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Research paper

An integrative intervention program for college musicians and kinematics in cello playing

Sang-Hie Lee[a,*], Stephanie Carey[b], Matthew Lazinski[c], Eun Sook Kim[d]

[a] College of The Arts, University of South Florida, Tampa, FL, USA
[b] Department of Mechanical Engineering & Center for Assistive, Rehabilitation & Robotics Technologies (CARRT), University of South Florida, Tampa, FL, USA
[c] School of Physical Therapy & Rehabilitation Sciences, Morsani College of Medicine, University of South Florida, Tampa, FL, USA
[d] Department of Educational & Psychological Studies, College of Education, University of South Florida, Tampa, FL, USA

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ABSTRACT

Introduction: College musicians preparing for performing careers must sustain physical-mental fitness as deficiencies can cause pain and injury and compound stress and anxiety. An integrative intervention program was embedded in a college music course.
Methods: The program included yoga, physical therapy exercises, and mental fitness & improvisation practices. Data were collected from a purposive sample of 34 over six semesters. We assessed the effects of the program by comparing pre-post data of (1) physical strength-flexibility-endurance tests and (2) psychometrics containing health-practice inventory (HPI), physical-musical efficacy (PME), and mental fitness and improvisation (MFI). Nonparametric Paired Sample Wilcoxon Signed Rank Tests were used to assess statistical significance of pre-post changes and Matched Pair Rank Biserial Correlation r was applied to demonstrate the effect size. (3) We observed kinematics of string players by plotting pre-post motion capture.
Results: Physical strength showed significant changes with left pectoral minor length (p = .01, r = .64) and deep neck flexor strength/endurance (p < .001, r = .92). HPI revealed healthy practice habits and life style in our collegiate musicians. Survey results showed significant changes in all PME and MFI composite indices: *physical awareness* (p = .002, r = .66) and *comfort* (p = .004, r = .60), *musical awareness* (p = .01, r = .68) and *comfort* (p = .001, r = .74), *calm mind* (p = .043, r = .49), *mental practice* (p = .028, r = .51), *calm recital* (p = .002, r = .74), *recall recital* (p = .022, r = .53), *comfort* improvisation (p = .001, r = .78), *in-the-moment* improvisation (p = .004, r = .72), and *satisfaction* improvisation (p < .001, r = .85). Kinematics showed positive changes in range of motion and fluency.
Conclusion: College musicians' integrative intervention program was effective with a modest postural change in our purposive sample (250).

1. Introduction

Performing arts medicine is an emerging field intersecting arts and medicine professions that has evolved since the inauguration of Performing Arts Medicine Association (PAMA) in the early 1980s. While performing arts educators and health providers have made impressive strides over the 40 years since the dawning of the field, students are still not receiving the proper training in their curricula on physical and mental aspects of music performance. Further, the majority of those who develop pain and injury do not have resources and specialized clinics to go to receive sufficient help. On the other hand, university students who are motivated to go into performing arts medicine field do not have a clear path to pursue. The upside is that there is a growing number of centers that focus on research and dialogue across the international community (http://www.artsmed.org/).

Playing-related musculoskeletal disorders (PRMD) are defined as pain, tingling, numbness, or other forms of discomfort that may prohibit the musician from playing his/her instrument at his full capacity [1]. According to a recent systematic review of studies on musicians' health problems, the lifetime prevalence of playing-related pain among musicians is as high as 85% [2]. Another meta-analysis study reported that the twelve-month prevalence of playing-related musculoskeletal complaints among professional musicians ranged between 41 and 93% with lifetime prevalence ranging between 62 and 93% [3]. While researchers have concluded that no clear causal understanding for musicians' musculoskeletal disorders could be established [4], a few have

* Corresponding author at: College of The Arts, University of South Florida, MUS 101 School of Music, 4202 East Fowler Avenue, Tampa, FL 33620-7350, USA.
E-mail address: slee@usf.edu (S.-H. Lee).

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used the cross-sectional data to help develop preventive measures in training future professional musicians, specifically collegiate musicians who are preparing for performing careers. Although no studies have yet recorded physical-mental problems that have deterred or ended musicians' careers, numerous anecdotal cases abound in the music world.

