The Effect of Pilates on Deep Abdominal Recruitment in Circus Artists

ST7P35 – SPORTS THERAPY AND EXERCISE SCIENCE DISSERTATION

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ABSTRACT

The topic of this study is the effect of Pilates on deep abdominal recruitment for circus artists, namely, aerialists and acrobats. Aerialists and acrobats place a significant demand on their bodies and are subject to considerable injury as a results of this. Furthermore, their high performance capacity makes studying them in a rehabilitative and “prehabilitative” setting, such as Pilates, to not only prevent injury, but also to elevate skill levels interesting. No studies incorporating Pilates and this population have been recorded so far, providing the perfect gap for this research topic.

The aim of this study was to research the effect of 5 weeks of Pilates sessions on the deep abdominal engagement of circus artists during inverted movements on aerial silks. A Pilates approach specific to co-contracting the pelvic floor and deep abdominals in various iterations of the inverted spine was investigated.

8 participants were recruited in person during training sessions at the National Center for Circus Arts as well as following workshops that the researcher taught at in Brighton earlier this year.

Prior to commencing Pilates sessions, objective data via EMG was collected with the electrodes placed in between the ASIS (hip crests) to record the recruitment of TrA from the following 5 orientations of the body and spine in space (for an image of the shapes see page 20): Inversion, Inverted Spinal Flexion, Inverted Spinal Extension, and Inverted Spinal Lateral Flexion to both directions.

With the electrodes placed on TrA, participants held each shape for 10 seconds each with 20 second breaks in between. The shapes were assigned in a randomized order. EMG measurements were taken with this method on week 1, week 3 and week 5, following Pilates sessions.

Statistical tests were run to assess the data including the Sphericity Test, The Shapiro-Wilk Test, Friedman's Test, a Parametric ANOVA Test and Bonferroni Post Hoc Test.

The results revealed a statistically significant effect of Pilates on inverted left lateral flexion of the spine over the course of a 5 week program (p value = .03, measured next to an alpha value of .05). While there was an effect, no statistically significant difference was uncovered after performing the Bonferroni Post Hoc Test.. The Friedman Tests revealed no statistically significant differences among the other dependent variables in the study.

As the first study to research this topic around this population, a longer study with a larger sample of participants is warranted to determine longer term results and impact of Pilates on deep abdominal engagement for circus athletes, who spend the majority of their training in inverted positions.

Key words: inner core unit, deep abdominals, transversus abdominis, pelvic floor circus artists, acrobats, aerialists, Pilates

INTRODUCTION

The population of study for this research are circus artists, specifically aerialists and acrobats, both of which spend a significant amount of time training upside down. The acrobats spent most of their time training skills that relate to pushing into the floor and partner work to upkeep their performance and training goals, while the aerialists spent most of their time training skills that related to pulling and hanging on apparatuses such as silks, rope, straps, and hoop. The deep abdominal strength that is necessary in order to train and perform within the circus artist population is significant, thus justifying the conduction of this study on the effect of Pilates on the deep abdominal recruitment of circus artists.

Pilates is a form of exercise that has been used for decades as a method for rehabilitation as well as preventing injury in multiple different athletes, especially dance populations. Pilates has historically helped prevent injuries by stabilizing and mobilizing the various joints of the body that are subject to injury during sport and day to day activities. It also has demonstrated a great ability to help rehabilitate existing injuries, especially low back pain, due to its emphasis in building deep abdominal strength as well as hip stability (Anderson & Spector 2005). In dancer populations specifically, a regular Pilates practice has been shown to elevate performance, flexibility and strength during traditional movements of arabesque, developpé and cambré (Amorim et al., 2011).

In this study, the Pilates sessions had a targeted goal of improving deep abdominal strength through the foundations of Pilates breathing, neutral spine, and engaging deep abdominals in a variety of positions of the spine such as spinal extension, flexion, and lateral flexion. The recruitment of the inner core unit in these sessions was emphasized through detailed breath education sessions, to teach the foundations of Pilates breathing. The inner core unit includes the pelvic floor, transversus abdominis, multifidi and diaphragm (Ward, 2022)

In tandem with the Pilates sessions, the orientations of the spine studied on the aerial silks were inversions, inversions with spinal flexion, inversions with spinal extension, and inversions with lateral flexion both to the right and to the left (see page 20 for images).

LITERATURE REVIEW

Theoretical Issues

The occurrence of athletes who demonstrate strength within their global core (larger trunk stabilizers such as rectus abdominis and erector spine) and weakness in their deep core, or inner core unit is significant and occurs regularly (Culleton-Quinn et al., 2022). The priority to strengthen the core globally rather than deeply is the standard of sport teams both at Olympic as well as recreational levels. Research has shown that as a result of the physical demands and goals of sports such running for example, additional strain is targeted at low back tissue when the deep abdominals are under recruited in comparison to global strength from muscles such as the erector spinae and rectus abdominis (Raabe & Chaudhari 2018). Neglecting the deep abdominals also neglects the inner core unit, which is comprised of the pelvic floor, the transversus abdominis, the multifidi, and the diaphragm (Ward, 2022).

Deep abdominal control is essential in inversion activities because the center of gravity in circus athletes is shifted to an upside down orientation, placing significant emphasis on maintaining full body balance, coordination, and control. This control stabilizes the core and helps ensure proper body alignment during complex maneuvers that can range significantly. Without strong abdominal engagement, athletes may struggle to achieve the necessary stability, increasing the risk of injury and compromising performance (Raabe & Chaudhari 2018). Additionally, as Rabe and Chaudhari (2018)

found in their research studying deep abdominal activation in runners, deep core activation supports the spine of an athlete, reducing strain on the lower back and promoting efficient movement patterns. This research can be directly tied to supporting a circus artist in transitions into and out of inverted positions.

The lack of research that has been done on circus artists in relation to strengthening deep abdominals is apparent, creating a great opportunity to study this group of athletes in depth. On PubMed, only one article appears when searching for circus artists and abdominal strength by Greenspan and Stuckney in 2023. This research analyzed abdominals by measuring the global strength of the lower abdominals through manual muscle testing (MMT). Manual muscle testing for the abdominals is a method of collecting data on muscle strength that occurs by asking the participant, lying supine to defy gravity by lifting his/her shoulder blades off the floor for a sustained period of seconds (Greenspan & Stuckney 2023). This MMT method of measuring muscle contraction completely neglects measuring deep abdominal strength, with its primary emphasis on measuring the strength of rectus abdominis, thus providing further reason for this study on deep abdominal recruitment to take place.

Furthermore, for the population of circus artists, no other investigations have been done to measure deep abdominal recruitment via Electromyography (EMG) studies. EMG studies are known to have the ability to identify recruitment of deeper muscles (McGill et al., 1996). Electromyography is specific in that it measures the electrical response of a skeletal muscular nerve in response to change or stimulus (Roberts & Gabaldon 2008). There are no recorded studies of EMG measuring the response of deep abdominal

muscular tissue in response to inverted activities, thus further justifying the case for this research.

