement and neuromuscular control training performed in the exercise classes may have improved the participants' breath control abilities. Muscle tension was also reported to be decreased, which again likely was due to improved posture, breath control and decreased pain. Finally, the improved posture, breath control and decreased muscle tension reported by the participants likely contributed to the increased playing endurance due to more efficient use of trunk and improved breath control. These findings further support the hypothesis that trunk endurance training positively affects instrumental performance.

At the end of the baseline period, participants reported a significant increase in pain intensity during playing, which may have resulted from a confounding scheduling occurrence. The participants had a break from school-required performances during the last two weeks of the six- week baseline period, but did continue with practice schedules and performances outside of school. Then at the end of the two-week break and the concurrent end of the six-week baseline period the participants returned to school with a full playing schedule of required school performances. The increase in playing time was not gradual for many of the participants and the second data collection session was administered at the end of the return week. One of the most important injury prevention guidelines for musicians is to increase practice or performance playing time gradually. These factors may have accounted for the reported increased pain intensity during playing described within the baseline period.

There were no statistically significant differences between the two exercise groups' trunk endurance or lumbopelvic control after the exercise intervention. Several factors may have contributed to this, with one important factor being the de-conditioned physical status of the participants at the start of this project. They had considerably less mean trunk endurance than a healthy comparable adult population (Ito et al., 1996). Mean trunk flexor endurance values for the current participants were 44% lower than those of a comparable adult population, while the mean trunk extensor endurance values were 47% lower than those of a comparable adult population. In addition, the mean age of the current participants was 20.9 years as compared to 45.0 years in the comparable adult population. The participants in the endurance class were more de-conditioned than the Pilates participants as determined by trunk muscle endurance values. Also, the endurance group exercise program was easier to teach and perform as the movements required less neuromuscular control. Therefore, the endurance participants might have demonstrated trunk endurance change more rapidly as they started with less trunk endurance and the Pilates exercises were more complicated to learn and perform because of the greater emphasis on trunk neuromuscular control. A longer exercise intervention might have resulted in a greater increase in mean trunk endurance values for Pilates participants.

Implications and recommendations

This preliminary study has demonstrated beneficial effects of two types of endurance exercise on aspects of musical performance. As the participants' trunk muscle endurance increased, they reported decreased fatigue and the presence, intensity and frequency of pain while playing. In addition, posture, breath control, muscle tension, and playing endurance all were reported to improve. Such improvements may help musicians better manage pain, fatigue, muscle tension and stress, all of which can impede playing. This can bring them closer to an injury-free state of wellness, which is essential for artists to achieve their highest levels of musicality (Figure 10).

Performance-related muscular disorders, and the necessity for their prevention and management, have become more widely recognized by both the medical community and music educators. The methods used in prevention and management of these disorders are aimed at managing posture, breath control, muscle tension, and playing endurance. Furthermore, they aim to remove impediments to musical playing, such as pain, fatigue, stress and ineffective management of muscular workload (Figure 10).

If further studies find beneficial effects of trunk endurance exercise for musicians, three strategies for enhancing wellness can be recommended: 1) developing effective exercise programs for the prevention and management of PRMD, 2) educating healthcare providers working with musicians to identify and treat PRMD effectively, and 3) encouraging musicians and music educators to support their students in the pursuit of healthful activities to lessen the occurrence of PRMD throughout their careers. The goal of such wellness education is to increase the number of musicians who are motivated toward a more healthful lifestyle by making them aware of the risks associated with performing, and therefore in a better position to prevent or at least manage performance-related injuries and disorders.