2. The problem

Collegiate musicians in training for music performance careers demand high levels of physical, emotional, and mental fitness, and yet most of them receive little to no education in preventive health germane to music performance. Moreover, prevention and rehabilitation of pain and injury are significantly hampered by the fact that musicians are reluctant to reduce or temporarily stop their playing to allow injuries to heal. The National Association of Schools of Music's advocacy on healthy music training [5] has prompted some institutions of higher learning to initiate efforts to address healthy practice behaviors for their music students [6].

Musicians' medical problems are related to "repetitive movements, long practice sessions, awkward positions, instrument shape and weight and technical difficulty" [7] (p. 221).

Therefore, Lockwood suggested the use of exercises to strengthen potentially overused muscles. Several researchers have employed physical exercise programs to help with muscle strengthening, flexibility, and endurance. Brandfonbrenner [8] used two exercise groups,– a strengthening exercises group who used therabands, exercise foams, and exercise gloves for finger exercises; and a flexibility group used warm-up and cool-down stretches. Results indicated that low-resistance, high-frequency strengthening exercises were more suitable for musicians than the high-resistance varieties, as the latter are primarily designed to produce muscular mass. Spahn et al. [9] applied pelvic-lower back-abdominal muscle exercises, Feldenkrais, autogenic training, yoga, the Alexander technique, functional relaxation, Aikido, Shiatsu, and Tae Kwon Do to increase musicians' physical resilience. Ackerman et al. [10] used biceps curl, reverse fly, lateral raise, triceps extension, shoulder forward flexion, bent-over row, back extension, shoulder extension, and opposite shoulder and hip extension, as well as sit-ups, and push-ups, targeted to the development of overall strength and endurance. de Greef et al. [11] complemented instrument-specific movement exercises to the warm-up and cool-down phases associated with practice in addition to the general conditioning exercises. These studies have emphasized the need for physical preparation for musicians, but the effects of strength and endurance exercises on mind-body-performance connections have not been addressed. As such, there is a need for clear and specific outcomes measurements to be developed to assess this relationship.

Body posture and motor control are inherently connected, and therefore, kinematic re-education of postural awareness is likely to influence a lasting change in the way a person controls body-mind behavior [12]. Recently, yoga, flow, and mindfulness meditation are receiving attention in the scientific community. For example, young adult musicians enrolled in two-month fellowship programs, – three separate cohorts in three consecutive years –, participated in a yoga and mindfulness meditation program and reported experiencing enhanced state of flow and mindful awareness and reduced confusion compared to the control group [13]. *Flow* is a state of complete immersion in an activity, that creates a rewarding and pleasurable state, which is the result of a balance between the task-at-hand and the skills necessary to perform the task [14]. *Mindfulness* is a form of meditation that is intensely focused on the awareness of the present moment, i.e., '*in-the-moment experience*' [15].

3. Study design

The purpose of this study was to examine the effectiveness of the mind-body health intervention program for collegiate musicians on their physical, mental and musical experience.

Our research setting is built in a course for college music performance majors which allows a quasi-experimental one-group pretest-posttest model [16] with a purposive sample. Demographic variables expressed in the survey questionnaire were not intended for controls but as subject descriptors. The treatments (independent variables) were musician-tailored yoga, upper-body physical therapy exercises, and mental fitness and free improvisation training. The aim of the study was to examine the effects of the integrative intervention program on: (1) improving the upper body posture, flexibility, muscular strength, and endurance; (2) increasing physical and musical efficacy; (3) increasing mental efficacy, sense of *in-the-moment experience* and *satisfaction* during free improvisation; and (4) effecting positive change in the body movement shown in motion capture. Outcomes measurements (dependent variables) for the intended aims were conducted in three forms: physical examination, psychometrics, and motion capture.

4. Methods

4.1. Ethical approval

The study protocol, consent form, psychometric survey, physical examination, and motion capture were approved by the ethical committee of University Institutional Review Board in 2013 and renewed each subsquent year. (Approval code: #Pro00014865. See approval letter in Appendix I.)

4.2. The course

Fit to Play: Mind-Body Integration for Musicians is an elective course (2-hour credit) for collegiate musicians, focusing on career-related issues in becoming a competent performer. It is offered once a year in the fall semester at the school of music of a large urban research university to graduate and upper-class undergraduate music performance majors. Integrative intervention program is embedded in the course designed to study the effectiveness of the program. The course is announced with a flyer describing the content and the research component. The flyer briefly explains the ethical process, consent form, benefits, and freedom to withdraw at any time during the study without penalty or sacrificing the course. Participation in the study and course registration are both completely voluntary.