Previous EMG studies on deep abdominal stability on populations outside of circus artists have revealed that the transversus abdominis, as well as the internal oblique increase in engagement when the pelvis is in an unstable environment (Kang & Kim 2014). An unstable environment in these instances consisted of the healthy population of athletes executing upper arm exercises, such as arm abduction with resistance bands, on a Swiss ball rather than a firm surface (Lee et al., 2012).

Kang and Kim's (2014) EMG findings on TrA and internal oblique activity increasing after destabilizing the pelvises of their research participants pointed to good reason to study circus artists in inverted positions of the spine, as a pilot study for collecting information on what will occur in the deep abdominals when athletes are in a sustained, somewhat destabilized lumbopelvic position.

Consideration of this study:

A large emphasis of this study is coupled with research pointing to a specific method of breathing and its relation to pelvic floor recruitment, which has the ability to change deep abdominal recruitment. Using foundational Pilates breathing techniques, softening and lifting the pelvic floor overtime, through a co-contraction of TrV and pelvic floor on the exhale, has the ability to change deep abdominal recruitment volitionally, but also

non volitionally in every day activities (An et al., 2024). In light of this research, the teaching strategies for this dissertation encompassed breath education as a foundation to each Pilates session.

Furthermore, research by Dinez 2014 explains that Type 1 fibers of the pelvic floor are responsible for “antigravity” actions. Since Type 1 fibers are endurance fibers, a program based on developing the recruitment of Type 1 pelvic floor muscle recruitment through strengthening the deep stabilizers using Pilates breath integration was deemed as appropriate. (Dinez, 2014) The “antigravity” aspects of this study included the repetitive inversion variations on the aerial silks required of the participants during the data collections.

Justifications for this study:

Again, the lack of research that has been done on the circus population is evident, creating a great opportunity to study this group of athletes in depth. Overall, the researcher was interested in understanding how much a Pilates practice can impact the longevity of circus artists, both from an injury prevention perspective as well as a performance elevation perspective. Specifically, Pilates and its relation to injury prevention for low back pain and pelvic girdle pain was considered as a reason to justify this study. Since it has been proven that deep abdominal core engagement is correlated with less low back pain and a decrease in injury (Lynders, 2019), Pilates exercises assigned during this study were designed to optimize these areas of concern.

While a significant amount of research exists to support Pilates and how much it can help with lumbopelvic stability, (Phrompaet et al., 2011) and its effect on alleviating pelvic girdle pain and low back pain (Stolze et al., 2012) in general populations, no research exists to test Pilates and its effect on circus artists. Similarly, little to no research has been done to show Pilates and its impact on circus and aerial performance.

Thus far, studies that exist to examine the circus artist population have investigated general risk factors for injury, as well as a broad look at overall strength levels (Greenspan & Stuckley 2023). While this research provides a baseline of knowledge for what to expect in the realm of the overall strength of aerialists and acrobats, it does not include measurable outcomes for deep abdominal tissues, nor does it include Pilates as a form of exercise and stability. This provides a significant gap for this research.

Studying the participants for 5 weeks for this project provided preliminary information of understanding what kind of impact Pilates has the potential to create on their inverted movement practice over a period of time that exceeds 5 weeks. Research by Moro et al (2020) shows that four to six weeks is the minimum period of time that is recommended to study changes and development in muscle recruitment, making the 5 week time frame an appropriate minimal window of time. To back this theory, transversus abdominis research on participants with and without low back pain by Selkow et al (2017) found that TrA recruitment increased significantly by all participants after a 4 week deep abdominal intervention.

Aims and hypotheses

Aims

The aim of this study was to research the effect of 5 weeks of Pilates sessions on the deep abdominal engagement of circus artists during inverted movements on aerial silks. A Pilates approach specific to recruiting the inner core unit in various iterations of the spine was investigated. Again, the inner core unit comprises the diaphragm, the pelvic floor, transverses abdominis, and the multifidi (Ward, 2022). Through teaching these participants an approach to Pilates that was very specific to activating these structures effectively over the course of 5 weeks, the aim was to increase deep abdominal control while moving through an inversion and spinal flexion, spinal extension and spinal lateral flexion, all from an inverted position.

These variations of the spine were selected in order to understand how TrA responds to variations of antigravity inversions on the aerial silks. While it is a challenge to capture the dynamic capabilities of these athletes, studying their abdominal response to inverted sustained movements was captured during the study.

A main objective was for the co-contraction of pelvic floor and TrA to increase and be optimized throughout the 5 weeks of focused Pilates sessions. Specifically, during an inversion, when the spine deviated into either spinal extension, flexion or lateral flexion, the expectation was for the body to rely more on either the deep abdominal stabilizers, or the global stabilizers, the later of which can overload the lumbar spine and surrounding structures. Through the various Pilates foundations and sessions over 5

weeks, the aim was for the participants to optimize deep abdominal engagement by not overlying on global stabilizers or the lumbar spine while moving from shape to shape upside down. The longer term goal of this study was to promote the longevity of circus artists through Pilates sessions that are designed to prevent injury and elevate training and performance.

Hypotheses

H_1: Following 5 weeks of Pilates sessions, deep abdominal transverses abdominis recruitment will increase during a held inversion in the aerial silks.

H_{10}: Following 5 weeks of Pilates sessions, there will be no change to deep abdominal transverses abdominis recruitment during held shapes in the aerial silks

H_2: Following 5 weeks of Pilates sessions, deep abdominal transverses abdominis recruitment will increase during inverted spinal extension in the aerial silks.

H_{20}: Following 5 weeks of Pilates sessions, there will be no change to recruitment of deep abdominal transverses abdominis during inverted spinal extension in the aerial silks.

H_3: Following 5 weeks of Pilates sessions, deep abdominal transverses abdominis recruitment will increase during both variations of inverted lateral flexion of the spine in the aerial silks.

H_{30}: Following 5 weeks of Pilates sessions, there will be no change to recruitment of deep abdominal transverses abdominis during both variations of inverted lateral flexion of the spine in the aerial silks.

H_4: Following 5 weeks of Pilates sessions, deep abdominal transverses abdominis recruitment will increase during inverted spinal compression in the air.

H_{40}: Following 5 weeks of Pilates sessions, there will be no change to recruitment of deep abdominal transverses abdominis during during inverted spinal compression in the air.

METHODOLOGY

Participants

8 participants were recruited in person during training sessions at the National Center for Circus Arts in London as well as following workshops that the researcher taught at in Brighton earlier this year. While 8 expressed interest in participating in the study and actively engaging in all parts of it, only 7 ended up completing the Pilates homework (recorded via Weekly Google Polls), and therefore, only their data has been recorded.