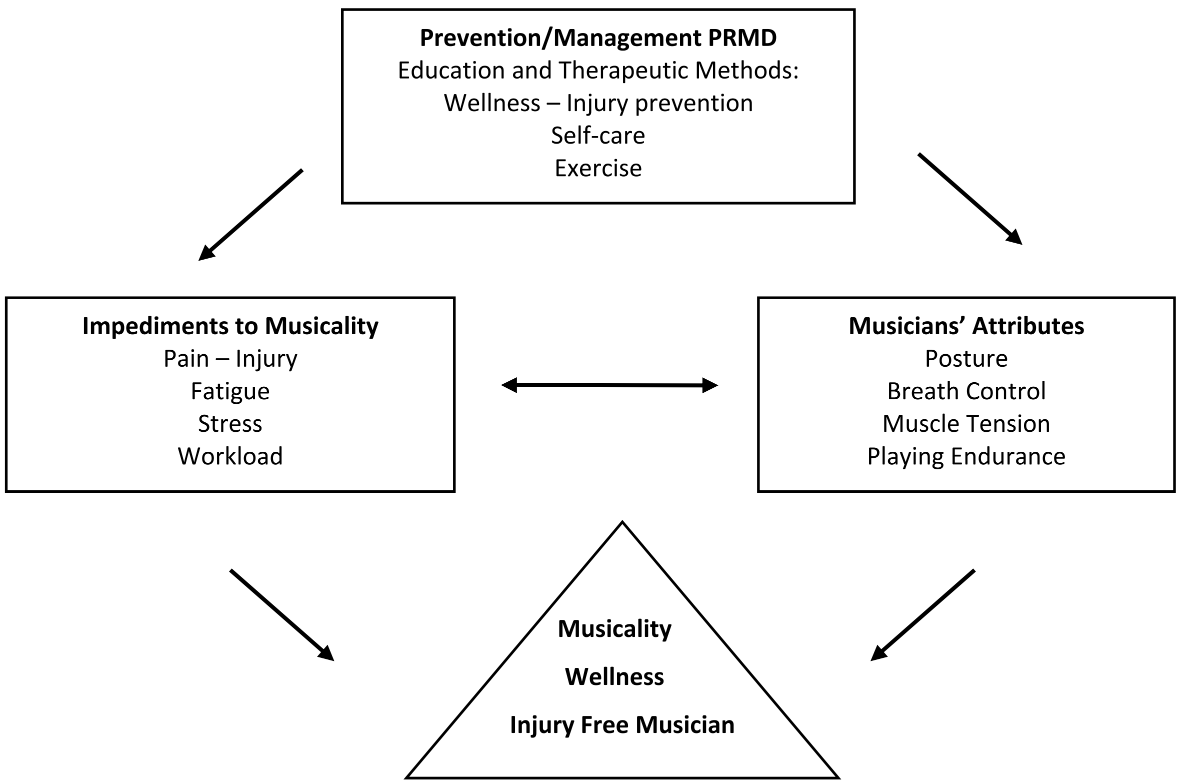

FIGURE 10. The multifactorial aspects and implications of wellness and musicality for the musician.

Limitations

As a result of the difficulties inherent in scheduling students, the sample size was small, it was impossible to achieve truly random assignment to each exercise group, and the duration of the study – and therefore the intervention period – could be no longer than a single semester.

Future research

Since this was only a preliminary study, randomized controlled trials with larger sample sizes are needed to assess the effectiveness and benefits of trunk muscle endurance and neuromuscular control exercise for instrumental musicians. In future exercise intervention studies, the length of the exercise intervention should be increased to allow participants more time to gain increased kinesthetic awareness. It would be better to undertake longitudinal studies to determine the most effective educational and therapeutic methods for injury prevention and treatment to manage musicians' injuries. Such studies could be undertaken within secondary-level university music programs, so as to avoid scheduling difficulties and increase group size. The physical status of incoming university music students should be assessed before they embark on a rigorous program of study, in order to address their needs at the outset. It would be useful to develop an objective measurement of breath control for future research into the effects of exercise. Finally, a reliable and valid questionnaire for use in research and treatment should be designed specifically for instrumental performers.

CONCLUSION

The results of this preliminary study support the hypothesis that trunk endurance and neuromuscular control exercise programs would improve trunk endurance and lumbopelvic control in instrumental musicians, potentially effecting positive changes during performance. While there is no evidence that one program was more effective than the other, it is clear that exercise of this nature is beneficial. Trunk endurance and neuromuscular control exercises are beneficial for instrumental musicians and should be part of an essential wellness program included within the curriculum for all music education and performance students.

