EFFICACY OF BALANCE TRAINING TO IMPROVE BALANCE OF YOUNG FEMALE GYMNASTS

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Abstract

Gymnastics is a popular sport that has potential strength, flexibility, and personal growth benefits for athletes. Both static and dynamic balance are developed from a young age and are fundamental to higher-level gymnastics. PURPOSE: To assess the efficacy of a balance training protocol in improving the dynamic balance of young female gymnasts. METHOD: 19 female Junior Olympic (JO) Level 3 gymnasts, ages 6-11, were randomly assigned to the Balance Training (BT) or control groups. The BT group completed a variety of balance exercises during each practice (2x/wk for eight weeks), including one-footed balance, hopping skills, and leaps onto surfaces of varying stability. Gymnasts in the control group continued with their normal gymnastics practices. Gymnasts were tested before training, after week 4, and after week 8 to assess improvements in the Balance Error Scoring System (BESS), Star Excursion Balance Test (SEBT), Center of Pressure Path length (COP Path length), and Joint Position Sense (JPS) scores. RESULTS: An improvement in SEBT for the gymnasts' dominant foot reaching anteriorly (p=0.03) was observed. Otherwise, there were no significant differences between improvements in scores for the control group and the experimental group. CONCLUSION: JO Level 3 gymnasts, who are early in their training and development, demonstrated no additional benefit from twice weekly balance training beyond normally prescribed practice and skills training. While anecdotal evidence suggested a possible acute effect on balance performance immediately following balance exercises, further research is needed.

Keywords: *proprioception, USAG Junior Olympic gymnastics, balance, vestibular*

INTRODUCTION

Women's gymnastics is a sport that is primarily performed by young female athletes, and has featured in the Olympics for decades (Sands, 1999). Among the many benefits of participation in this sport are those that come from adaptations that occur due to the sport's anaerobic, strength, and flexibility challenges (Sands, 1999). Gymnasts require incredible dynamic balance and proprioceptive abilities to perform skills on all four competitive events. Along with visual and vestibular input, proprioceptive input helps maintain balance (Claxton et al., 2006) by providing precision in both the conscious and unconscious control of moving limbs (Holm et al., 2004). While the training of gymnastics skills may be expected to improve balance and proprioception over time, there is currently no evidence indicating whether targeted training can further develop these abilities in young female gymnasts.

Dynamic balance is described as the ability to maintain postural control or equilibrium by controlling the body's center of gravity within its base of support during any skills in which motion of one's center of gravity occurs due to muscular activity (Claxton et al., 2006; DiStefano et al., 2009, 2009; Kinzey & Armstrong, 1998). As a contributor to dynamic balance, proprioception can be explained as the knowledge of the location of one's body in space. More specifically, proprioception is the combination of discreet kinematic input from sensory receptors in the muscle, skin, and joints, and from central signals arising from motor output (Taylor, 2009). These factors are particularly pertinent to skills performed on the balance beam and floor exercises, as well as landings from aerial skills and dismounts from each event.

It was not until recent decades that balance training was recognized as a tool that would be beneficial for healthy young athletes, due to its potential to reduce risk of injury and contribute positively to athletic performance (Claxton et al., 2006). Neuromuscular training regimens, which may include protocols that challenge the young female athletes' strength, agility, or balance, have been shown to improve balance and proprioception in non-gymnasts (Filipa et al., 2010; Holm et al., 2004). There is limited balance and proprioception research including female subjects under the age of 18. Therefore, evidence-based approaches to improve and measure dynamic balance and proprioception in gymnasts are relatively scarce. It is of interest to investigate a potential training protocol to achieve such effects.

Thus, the aim of this study was to implement and assess a balance training protocol for its efficacy in improving dynamic balance and proprioception of young female gymnasts using both standardized laboratory and modified gymnastics specific tests. More specifically, we focused on young female gymnasts training at an early competitive level (USAG Level 3). It was hypothesized that this training intervention would result in greater balance and proprioception improvements than those achieved by a control group of gymnasts continuing with conventional gymnastics practices only..

METHODS

19 female subjects, ages 6-11, participated in this study. Subjects averaged a height of 131.45+/-8.46 cm and had the skills to compete as United States of America Gymnastics (USAG) Junior Olympic (JO) Level 3 gymnasts. This was the first JO Level of competitive gymnastics for all gymnasts participating in the study. Attendance was recorded to ensure compliance. Gymnasts attended 88% of the training sessions on average, including at least one during every week of training. Gymnasts who were physically unable to perform strenuous physical activity causing them to refrain from any part of their typical gymnastics practice were excluded from the training intervention. All gymnasts were part of the same team and practiced together twice per week for a total of eight hours. To control for developmental differences, gymnasts were matched by age and gymnastics experience, then pairs were randomized into either the control or the experimental group.