The participants included a mix of professionals and recreational circus artists who have all been doing aerial and acrobatics for a minimum of 2 years. They trained a minimum of 3 hours and a maximum of 10 hours collectively per week to upkeep their abilities. All of them were healthy and free from existing injuries.

Informed consent was collected prior to beginning by each participant via a Participation Agreement form which outlined the expectations of the study. Ethical approval was also attained via London Metropolitan University's advisors prior to the study commencing as well to assure standards were met appropriately to maximize on safety.

Study Design

Materials

To conduct this study, the following materials were acquired based on prior research collected on deep abdominal recruitment of the transverses abdominis.

Electromygraphy Machine (EMG): An EMG machine was used to collect data on deep abdominal recruitment of transverses abdominis. Nu- Tek EMG biofeedback was purchased after consultation with pelvic health physiotherapists to ensure that the best possible data was collected (Win Health Medical Ltd, n.d.). Multiple studies have shown the effectiveness of using EMG to measure deep abdominal recruitment of TrA coupled by pelvic floor recruitment, thus justifying the method of this study, including research by Tahan et al in 2013.

The following Pilates props were given to each participant to allow them to complete their Pilates sessions:

- medium sized soft ball, inflated at 75%
- medium density theraband
- 1.5 kilo weighted ball

Other equipment included:

- Google Sheets on a computer
- iPhone - timer
- Crash mat
- Aerial Silk

- 7 electrode pads
- Alcohol Swabs

Procedure

While this study is the first of its kind as far as studying this population with an EMG machine, the researcher chose to follow the EMG placement guidelines of King and Kim (2014) who placed the EMG electrode pads about 1 cm inward from the hip crests to measure deep abdominal recruitment while the pelvis was in an unsteady environment (in this case on a Swiss ball). Guidelines were created for the participants to place the electrodes as low as possible underneath the hip crests in order to avoid overlapping with oblique muscle fibers.

Prior to getting started with the Pilates sessions, objective data via EMG was collected with these electrode placements to record the recruitment of TrA from the following 5 orientations of the body and spine in space.

- Inverted (1 shape - Square 1 in image below)
- Inverted Spinal Compression and Hip Flexion (1 shape- Square 2 in image below)
- Inverted Spinal Extension (1 shape - Square 3 in image below)
- Inverted Spinal Lateral Flexion to both directions (2 shapes- Left lateral flexion shown in Square 4 in image below)

Participants were asked to execute spinal inversion extension, flexion, and lateral flexion (left and right) of the spine, all from an upside down, or inverted, orientation on

the aerial silks. They were asked to hold each shape for 10 seconds each to measure longevity of deep abdominal engagement to be as close as possible to mimicking the endurance that might be expected of them during training and performance. They were asked to perform each shape three times. The measurement at second number 5 was recorded, and an average reading was used in the data analysis. Each participant was given a rest periods of 20 seconds in between each take to allow the abdominals to relax before contracting again. This 20 second resting period was determined upon researching that rest periods of 20 seconds to 1 minute resulted in “higher repetition velocities during repeated sub-maximal muscle actions” (De Salles, 2009). Since this was a repeated activity of using the same muscles, 20 seconds was an appropriate amount of time to rest.

During week 3, following this original data collection, after Pilates training commenced, TrA was measured using the same EMG methodology to research the same orientations of the body and spine. The final data collection utilizing the EMG machine occurred during the last week of the study, on Sunday number 6, after 5 weeks of Pilates training.

Pilates session training included weekly sessions with the researcher streamed either virtually and offered in person. Pilates homework requirements involved the participants doing 3 solo Pilates sessions each week focused on the material covered from the in person class each Sunday. To keep participants accountable for their homework, weekly Google Form Polls were sent out each week to ask if they had completed their homework, as well as to take an account of other training and physical involvements throughout each week (ie how much time they spent teaching, and how much time they spent strength training).

Data Analysis

Data was analyzed using the Jamovi Software. The alpha value used in this study was .05. Data collected that was below this number was considered statistically effective or significant. Data collected above this number was considered statistically insignificant.

The independent variable in this study was time, and measurements were taken at weeks 1, 3, and 5. The dependent variables were the mean of the TrA contractions measured during 5 inverted aerial shapes or exercises:

- Mean of Inversion
- Mean of Inverted Spinal Flexion
- Mean of Inverted Spinal Extension
- Mean of Inverted Spinal Flexion to the right
- Mean of Inverted Spinal Flexion to the left

The mean was the chosen measurement to take to match previous TrA research recorded by Arora and Phadke (2021) as an appropriate measure for TrA activation. Additionally, the modes of the data were not always consistent or present amongst all participants during data collection.

Before proceeding to analyze the data, information was gathered to determine whether or not parametric assumptions were met. Study design met the first two assumptions

because, the interval ratios of mV output pointed to the data being continuous, and the repeated measure of design (data taken at 3 time intervals), satisfied two parametric data requirements. To determine normality and to assess the presence of outliers, the Shapiro-Wilk Test was run. “Box plots” and “Outliers” were checked to access normality and outliers. The Sphericity Test fulfilled the fourth assumption and revealed no widespread differences between the five dependent variables ($p>.05$).

When running the Shapiro-Wilk test, the outliers displayed in the box plots (in appendix pages 47-49) indicated that the following sets of data strayed from normality:

- Mean of raw spinal flexion
- Mean of right flexion
- Mean of week 3 inversion

The Shapiro-Wilk test also found that the "mean of extension” and “mean value of week 3 inversion” violated normality, as two of their p-values had a value of less than .05.

After analysis of the data, it was determined that 4 out of the 5 following variables did not pass the parametric assumptions. This therefore, made it so the data related to any of the relevant dependent variables was subject to a Friedman’s Test instead, a nonparametric ANOVA test.

- Mean of raw extension

- Mean of week 3 inversion
- Mean of raw flexion
- Mean of right flexion

The Friedman test was used for 4 out of the 5 tests run for all data related to extension, inversion, flexion and right flexion. The only dependent variable where a parametric ANOVA test was run was with the “mean value of inverted left flexion.” This is because all parametric assumptions were met in this variable. Following the parametric ANOVA test on inverted left lateral flexion, a Bonferroni Post Hoc Test was conducted to see if a statistically significant difference could be identified within the three points of time measured.

RESULTS

Table 1 displays the results of the Friedman Test that was performed on the dependent variables of the study that were determined to be nonparametric. X^2, df and the p-value were notated to capture the relationship between time, an increase in Pilates sessions and differing variations of the spine while holding an inverted shape. No statistically significant difference was present between these variables, as the p-values were greater than the alpha value of .05.