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APPENDICES

Appendix A: Questionnaire

Musician Survey: Self Report Data

Name: _________________________

1. I experience muscle fatigue after playing my instrument for the following length of time:

   0 min 30 min 1 hr. 1.5 hr. 2 hr. 2.5 hr. 3 hr.

   Location of muscle fatigue: __________________________________

2. My perceived level of exertion after playing my instrument 45 minutes without rest (how tired you feel in general) is:

   Very Low Very High

3. I experience pain while playing my instrument when I have been performing for the following length of time:

   0 min 30 min 1 hr. 1.5 hr. 2 hr. 2.5 hr. 3 hr.

4. My level of musicality (being able to enjoy the process of making music and not only be concerned with the outcome) while playing my instrument is:

   Very Low Very High

5. I experience muscular tension while playing my instrument after:

   0 min 30 min 1 hr. 1.5 hr. 2 hr. 2.5 hr. 3 hr.

6. The intensity of pain that I experience while playing my instrument is:

   Very Low Very High

7. The frequency of pain that I experience while playing my instrument is:

   0 25 50 75 100
   Never Rarely Sometimes Often Every time I play

Appendix B: Additional questions in questionnaire administered in Test Session 3.

Question No. 1. Do you notice any change with playing your instrument? Some examples might be: is there any change in pain level, breathing pattern or breath control while playing your instrument, changing endurance while playing your instrument, or more neutral posture while playing your instrument?

Question No. 2. Is there anything different in your functional activities of daily living (i.e. sitting at the computer, posture, other activities, sports activities or other examples you can give)?

Question No. 3. How would you describe this class experience in terms of the daily class exercises and in terms of motivation for future goals regarding wellness?

Question No. 4. Do you have any other comments?

Appendix C: Part 1. Stott Pilates Mat Class Exercises (Merrithew, 2001).

Figure 1. Abdominal prep
Lie on back, legs bent, arms toward ceiling. Exhale, pressing arms down to sides, curling up head and upper torso. Inhale, return to start position.

Figure 2. Hundred
Lie on back, legs bent, arms toward ceiling. Exhale, pressing arms down to sides, curling up head and upper torso. Hold. Pump arms in small flutter movements.

Figure 3. Roll-up
Lie on back, legs straight, arms overhead. Exhale, bringing arms forward curling up from top of spine. Inhale as begin roll back, exhale as slowly completing roll back down.

Figure 4. One leg circle
Lie on back, leg extended on mat, other leg straight up. Inhale, circling leg across body and exhale as you finish circling down and around to beginning. Maintain still pelvis.

Figure 5. Rolling like a ball
Sit with knees to chest. Inhale, roll back to shoulders. Exhale, roll back to seat.

Figure 6. Single leg stretch
Lie on back, one leg knee to chest with the other leg at 45 degrees. Exhale, curling up head and upper torso. Holding torso position exchange leg positions.

Figure 7. Single leg stretch with obliques
Lie on back, legs bent to chest, hands behind head. Exhale, lifting head and upper torso. Twist torso and elbow to opposite knee, extending other leg to 45º. Inhale, twisting to other side, changing legs.

Figure 8. Double leg stretch
Lie on back, hand holding knees to chest. Exhale, curling up head and upper torso to knees. Hold curl, inhale and extend arms and legs toward ceiling. Exhale, bringing legs and arms back in.

Figure 9. Spine stretch forward
Sit up straight, bent legs open slightly wider than hips, feet flexed, hands behind on mat. Inhale. Exhale, rounding torso over. Inhale, sitting up.

Figure 10. Saw
Sit up straight, legs open slightly wider than hips. Extend arms to side. Exhale, rounding spine over leg, reach opposite hand toward outside of foot, other arm back, palm up.