4.3. The integrative intervention program

The integrative intervention program is designed to help increase physical strength, flexibility, and endurance in the upper body, and physical, mental and musical efficacy focused on awareness and comfort levels during music performance. In a weekly 2-hour class, students discuss textbook materials [17,18] that deal with music practice and performance issues in the first hour; and practice yoga, physical-therapy exercises, and mental fitness and improvisation in the second hour in rotating weeks.

4.3.1. Yoga sessions

Yoga instruction was given every third week by a certified yoga instructor. Yogic techniques included Breath Techniques or "*Pranayama*" (*Prana* = life force; *Yama* = to control or channel), Physical Poses or "*Asanas*," Meditation and Relaxation Training, and Mindfulness training which focused on concentration and receptive awareness to help increase the student's physical and mental awareness. A performance sheet was given to record personal 20–30-minute daily yoga practice.

4.3.2. Physical therapy exercises

Physical therapy exercises were carefully selected considering the most important aspects in musicians' body based on the theoretical framework and the purpose of the study. Musicians' exercises were focused on the upper-body and excluded lower-body concerns because while musicians need to maintain good balance and whole-body posture, specific music techniques involve primarily the upper body strength, endurance, and dexterity. After conducting the base-line flexibility/posture, muscular strength/endurance, and cardio endurance tests, each student was given an individually prescribed set of exercises addressing specific deficiencies encountered. They were required to execute these exercises 20 minutes per day and record their practice in *Fit to Play Exercise Tracking Form* developed by the team PT instructor. Four intermittent instructional classes were provided to monitor and guide musicians' exercises. The base-line tests were repeated at the end of the semester.

4.3.3. Mental and improvisation training

Tri-weekly mental training included deep breathing, clearing the clutter of the mind, developing imagery, doing mental rehearsal, and mental recall of their music adopting Connolly-Williamon mental skills training program [19]. This was followed by free improvisation in small groups focusing mindfully (awareness) on his/her own heart and sound, the collaborators' mood and sound, and the environment. Instructions for improvisation were developed adopting some of YoYo Ma's *free improvisation* coaching principles (see improvised music examples [20,21]). A word of caution is that we purposely avoided using jazz improvisation techniques in which harmonic/rhythmic structure and styles are prescribed for the improvising musicians. Our musicians are asked to empty their minds of cognition of form, style, or technique and simply sink into their heart and begin making music. They were instructed to trust their own mind-body technical tools and expressions accrued from years of training. All they had to do was clear their minds of any prescriptive notion and start to tap into their inner musician and be *in-the-moment* by listening to their heart and co-musicians' sound. They were to be non-judgmental, and focus on the body, mind, sound, and musical self. This was very difficult for the classically as well as jazz trained musicians to do. In time, they played freely with no prescribed conception while listening deeply into their inner musical heart and shifting quickly with the flow. This was often recorded and followed by listening to and critiquing their performance. Our improvisation coaching criteria are comprehensive in so far as we are aware.

4.4. Subjects

Data were collected in six semesters in six years (2013 spring $n = 2$, 2013 fall $n = 6$, 2014 fall $n = 6$, 2015 fall $n = 6$, 2016 fall $n = 7$, 2017 fall $n = 7$) accruing the total N of 34 – there were no drop outs. This was about 10% of the eligible performance majors each semester (about 60) and about 10% of the total music student body of about 350.

Demographics of subjects were 23 graduate and 11 undergraduate musicians, representing 18 females and 16 males. There were nine strings, two woodwinds, four brass instruments, eight pianos, and eleven singers. Some music students indicated the single career goal of performing or teaching, but most indicated double or triple career goals, resulting with 29 performing, 21 teaching, 5 research and 11 other interests (e.g., song writing, recording, conducting).

Year		Gender		Instrument group		Career goal(s)	
Freshmen	1	Female	18	Strings	9	Teaching	21
Sophomore		Male	16	Woodwinds	2	Performing	29
Junior	3			Brass instruments	4	Research	5
Senior	7			Piano	8	Other	11
Graduate	23			Voice	11	e.g. recording, song writing, conducting	
Total	34		34		34		66

4.5. Outcomes measurements

4.5.1. Physical measurements

- Flexibility/Posture:
  - Forward Head Posture (craniovertebral angle measured in degrees).
  - Active Cervical Range of Motion (sum of all motions measured in degrees).
- Muscular Strength/Endurance:
  - Pectoral Minor Length (measured in cm).
    Deep Neck Flexor Endurance Testing (measured in seconds the holding time of the neck off the floor).
- Aerobic Endurance Testing:
  - YMCA Sub Maximal Step Testing (measured by heart beat per minute).