Table 1: Results for Friedman Test Performed on Nonparametric Data Sets

	X^2	df	p-values
Inversion	1.33	2	0.513
Inverted Spinal Flexion	0.609	2	0.738
Inverted Spinal Extension	3.74	2	0.154
Inverted Lateral Flexion to the Right	4.33	2	0.115

Table 2 represents the results from the ANOVA test performed on the Inverted Spinal Lateral Flexion to the Left. The p-value below the alpha value of .05 signifies that the Pilates sessions had a statistically significant effect on deep abdominal recruitment while the participants performed “Inverted Lateral Spinal Flexion to the Left.” The f-value in Table 2 determines the variability of the means between the three measurements taken. The f-value is well above 1, thus supporting rejection of the null hypothesis, which claims for no relation between Pilates sessions and deep abdominal engagement

in aerialists overtime. F-values that are closer to 1 support the null, while f-values that are well over 1 support the original hypothesis, as this amount of variation between measurements is more than what chance should be able to account for. Similarly, the mean square in *Table 2* presents a high average of 1812, further supporting rejection of the null, because it reports that there is a high variability between mean measurements taken throughout the study between the time intervals, Weeks 1, 3, and 5. Lastly the sum of squares, being at 3,624 indicates a high variation between data points, further supporting rejection of the null.

Table 3 details results from the Bonferroni Post Hoc test completed after the ANOVA test for this set of data. Time increments measuring differences between data between weeks 1-3, 3-5 and 1-5 were assessed. All p-values were greater than the alpha value of .05, which reveals that no statistically significant difference within the timeframe of the study was identified.

Table 2: Results for ANOVA Test Performed on Parametric Set of Data

	p-value	F- value	Mean square	Sum of Squares
Inverted Spinal Lateral Flexion to the Left	0.03	4.86	1812	3624

Table 3: Results of Post-Hoc Bonferroni Test Performed on Parametric Set of Data

Time	Weeks 1-3	Weeks 3-5	Weeks 1-5
Inverted Spinal Lateral Flexion to the Left p-values	0.26	0.124	1.0

Figure 1 represents the mean deep abdominal engagement of the group as a whole over the course of the 5 week Pilates program. While “inversion” increased from ~ 20 mV to ~39 microvolts (mV), Inverted Spinal Flexion stayed relatively the same, with data that ranged from ~46 mV to ~49 mV. “Inverted Spinal Extension” experienced an increase from ~56 mV to ~89 mV.

Lastly “Inverted Right Lateral Spinal Flexion” and “Inverted Left Lateral Spinal Flexion” changed from ~56 mV to ~89 mV and ~53 mV to ~103 mV respectively.

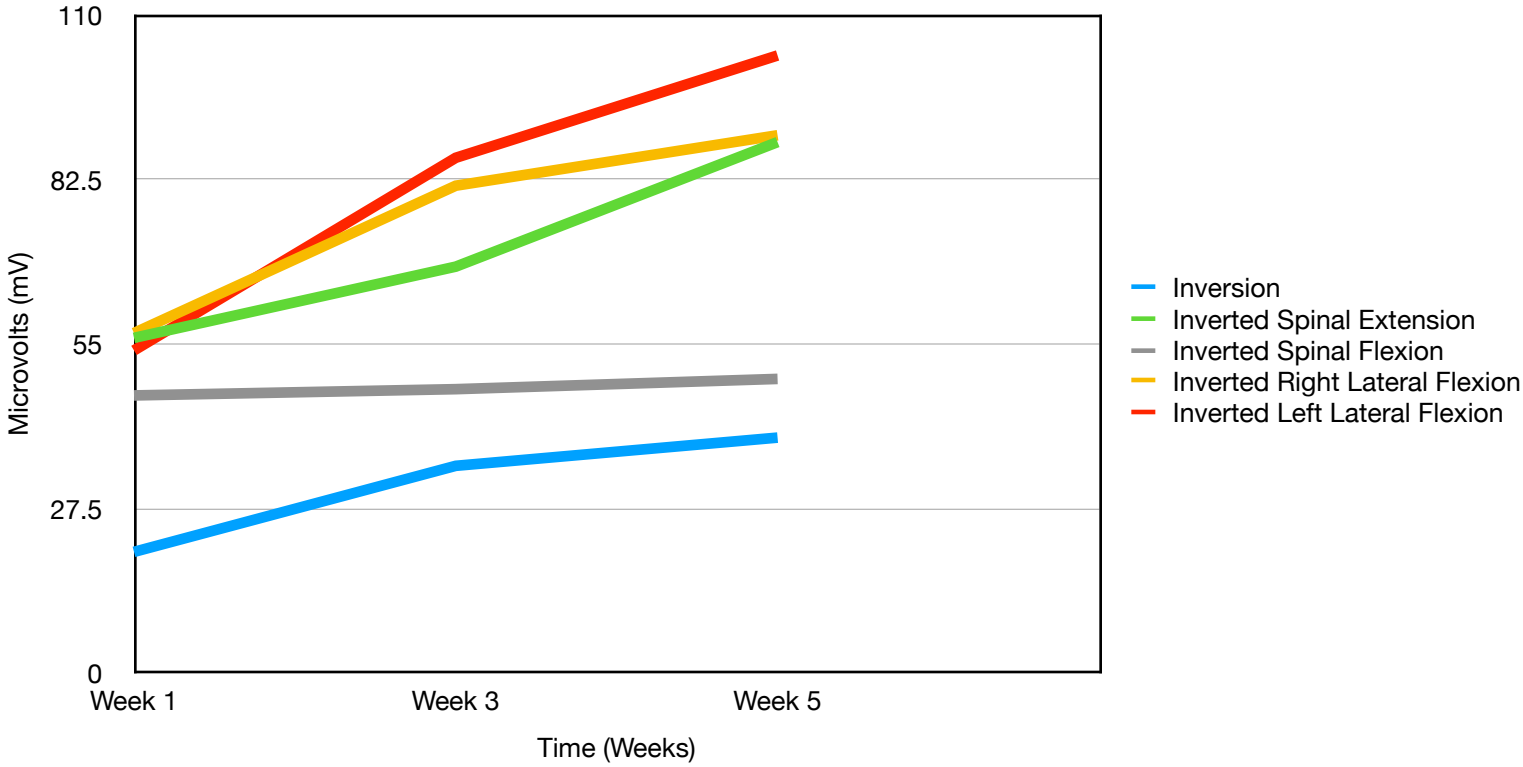

Figure 1: Mean of Group Average Deep Abdominal Engagement Over 5 Weeks

DISCUSSION

The following four hypotheses reference the 5 variations of the spine that were studied with this group of participants on the aerial silks.

Hypotheses

H_1: Following 5 weeks of Pilates sessions, deep abdominal transverses abdominis recruitment will increase during a held inversion in the aerial silks

H_{10}: Following 5 weeks of Pilates sessions,, there will be no change to deep abdominal transverses abdominis recruitment during a held inversion in aerial silks.