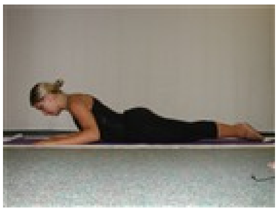

Figure 11. Breast stroke prep
Lie on stomach, elbows bent, lower rib remaining on mat. Inhale, raising upper torso, coming up to forearms. Exhale, slowly lowering torso back to start position.

Figure 12. Swan dive prep
Lie on stomach, elbows bent. Inhale, raising upper torso, coming up to palms. Exhale, lowering torso back to start position.

Figure 13. Heel squeeze
Lie on stomach, legs apart. Supporting abdomen, bend knees and gently squeeze heels together.

Figure 14. Oblique roll back
Sit straight, legs bent with feet on the mat. Exhale, slowly rounding back halfway. Reach arm behind. Inhale, returning.

Figure 15. Spine twist
Sit up straight, legs pressed together, feet flexed. Reach arms out to sides, palms forward. Exhale, twisting twice to one side. Inhale, returning. Keep arms straight, legs pressed together.

Figure 16. Side kicks
Lie on side, back straight in line with edge of mat, legs hinged 30 degrees in front of torso. Lift top leg to hip height. Bring top leg forward and then back without moving torso.

Figure 17. Side leg series
Lie on side, back straight in line with edge of mat, legs straight. Lift top leg to hip height, slowly return down to start position.

Figure 18. Teaser
Lie on back, legs on 45 degree diagonal. Exhale, curling up to V position, keeping legs in place. Inhale, holding V position, exhale slowly rolling back to start position.

Figure 19. Seal
Balance on seat, holding legs. Clap feet together three times. Inhale, rolling back to shoulder. Pause slightly to clap feet together three times. Exhale, roll back to start.

Figure 20. Push-ups
Inhale, lowering to push-up position, elbows next to ribs. Exhale, pushing up to arms straight. Repeat 3 times. Arms straight, inhale, walking hands back to feet. Hang over in forward bend. Exhale, rolling spine up to stand. Inhale. Reverse sequence into push-up position.

Appendix C: Part 2. Trunk and proximal upper extremity endurance exercise class (Ackermann et al., 2002).

Figure 1. Biceps curl
Standing with arms straight by sides, raising weights to shoulders by bending elbows only.

Figure 2. Reverse fly
Prone over Swiss ball, arms at 90º of abduction with elbows bent to 90º and arms internally rotated so that forearms are perpendicular to the floor. Shoulder blades slide closer together to raise elbows.

Figure 3. Lateral raise
Standing, arms straight by sides, weights raised to 90º of shoulder abduction.

Figure 4. Triceps extension
Prone over ball with arms at 90º shoulder abduction and forearms perpendicular to the floor. Extend elbows.

Figure 5. Shoulder forward
Standing with weights in hands and arms straight by sides. Weights raised forward to end of range of forward flexion, keeping elbows extended.

Figure 6. Bent over row
Standing, bending forward from hips with lumbar spine neutral and one knee bent up onto chair to support position. Place one hand on mat. Hang other arm, with weight, toward floor. Raise weight vertically to side of the body.

Figure 7. Back extension
Prone over ball, gradually extending spine from neck through to lower back while holding weights up against sternal notch.

Figure 8. Shoulder extension
Prone over ball with arms hanging to ground with thumbs facing forward (arms in external rotation). Holding weights in hands bringing arms back toward body and into full shoulder extension while internally rotating arms.

Figure 9. Opposite shoulder and hip extension
Prone over ball, raising one arm and the opposite leg simultaneously with arms and knees straight.

Figure 10. Sit-ups
Lying supine, arms crossed with hand on opposite shoulder. Contract abdominals and curl up from the head, keeping pelvis in neutral position. Hold and then lower to start position.

Figure 11. Side-plank position
Side-bridge position with the legs extended or knees bent. Support on bent elbow with other arm across chest and hand on opposite shoulder. Hips lifted to form plank position from shoulder to knee or foot.

Figure 12. Push-ups
On hands and knees with hips extended or hands and toes with hips extended, trunk in plank position. Maintain plank position; bend elbows and lower body towards floor, then return to start position.

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