To measure Flexibility/Posture, we used Craniovertebral angle (CV) of forward-head posture [23]. Craniovertebral (CV) angle is the angle formed by a horizontal line through the spinous process of C7 (seventh cervical spinal disk) and a line from the spinous process of C7 through the tragus of the ear [24]. The faulty forward-head posture predisposes individuals to pathological conditions such as thoracic outlet syndrome and cervical spondylitis changes [25] and can cause rotator cuff tears as well [26]. Cervical retraction brings these landmarks into vertical alignment, effectively reversing the forward-head position. Active Cervical Range of Motion, sum of all motions, was measured using a goniometer.

For Muscular Strength/Endurance, Left and Right Pectoral Minor Lengths were measured by placing the patient in a supine position and measuring the distance of the shoulder above the table. Deep Neck Flexor Endurance Testing was done by the length of time the deep neck flexors were held in their proper position (i.e., lifted from the floor) [23,27]. For Aerobic Endurance Testing, we used the *YMCA* Sub Maximal Step Testing. Musicians were asked to perform 12-inch steps for three minutes, keeping pace with a metronome set at a speed of MM = 60 quarter notes per minute. Their pulse was taken immediately after completion of the task to determine submaximal aerobic capacity.

4.5.2. Psychometrics: survey questionnaire

A four-part survey questionnaire was modified from a previous study [28]. Demographics included class (i.e., undergraduate & graduate), gender, instrument group, and career goals. The Health-Pain-Injury Inventory (HPI) asked questions on general health, health habits, drug/alcohol/caffeine/substance use, work hours, frequency of music-related pain and injury, pain locations, practice habits (daily practice hours, warm-up & cool-down), and comfort levels with instrument and repertoire. The Physical and Musical Efficacy (PME) included physical awareness and comfort levels on posture, tension, and movement flexibility, as well as musical awareness and comfort regarding technique, tone, and musical flow/fluency. Mental Fitness and Improvisation (MFI) questions included how long it took to calm the mind and achieve imagery, mental practice, mental recall; and comfort, sense of in-the-moment and satisfaction with their own sound, their colleagues' sound, and the environment during improvised performance. Content

Table 1
Physical examination (N = 33): significance tests (two tailed) & effect size, r.

	Pre	Post	Wilcoxon signed rank test, Z	Sig	Matched pair rank biserial correlation, r
Posture/flexibility measures					
Craniovertebral Forward-Head Angle (degrees)	52.26	52.16	0.11	.92	−.03
Craniovertebral Retracted Angle (degrees)	63.10	63.13	0.00	1.00	.00
Active Cervical ROM (degrees)	332.52	341.00	1.56	.12	.38
Physical strength measures					
Pectoral R (cm)	6.05	5.88	1.52	.13	.40
Pectoral L (cm)	**6.23**	**5.83**	**2.52**	**.01***	**.64**
Deep Neck Flexor Endurance Testing (sec)	**22.05**	**31.93**	**4.15**	**.00***	**.92**
Submaximal cardiovascular testing					
3-minute YMCA Step Test (heart beat per min)	107.18	106.33	0.26	.80	−.06

Bold faces indicate statistically significant values.
* $p < .01, .001$.

validity of the survey instrument was achieved by developing the psychometrics based on an analysis of the comprehensive literature on musicians' performance-related musculoskeletal disorders [1–4,8–11,29–33] and a published pilot test [28]. Cronbach's Reliability tests for PME and MFI showed high *alpha* estimates for all variables, ranging from *alpha* .78 to .88.

4.5.3. Motion capture

Student musicians visited the University Center for Assistive, Rehabilitation & Robotics Technologies (CARRT) to take pre and post individualized motion capture videos as they played their instrument playing a scale and a piece. Motion capture was applied to measure kinematic changes in the musicians' use of the body before and after the intervention program. We used an eight-camera Vicon optical motion analysis system (Vicon, Oxford, UK) with thirty-one passive reflective markers attached to the musician's body using neoprene straps and double- sided adhesive markers. Two standard digital cameras and in some cases, two force platforms (AMTI, Watertown, MA) were used to collect the kinetic data. Prior to data collection for each music instrument, we calibrated the motion capture instrumentation according to the manufacturer's guidelines. Motion data were collected while musicians played a scale and a chosen piece of music each for three trials. The same pieces were played before and after the intervention program. A Visual 3D (C-motion, Germantown, MD) system was used to create joint centers, define limb segments, and calculate joint angles.