While a very slight increase of deep abdominal engagement occurred in this study, not enough to be considered a statistically significant increase, and thus the null hypothesis has been accepted.

To further explain, the researcher viewed the straight “inversion” during the study, as the “neutral” spine of the project, where the natural curvature of the spine was encouraged to take shape in an upside down position. To teach neutral spine from a supine position during Pilates sessions and Pilates self lead homework, the group learned how to execute movement while maintaining a neutral curve under their lumbar spine without compromising their “rib to pelvic” connection, and falling into an excessive anterior tilt of

the pelvis subsequently. It is in this position that the foundations of Pilates breathing and deep abdominal engagement was taught.

Furthermore, based on the fact that much of the weight distribution of an aerialist or acrobat during an inverted, “neutral” spine is in his or her upper body, with the pelvis stacked neutrally on top of the shoulder girdle, it would make sense for less recruitment to be required of the deep abdominals. Not much spinal deviation away from neutral is occurring from this position, so an increase in deep abdominal recruitment is not necessary (see square 1 on page 20 to see “neutral spine” held during an inversion).

H_2: Following 5 weeks of Pilates sessions, deep abdominal transverses abdominis recruitment will increase during inverted spinal extension in aerial silks

H_{20}: Following 5 weeks of Pilates sessions, there will be no change to recruitment of deep abdominal transverses abdominis during inverted spinal extension in aerial silks.

While a slight increase of deep abdominal engagement occurred during spinal extension with Pilates during this study, it was not enough to be considered statistically significant, thus the null hypothesis has been accepted.

The researcher believes this to be as a result of the small sample size. As discussed in detail earlier, Pilates that emphasizes the inner core unit, includes the multifidi, and the mutlifidi ignite during spinal extension especially to stabilize the back, in combination

with TrA (Ward, 2022). As a result of this in a larger sample size, over a longer period of time, the researcher believes these results would show a statistically significant increase of TrV engagement, along with multifidi recruitment.

The Pilates sessions and self led homework sessions included elements of finding spinal extension to the mid range of most of the participants' capabilities in a few different exercises, such as a contemporary variation of the quadruped exercise, "bird dog," as well as a traditional variation of prone Pilates swimming, with an emphasis on breath control. The nontraditional "bird dog" Pilates exercise was taught with the aim at allowing the participants to approach their mid range of motion towards spinal extension with a controlled approach that led them back to neutral spine each time.

H_3: Following 5 weeks of Pilates sessions, deep abdominal transverses abdominis recruitment will increase during both variations of inverted lateral flexion of the spine.

H_{30}: Following 5 weeks of Pilates sessions, there will be no change to recruitment of deep abdominal transverses abdominis during both variations of inverted lateral flexion of the spine.

The ANOVA test revealed a statistically significant ($p=.03$) effect on deep abdominal recruitment over the 5 week study when the participants were executing "inverted lateral flexion to the left." However, the Bonferroni Post Hoc test performed afterwards revealed that there was no statistically significant difference within the time frame of the

study, Weeks 1-5. These results are likely due to the small sample size of only 7 participants. The results also have the potential to relate to the Bonferroni Post Hoc test's reputation for being conservative. The Bonferroni Post Hoc test is termed "conservative" because it reduces the risk of error by lowering the alpha value for individual comparisons. This would require the p-value to be much smaller to achieve significance (Kenton 2021).

While there was an increase in deep abdominal recruitment over the 5 week study when the participants were executing "inverted lateral flexion to the right," it was not a statistically significant difference.

Due to the objective findings of the Bonferroni Post Hoc and Friedman tests performed, the null for this hypothesis was accepted as well.

To give further context into this study, originally, the researcher planned to measure the oblique abdominal engagement progressions with Pilates sessions as well in this population. Due to time constraints, that was not possible. In response to this, the researcher collected the same data on TrA that would have been collected on the obliques and led the Pilates sessions and assigned Pilates homework to capture actions such as deep abdominal twisting and lateral flexion. Exercises such as "roll back with oblique twist" and "side lying lat pull downs" with a 1.5 kilo weighted ball were assigned to the participants to fire the inner core unit in concert with the obliques.

H_4: As Pilates sessions increase, deep abdominal transverses abdominis recruitment will increase during inverted spinal compression in the air.

H_{40}: As Pilates sessions increase, there will be no change to recruitment of deep abdominal transverses abdominis during during inverted spinal compression in the air.

Over the course of this study, there was little to no increase of deep abdominal recruitment during “inverted spinal compression,” and the null has therefore been accepted.

During the Pilates sessions, there was little emphasis on spinal compression with the exercises assigned, so the researcher attributes a plateau in deep abdominal engagement during spinal compression upside down to this factor. The researcher’s focus was on fine tuning deep core strength with the other shapes of the spine upside down.

Explanation of Results

Overall, the only dependent variable to deliver statistically effective results was “inverted lateral flexion to the left.” None of the defendant variables, however, delivered a statistically significant difference in their results, due to the findings of the Bonferroni Post Hoc Test. The researcher believes that if the sample size had been much larger (double to triple), and if the study timeline had gone on for much longer (up to a few months), then statistically significant results would have occurred in each of the areas. If

more Pilates exercises had emphasized flexion and spinal compression, then the results related to spinal flexion would have probably shown more of an exponential increase.

Interpretation of Results

The pelvis being in an unstable environment is an indication that the deep abdominals will be recruited more. Kang and Kim (2014)'s research showing how TrA and internal oblique switched on more with the pelvis performing arm exercises on an unstable Swiss ball is proof of this.

Due to the fact that the Pilates sessions had a huge emphasis on not only deep abdominal engagement, but also pelvic floor co-contraction, as a result of the Pilates breathing foundations that were taught, it is logical that Pilates impacted some shapes of the spine more than others. While spinal inversion for example maintained low deep abdominal engagement numbers, right and left inverted lateral flexion, displayed increases in low deep abdominal engagement numbers. It would make sense for the deep abdominals to not have to engage as much because the pelvis is stacking naturally over the the shoulders rather than extending back or flexing forward (placing extra load on the spine). Likewise, it is sensible for the deep abdominals to engage more during inverted lateral flexion from side to side, as moving the spine away from the midline creates an unstable position for the pelvis, therefore causing an increase in deep abdominal engagement.

Practical Implications

The statistically significant effect over the course of 5 weeks of Pilates on deep abdominal engagement during “inverted spinal flexion to the left,” and the non statistically significant increase of deep abdominal engagement in “inverted spinal flexion to the right” as well as “inverted extension” has led the researcher to believe that if the sample size had been larger and if the study had been longer, than more of the results would have been identified as statistically significant.

Regardless, the data collected during this study despite whether or not it is significant from a statistical objective perspective is still meaningful because their deep abdominal engagement did increase, as is reflected in Figure 1. This increase happened, specifically during movements that are seen as challenging for the lumbar spine to handle if the deep abdominals are poorly engaged.