We approached each instrumentalist presenting a unique set of body and instrument ergonomics, as well as desired physical and musical awareness, comfort, and musical outcome. Motion analysis through the within-subject approach [22], therefore, provided a tool to capture the individual's unique set of techniques of integrating body-mind in the maturing process as musicians. Specifically, motion analysis provided individualized instrument-specific information for each musician's body ergonomics. In both the baseline and post motion capture sessions, the composite of three repetitions formed the motion pre- and post- data. Measurements for joint angles of all instrumental musicians' shoulder, elbow, wrist, and torso were calculated and compared before and after the program. Again, we included only what we believe are the essential elements of the body movement of each instrumental playing.

4.6. Statistical methods

The pre- and post- physical measurements and PME and MFI scores (Likert type, 1–5) were analyzed using Nonparametric Wilcoxon Paired Samples Signed Rank Tests to assess statistical significance (SPSS version 22), where changes in the interval scales were converted to differences in rank order. A nonparametric test was preferred with our small sample datasets as distributional *normality* was not assumed, and *pairing* took the data dependency into account [34]. In addition, we used the Matched-Pair Rank Biserial Correlation r to demonstrate the effect size [35,36].

5. Results

5.1. HPI data and pain location

Overall, music students' health habits, i.e., eating, sleeping, work hours, practice hours, substance use, general energy level, and attendance at rehearsals, seemed well balanced. This behavior patterns reflect the serious and competitive culture in the school of music. Within the research university setting, performance majors are highly selected for their talent (pre-college musical training) and the school's cultural environment is strongly supportive of their practicing regulation and practicing hours. All music students have swipe card to the new music building that has ample practice facility available at all hours including evenings and weekends.

Report of frequency in musicians' warm-up exercises remained the same while cool-downs have increased at the end of the program. Pain location and frequencies decreased slightly in the post survey. Most frequently, pain remained in the neck and shoulders of the musicians. There were notable decreases in pain in the wrist (9 to 5, frequency in real number not in rating), lower arm (5 to 2), lips (5 to 2), and jaw (9 to 6). We hypothesize that the decrease in facial area pain may be related to the increased range of motion in the jaw that we observed. The decrease in the wrist and lower arm pain are worth further examination to see if there might be a possible direct relationship with the physical or yoga exercises.

5.2. Physical examination

Nonparametric Wilcoxon Paired Samples Signed Rank Tests results revealed significant changes in pectoral left minor length (L p = .01, r = .64) and deep neck flexor endurance ($p < .001$, r = .92), denoting increased muscular strength/endurance. The average combined male-female deep neck flexor strength increased from 22.05 seconds to 31.93 favorably matching with the average university students' score [23]. The pre-strength deficit among musicians may be due to the prolonged forward head posture that is needed to play musical instruments. However, the significant increase in strength after the intervention program (r = .92) is encouraging (Table 1).

There were no significant changes in the retraction of the craniovertebral forward-head angle, active cervical ROM, or YMCA aerobic endurance tests.

5.3. Physical and musical efficacy & mental fitness and improvisation tests

Table 2 shows significant changes in the PME measures, i.e., *overall physical awareness* measures (p = .002, r = .66), *posture* (p = .005, r = .68) *tension* (p = .011, r = .62), *movement* (p = .026, r = .50), *physical comfort composite* (p = .004, r = .60), *posture* (p = .002, r = .66), and *movement* (p = .015, r = .51). However, comfort in tension did not improve. All *musical awareness and comfort* indices showed

Table 2
PME (N = 34) & MFI (N = 26): significance tests (two tailed) & effect size, r.