Methodological Limitations

Discussed below include a few methodical limitations to this study. If improved, a change in the data output could occur.

Type of Athlete

The aerialists and acrobats in this group were a niche of movers, but still utilized very different muscle groups on a regular basis. Specifically, while the acrobats utilized more push muscles, the aerialists targeted more of their pull muscles on

a regular basis. This difference in muscle strength training could have some sort of an impact on their deep abdominal engagements. Acrobats might have shortened, tighter abdominals due to their relationship to the floor being dependent on them holding a static shape for long period of time. Aerialists could possibly have more lengthened abdominals due to the hanging mechanism not requiring as much of an isometric hold but more so reliant on responding to moving around a suspended apparatus. It would be worthwhile to study these groups separately in future studies to see if a difference occurs in deep abdominal engagement.

Variations in Weekly Time Allocations for Training

The study participants spent a large variety of time teaching practices such as aerial silks, aerial straps, rope, and yoga throughout each week. They also spent varying amounts of time strength training in other disciplines like yoga, as well as with weights in a gym setting. Their weekly check in forms indicated that depending on the demands of each week, they would spend anywhere from 2-15 hours training in their acrobatic and aerial disciplines, and 0 - 8 hours strength training. The only true constant additional external stimulus to their training for each of them was the 30 minutes of required solo Pilates sessions in addition to their 45 minute Pilates class with the researcher on Sunday afternoons.

Slight Variations in Aerial Shape

While specific guidelines, and specific demonstrations were given on exactly what shapes to perform and hold for a period of 10 seconds, there were subtle variations that the researcher noticed each participant make during the study. For example, during lateral flexion, some participants performed a slight “pike,” or flexed position at the hips, while others remained more lengthened. And during spinal extension, some participants had more mobility in their mid to upper back than others, creating more emphasis on the low back musculature to support and engage the spine.

If the researcher had implemented the use of goniometer, it would have been a more specific shape for each person, to ensure slightly more consistency. If this research were to be repeated, this is something that would be part of the plan to implement.

Specifically, the researcher would have used the following anatomical landmarks for each variation of the spine. These approximate measurements have been put forth to help guide future researchers with estimations that have been targeted as possible for most aerialists and acrobats, whether they be professionals or recreational circus artists.

- Inversion: The bottom angle of the goniometer would be placed to align the earlobe, glenohumeral joint, and greater trochanter, and the top angle would align the lateral malleoli.

- Inverted Extension: The top angle of the goniometer would be placed to align 20-30 degrees of posterior extension, with the lateral malleoli as a point of reference. The bottom angle of the goniometer would be placed to align about 10-15 degrees of upper back extension, with the glenohumeral joint as the point of reference. The mid point for the goniometer would be the greater trochanter.
- Inverted Compression: The top angle of the goniometer would be placed to align the glenohumeral joint and lateral malleoli towards anterior compression of the body to about 30 degrees of flexion. The mid point for the goniometer would be the greater trochanter.
- Inverted Lateral Flexion: The top angle of the goniometer would be placed to align the glenohumeral joint and the bottom to align the lateral malleoli to about 50 - 60 degrees of lateral flexion. The mid point for the goniometer would be the greater trochanter. This would be the procedure for both left and right lateral flexion. The mid point for the goniometer would be the greater trochanter.

Capturing the best quality data

The researcher worked within the financial means provided during this project. While it was possible for the university to provide the EMG machine, the accompanying software for the EMG that would have made collecting the data more specific was out of budget. Therefore, the researcher collected the data in real time by recording the number that appeared on the EMG on the fifth second during a 10 second hold. This method, inevitably came with its own set of potential skew in accuracy. To account for gathering the most realistic “mean” possible, each participant repeated each shape 3 times and the mean average of those shapes was taken to record that shape’s respective measurement.

During the data collection periods, the participants were varying levels of “warmed up” prior to taking their measurements. This was not a factor that was controlled during the data collection window and could have impacted their deep abdominal engagement. For example, while some of the participants rested before their data was collected, others spent time training on aerial apparatuses (the aerialists) and doing multiple handstands (the acrobats). Now that the researcher has a firmer grasp on time management for the collection of the measurements, if another study occurs in the future, more specific guidelines would be put around the activities that are permitted for the participants to do before the data is collected. For example, participants would be required to rest for 10-15 minutes before each data collection to ensure the abdominals are in a more neutral and relaxed state.

CONCLUSION

Lack of study surrounding aerialists and acrobats and effective deep abdominal warm up practices serves as a significant issue for this population. While aerialists and acrobats do not take up a massive sector of the athletic population, their exercise rehabilitation should still be prioritized like similar sport categories such as dance, gymnastics and diving.

There was a statistically significant effect of Pilates over a 5 week time span on the participant's overall deep abdominal engagement during inverted left lateral flexion. While this "effect" was not deemed "significantly different," the double in deep abdominal output by the end of the study leads the researcher to believe that far more investigation should be done, with both a greater time span, as well as a larger sample size of participants in order to dig deeper and contribute to the field of effective deep abdominal warm up practices and performance elevation. The rest of the objective data collected between deep abdominal engagement and Pilates sessions was shown to be statistically insignificant.

Recruiting double to triple the amount of participants, and studying the group for a period of at least three months is also highly recommended. Furthermore, assigning 4 individual Pilates homework per week is advised in order to further promote deep abdominal recruitment over a period of 1-3 months.

A methodology change recommended for further research would be to use a goniometer to create as much uniformity within the aerial shapes as possible for different inverted variations of the spine such as inversion, flexion, extension, and lateral flexion. The outline of using a goniometer detailed above provides realistic parameters to continue research (pages 36-37).

Another methodology change the researcher would recommend for further research would be measuring the mV output of the obliques with Pilates sessions. Since obliques are another major emphasis of abdominal engagement in Pilates, it would be interesting to see how they might increase in recruitment with an increase in Pilates sessions.

Lastly, in order to collect data that is even more specialized to aerialists or acrobats, individually, it would be interesting to do separate studies on each population in the future rather than study them together. As explained earlier, since the nature of acrobatic movement and aerial movement is the opposite mechanism (pull strength vs push strength), it would help to clean cut the data and study the effect of Pilates on these athletes separately.

The researcher's 5 week study period was in response to the time limitations allotted for the masters program dissertation guidelines, as well as availability within the group. Likewise, the 3 session requirement for each participant was dictated in response to rationalizing that compliance would increase if there was a reasonable time requirement of 3 self led sessions a week, rather than 4. Respectively, it was the researcher's

original plan to measure the output and change of the obliques as well. This did not end up happening because of time constraints. Lastly, due to the hybrid training spaces of acrobats and aerialists that the researcher recruited the participants, it was a challenge to isolate the group of volunteers for this particular study.