PME	Wilcoxon singed rank test, Z	Sig	Matched pair rank biserial correlation, r
Physical awareness composite	**3.07**	**.002***	**.66**
Posture	**2.80**	**.005***	**.68**
Tension	**2.53**	**.011***	**.62**
Movement	**2.23**	**.026***	**.50**
Physical comfort composite	**2.88**	**.004***	**.60**
Posture	**3.05**	**.002***	**.69**
Tension	1.60	.110	.37
Movement	**2.42**	**.015***	**.51**
Musical awareness composite	**3.18**	**.001***	**.68**
Technique	**2.50**	**.013***	**.70**
Tone	**2.56**	**.011***	**.58**
Flow	**2.22**	**.027***	**.54**
Musical comfort composite	**3.29**	**.001***	**.74**
Technique	**3.12**	**.002***	**.76**
Tone	**2.82**	**.005***	**.71**
Flow	**2.77**	**.006***	**.69**
MFI			
Calm mind composite	**2.03**	**.043***	**.49**
Breathing	1.08	.280	.27
Emptying	**2.83**	**.005***	**.72**
Imagery composite	1.93	.053	.45
Favorite place	**2.42**	**.016***	**.56**
Favorite music	**2.08**	**.038***	**.54**
Mental practice composite	**2.20**	**.028***	**.51**
Stage walking	1.87	.061	.50
First phrase	**2.05**	**.040***	**.54**
Whole recital	**2.17**	**.030***	**.54**
Calm recital composite	**3.12**	**.002***	**.74**
Stage walking	**2.50**	**.012***	**.66**
First phrase	**2.04**	**.041***	**.52**
Whole recital	**2.49**	**.013***	**.62**
Recall recital composite	**2.29**	**.022***	**.53**
Stage walking	1.78	.075	.46
First phrase	1.89	.058	.48
Whole recital	**2.73**	**.006***	**.75**
Improvisation comfort composite	**3.42**	**.001***	**.78**
My own sound	**2.71**	**.007***	**.61**
Colleagues' sound	**2.86**	**.004***	**.74**
Environment	**3.13**	**.002***	**.73**
Improvisation in-the-moment composite	**2.90**	**.004***	**.72**
My own sound	**2.27**	**.023***	**.64**
Colleagues' sound	**2.70**	**.007***	**.72**
Environment	**2.75**	**.006***	**.67**
Improvisation satisfaction composite	**3.53**	**.000***	**.85**
My own sound	**3.22**	**.001***	**.88**
Colleagues' sound	**3.07**	**.002***	**.82**
Environment	**3.73**	**.000***	**.85**

Bold faces indicate statistically significant values.
* p < .05, .01, .005, 001.

significant improvements. The majority items in the mental fitness tests also indicated significant changes: Collegiate musicians changed significantly in *calm mind composite* (p = .043, r = .49), specifically, *emptying mind* (p = .005, r = .72), *imagery of their favorite place* (p = .015, r = .56), *favorite music* (p = .038, r = .54); *mental practice composite* (p = .028, r = .51), as well as in the *first phrase* (p = .040, r = .54), *whole recital* (p = .030, r = .54); *calm mental recital composite* (p = .002, r = .74), and specific *calm stage walking* (p = .012, r = .66), *first phrase* (p = .041, r = .52), *whole recital* (p = .013, r = .62); and finally the *recall recital composite* (p = .022, r = .53), and the *recall whole recital* (p = .006, r = .75). A few items showing no significant changes were *calm mind in breathing, composite imagery, mental practice walking on stage, recall recital walking on stage, and recall of the first phrase*. All of the improvisation exercises showed significant improvement. These changes in college musicians' improvisation experience were greater than expected.