Regardless of the outcomes from all directions, the researcher was honored to be the first to contribute pilot EMG findings for deep abdominal engagement to this field and looks forward to future collaboration opportunities, additional studies and evolution of Pilates specific work in the aerial and acrobatic movement field.

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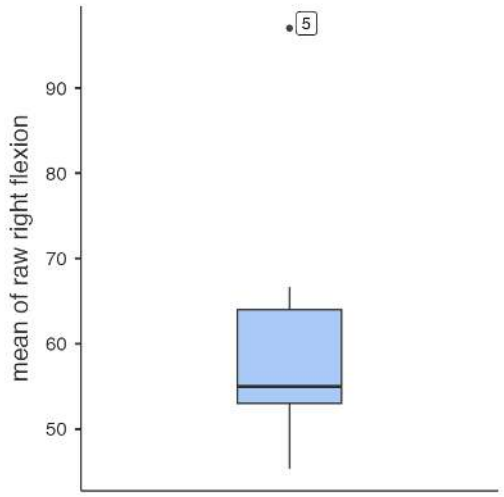
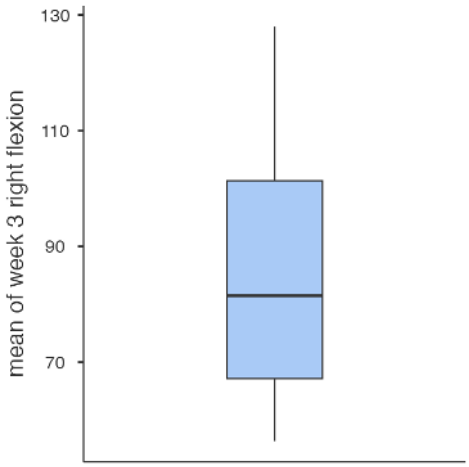
APPENDICES

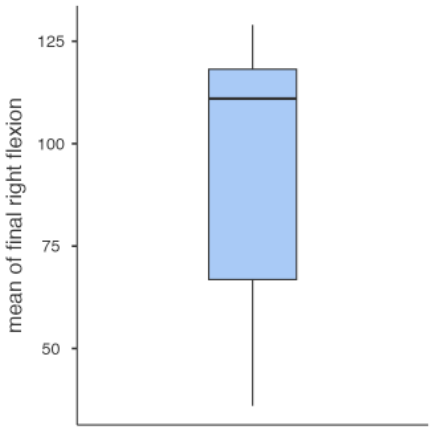
Repeated Measures ANOVA

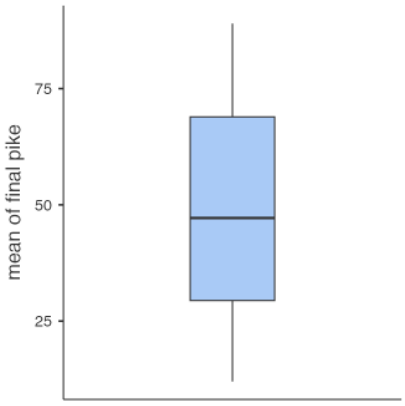
Within Subjects Effects					
	Sum of Squares	df	Mean Square	F	p
RM Factor 1	7303	2	3651		0.035

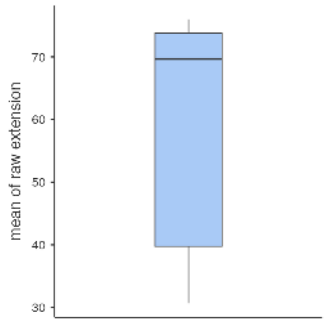
o Raw Box Plots from Shapiro-Wilk Test From Jamovi Determining Outliers