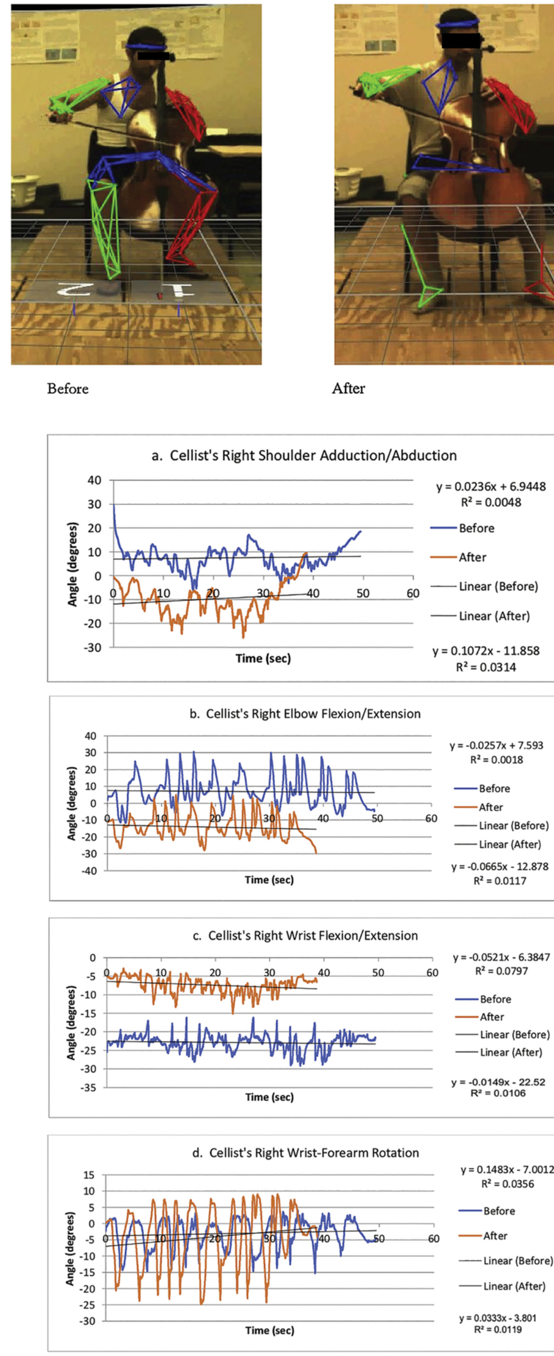

Fig. 1. Cello Player with graphs. (a) Right Shoulder Abduction/Adduction. (b) Right Elbow Flexion/Extension. (c) Right Wrist Flexion/Extension. (d) Right Wrist-Forearm Rotation.

5.4. Motion analysis results

Motion capture data of twenty-three instrumental musicians (with eleven singers' motion capture reported elsewhere) verified improvements in the smoothness of motion, range of motion, and weight balance after the intervention program. In this report, we demonstrate the nature of the improvement noted with a kinematic analysis of a cellist. In the graphs in Fig. 1, our cellist's post data showed larger motion in the right shoulder, wrist, and wrist-forearm rotation, while keeping the elbow flexion the same as before. This cellist holds (a) his bowing shoulder higher allowing more abduction/adduction, (b) keeping the elbow flexion relatively steady, (c) using much greater flexion at the wrist with (d) larger wrist-forearm rotation. The kinematics together demonstrate greater ROM, fluidity in movement, and smoother coordination of the shoulder, arm and hand.

6. Discussion

Compared to sports medicine, the history of music medicine is relatively short. Performing arts medicine researchers have greatly advanced the knowledge of the etiology and remedies for musicians' physical and mental problems since the early 1980s. However, efficient prevention of medical problems among developing, professional musicians is still in infancy.

Intervention with musicians' posture remains one of the major challenges. In one study, it was found that 54% of music students had a postural disorder [37] and further, most advanced music students tend to adopt incorrect posture whether standing or sitting while playing [38].

The term upper crossed syndrome [38], likely, one of the most studied postural deviations in the upper quarter of the body, occurs in the cervicothoracic region and inhibits neck flexors and scapular depressors and retractors with shortened and tightened trapezius, sternocleidomastoid, and pectoral muscles. This syndrome predisposes a person to a common postural abnormality of the cervical spine termed forward-head posture. Our data revealed improvement in muscular strength and flexibility in the left pectoral minor length, and strength and endurance in the deep neck flexor, but it was not enough to effect sufficient changes in overall posture and aerobic endurance. We postulate that correcting one's posture and developing overall aerobic endurance may take longer than 16 weeks to effect significant changes.

The integrative mind-body training program helped collegiate musicians to adopt more cool-down exercises and show slightly decreased pain in some locations. Neck and shoulder muscles remain the most prevalent locations for pain and injury among musicians. Our data provide evidence of decreased pain frequency in wrist, lower arm, lips, and jaw. Although statistical significance was not obtained with small number of pain reports, these changes are worth noticing in this individual-driven purposive sample. We wonder whether yoga practice may be responsible for pain relief in the shoulder, wrist, and lower arm, while forward-head posture exercise with craniovertebral angle adjustment may be responsible for reduced pain in the lip and jaw areas. These slight changes suggest the need for further research targeted to examine the relationships among the pains noted in these areas.

The changes in the individualized kinematic motion analyses supported our data with visible demonstrations of improvement. While kinematic knowledge is critical, it is difficult to make sweeping generalization because each instrument presents a unique set of body-instrument ergonomics specific to each musician. Therefore, a within-subject approach [22] provides an appropriate avenue to study musicians' ergonomics.