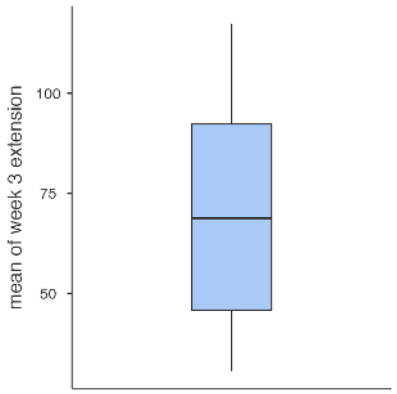


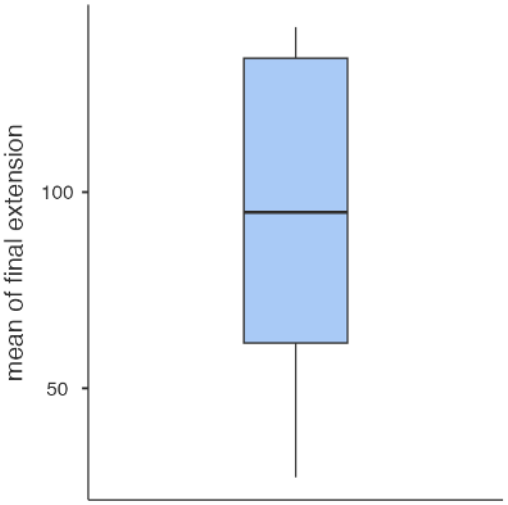


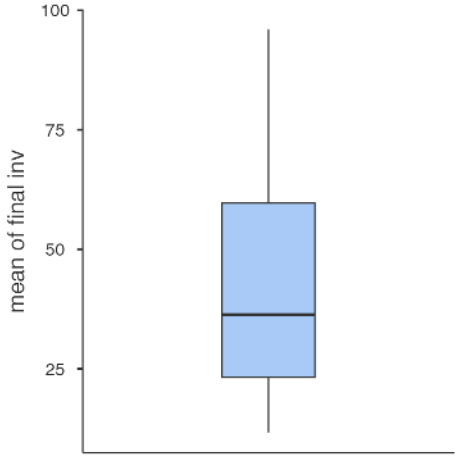





mean of raw extension
70
60
50
40
30


mean of week 3 extension
100
75
50


mean of final extension
100
50


mean of final inv
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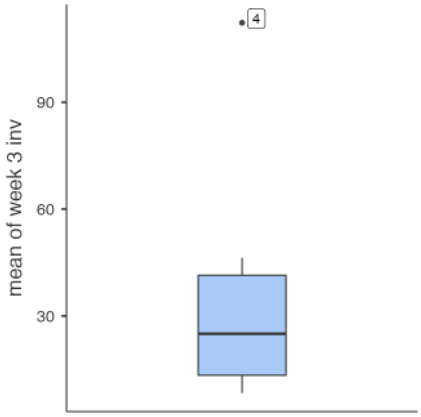
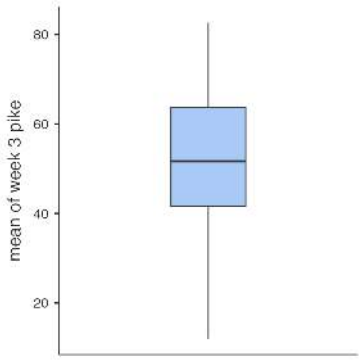
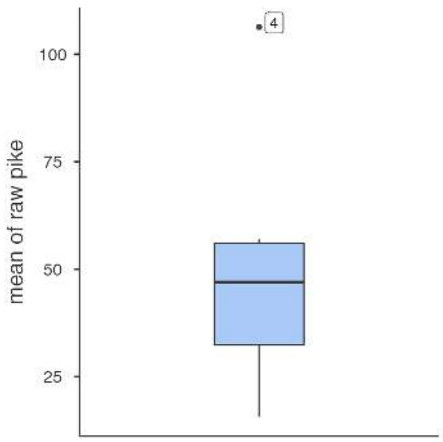
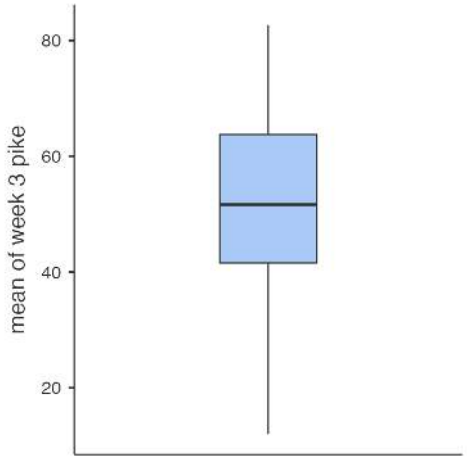
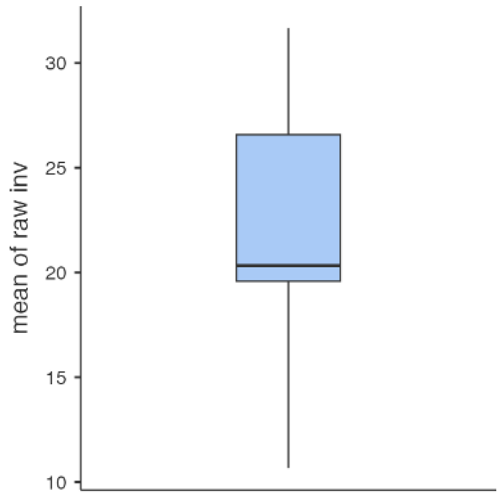
75
50
25


mean of week 3 inv
4
90
60
30


mean of week 3 pike
80
60
40
20







- Sphericity test raw output

Assumptions

Tests of Sphericity

	Mauchly's W	p	Greenhouse-Geisser ε	Huynh-Feldt ε
Time	0.646	0.336	0.739	0.922

- Bonferroni Post Hoc Test Raw Output:

Post Hoc Tests

Post Hoc Comparisons - Time

Comparison							
Time		Time	Mean Difference	SE	df	t	$p_{bonferroni}$
Week 1	-	Week 3	−34.4	16.2	5.00	−2.128	0.260
	-	Week 5	−47.8	17.5	5.00	−2.729	0.124
Week 3	-	Week 5	−13.4	13.9	5.00	−0.965	1.000

o Copy of the documents sent out after each week:

Week 1 Copy (Weekly Pilates HW Check Ins)

Participation Agreement Form - Blank

Risk Assessment - Filled out

Ethical Approval Form- Filled out

Nonparametric Descriptors Output from Jamovi

Descriptives

	mean of raw inv	mean of raw pike	mean of raw extension	mean of raw left flexion	mean of raw right flexion	mean of week 3 inv	mean of week 3 pike	mean of week 3 extension	mean of week 3 left flexion	mean of week 3 right flexion	mean of final inv	mean of final pike	mean of final extension	mean of final left flexion	mean of final right flexion
N	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Missing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mean	21.8	50.4	58.5	56.2	61.9	37.8	50.7	70.7	90.6	86.3	44.4	49.2	92.8	104	93.3
Median	20.3	47.0	69.7	57.7	55.0	25.0	51.7	68.8	83.3	81.5	36.3	47.2	94.8	104	111
Standard deviation	7.47	31.3	21.8	12.5	18.5	39.0	24.2	33.7	40.3	27.0	31.6	29.5	47.1	49.3	38.6
Minimum	10.7	15.7	30.7	36.3	45.3	8.33	12.0	30.7	43.3	56.3	11.7	12.0	27.3	38.0	36.0
Maximum	31.7	106	76.0	69.7	97.0	112	82.7	117	155	128	96.0	89.0	142	161	129
Shapiro-Wilk W	0.932	0.916	0.740	0.925	0.814	0.787	0.985	0.940	0.966	0.951	0.920	0.945	0.915	0.924	0.838
Shapiro-Wilk p	0.597	0.479	0.016	0.545	0.078	0.045	0.973	0.656	0.862	0.747	0.506	0.697	0.469	0.533	0.126

Raw Mean Data Submitted to Jamovi

o

Participant	mean of raw inv	mean of raw pike	mean of raw extension	mean of raw left flexion	mean of raw right flexion	mean of week 3	mean of week 3 pike	n 3
1	31.6666666666667	29.6666666666	72.3333333333333	36.3333333333333	54	26.6666666666	55	1
3	11	22.3333333333	41.3333333333333	40.3333333333333	26.3333333333	15.6666666666	28.3333333333	5
4	10.6666666666667	15.6666666666	30.6666666666667	51.6666666666667	45.3333333333	8.33333333333	12	3
5	28.6666666666667	106.333333333	67	63.6666666666667	66.6666666666	112.333333333	48.3333333333	6
6	20.3333333333333	53.3333333333	76	66	97	46.3333333333	39.3333333333	6
7	19.3333333333333	40.6666666666	30.6666666666667	50	52.6666666666	23.3333333333	82.6666666666	3
8	20.3333333333333	57	74.3333333333333	69.6666666666667	56	10	66.6666666666	

mean of week 3 extension	mean of week 3 left flexion	mean of week 3 right flexion	mean of final inv	mean of final pike	mean of final extension	mean of final left flexion	mean of final right flexion
117.333333333	43.333333333	63.6666666666	24	28.6666666666	115.333333333	38	36
51.6666666666	59.333333333	52.6666666666	9	49.333333333	64.6666666666	98.333333333	69.6666666666
38.333333333	154.666666666	106.666666666	11.6666666666	12	27.333333333	148	118.666666666
69.333333333	117.666666666	128	96	89	74.333333333	161	129
68.333333333	89.6666666666	77.6666666666	63.333333333	71	142	78	116.666666666
30.6666666666	77	85.333333333	23	31.6666666666	57.333333333	69	54
100	61.333333333	56.333333333	48.6666666666	62.6666666666	140.333333333	130.333333333	105.333333333