7. Limitations

Due to the intense individualized nature of the study, the size of the study participants is limited and the findings are not generalizable to larger population. The small number, however, allowed us to conduct intimate discussions, individual physical measurements and ergonomic-specific motion capture. A larger sample study directed for a longer period of time could support a stronger evidence for preventive nature of this program.

Mental anxiety continues to be the major issue for many performing musicians as expressed in open-ended comments at the end of the survey. It is possible that daily physical exercise, yoga practice, mental exercise, and free improvisation might have had cumulative effects on becoming freer with the mind-body expression, as a subject noted,

> *"I felt anxiety when we first started to improvise. Improvisation is not something I normally do with my voice. Once we got into it I started to feel more confident. I do daily exercise > 80% and yoga > 80%."*

As an intervention strategy, our program covered some of the key components necessary in total musical training. However, we did not explore the in-depth 'flow' state [39] that some students experienced as they became more comfortable with free improvisation. A future study could examine detailed process in mental fitness and free improvisation.

8. Conclusion

We conclude that our integrative intervention program produced significant changes in two of the five upper-body strength/flexibility/endurance measurements showing slight changes in the overall posture and aerobic endurance. The study provided positive effects on the musicians' sense of physical and musical efficacy in terms of awareness and comfort, as well as musicians' mental fitness and sense of in-the-moment experience and satisfaction in free improvisation. Motion analysis data specifically demonstrated how the changes were manifested in the individualized kinematics, which corresponds to the musicians' general positive response. We believe our instrumentalists' motion capture archive with the accumulated data over the years will give us an opportunity to analyze them and gain insights into instrument-specific physical requirements and the precise ergonomic problems to guide a future instrument-specific study.

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Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.eujim.2018.10.014.

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Sang-Hie Lee, PhD, EdD, MM is an innovative performer-researcher-teacher. As the founder of *Ars Nostra*, she promotes performances of new music by international colleagues and contemporaries. Her performances are featured in Ravello, Centaur, Albany, and Capstone Records labels. She is the author of the new book, *Scholarly Research for Musicians* (Routledge, 2017). Dr. Lee was the founding Editor of the College Music Society's *Cultural Expressions in Music Monographs Series* and currently serves on the Editorial Board of International Journal of Music Education–Research. Dr. Lee has published over 62 research articles, conference proceedings, critical reviews, and abstracts in international and national journals. A former Associate Dean of the College of Fine Arts, she now serves as Professor of Music at the University of South Florida. Her research interests are musicians' health and performance training, pianists' hand biomechanics, neuroscience in music performance, and music faculty vitality in academic organization.

Stephanie L. Carey, Ph.D is an Assistant Research Professor at the University of South Florida, Department of Mechanical Engineering. She is the research coordinator for USF's Center for Assistive, Rehabilitation and Robotics Technologies (CARRT). She has developed an Introduction to Bioastronautics course and a Rehabilitation Engineering course. She has worked at the University of Miami's Center of Excellence, The Miami Project to Cure Paralysis and for Peak Performance Technologies, now Vicon Motion Systems. She is also a researcher at the Center of Innovation on Disability and Rehabilitation Research at the Tampa VA. She earned a B.S. in Engineering Science from the University of Florida, and a M.S. in Biomedical Engineering from the University of Miami and a Ph.D. in Biomedical Engineering from the University of South Florida (USF).

Matthew Lazinski, PT, DPT, OCS has been a practicing physical therapist since 2000 after receiving a Masters Degree in Physical Therapy from Washington University in St. Louis, and received his DPT from Regis University in 2008. Dr. Lazinski was board certified in orthopedic physical therapy in 2006 and is currently Associate Clinical Professor at University of South Florida. Clinical research interests include physical performance function testing for activities of daily living, music training injury prevention and stroke gait rehabilitation.

Eun Sook Kim, PhD is an Associate Professor of Educational and Psychological Studies in University of South Florida. As a quantitative methodologist, her goals are to investigate methodological issues prevalent in the social science research, and to provide practical guidelines to the research community. To achieve these goals, she has conducted Monte Carlo simulation studies, systematic reviews of the application of statistical methods, and applied research studies. She is interested in the behaviors of innovative statistical methods particularly structural equation modeling, multilevel modeling, factor mixture modeling, and measurement invariance testing under various research settings and has been involved in research on propensity score analysis, multilevel CFA, Bayesian estimation, and robust ANOVA.