Training intervention took place twice per week for eight weeks and was integrated into their regular gymnastics practices. The training stimulus consisted of agility dot exercises, a one-footed static balance task, and a dynamic one-footed landing task. The difficulty of the exercises increased at the end of week 2 and again at the end of week 5. Balance and proprioception were assessed at the beginning, middle, and end of the eight weeks. Testing was performed in a laboratory setting and consisted of four assessments: Center of Pressure Path length (COP Path length) following a landing from a split leap, the Balance Error Scoring System (BESS) test, the Star Excursion Balance Test (SEBT), and the Joint Position Sense (JPS) test. Assessments aimed to identify improvements in gymnastics-specific performance outcomes as well static balance, dynamic balance, and proprioception, respectively. Technicians and raters were blinded to the gymnasts' groups and followed scripts to ensure unbiased testing.

The agility dot drill was included as an exercise intended to stress dynamic balance, leap/landing dynamics, and proprioception, specifically, of the foot and ankle. The exercise was incorporated into the experimental group's warm-up. All 19 gymnasts began their practice with running and stretching. The ten gymnasts receiving balance training then performed six repetitions of each of the day's three prescribed dot patterns. Agility dot hopping patterns were done on five dots in the shape of an X (Figure 1) and included both one-footed and two-footed challenges of increasing difficulty as training progressed. The control group proceeded with a normal team warm-up, which did not include specific balance training interventions

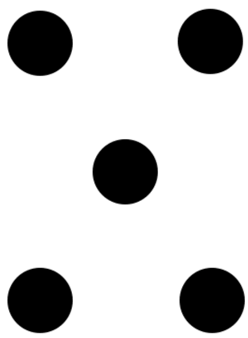

Figure 1. Layout for the dot drill. Outer dots were spaced at 24in x 36in (54cm x 91cm)

The stationary balance exercise was completed during the gymnasts' daily rotation on the balance beam. Gymnasts stood on one foot for 10 seconds, repeating this for each foot three times. The difficulty of the exercises increased in such a way that the first phase was performed on a foam balance pad (Airex, Switzerland); moved at the end of week 2 to a less stable surface, a BOSU ball (BOSU, USA), and then again, after week 5, to the least stable surface, a Dyna Disc (Exertools, USA). Between established progressions, gymnasts were individually monitored as they transitioned to more challenging versions of the one-footed static balance task; an additional challenge was moving their arms from abducted with extended elbows to placing hands on hips, and further performing the task with their eyes closed.

The dynamic landing exercise was also completed during the gymnasts' daily rotation on the balance beam. The ten leaps were divided in half: five on each foot were performed both before and after the static balance exercise. Gymnasts performed split leaps, landed on one foot inside an area of the floor that had a taped rectangle approximately 40cm x 60 cm. They were instructed to stick and hold their landing for three seconds. In the first phase gymnasts landed the leap on flat ground, which was transitioned at the end of week 2 to a foam balance pad, and then again after week 5 to a BOSU ball.

Testing took place in a laboratory setting. Testing sessions began with a prescribed warm-up that included three practice leaps on each leg and six reaches per foot in each of the three SEBT reaching directions. Gymnasts were randomly divided to start at one of four stations. Upon completing their first station, gymnasts would transition independently through the other three tests.

Gymnasts performed a one-footed landing on a force plate (Bertec, USA) following a split leap with a two-step lead-in. This sport-specific skill simulates the leap skill performed in the JO Level 3 balance beam routine. Three leaps were performed on each foot and gymnasts were instructed to hold their landing for at least three seconds. The order of self-identified dominant (D) or non-dominant (ND) foot was randomized. COP path length has been utilized in past studies with the force plate being commonly recognized as a gold standard for measuring acute differences in balance abilities (Sabchuk et al., 2012). Gymnasts' COP Path length was measured for a minimum of three seconds; trials in which gymnasts were hopping upon landing or the landing was not held for three seconds were discarded then repeated.

The BESS is a reliable and valid static balance test (Hansen et al., 2017) that consists of three skills: a two-footed stance, a one-footed stance on the non-dominant foot, and a tandem stance with dominant foot in front on a foam balance pad (Airex, Switzerland). All skills required gymnasts to have their eyes closed and their hands on the hips. Two trained, unbiased raters scored gymnasts and total errors were calculated and averaged between the two raters. An overall higher score indicates poorer performance. The traditional BESS test involves performing each of the stances both on the floor and on the Balance Pad, but the floor portion was eliminated for this study due to its relative ease in this population; it was not expected to be able to assist in the discernment between two high performers (DiStefano et al., 2009). A summative total score was calculated as a total error of each of the three positions.

The SEBT is a reliable and valid tool used to assess dynamic balance abilities (Ricotti, 2011). For this study, each subject's ability to extend their non-supporting leg was measured in three directions: anterior, posterolateral, and posteromedial. Distances were measured using tape with inch gradations. Gymnasts performed three reaches in each direction, standing with the big toe of their supporting foot on the center. The order in which the reaches were performed was randomly selected, as was the foot with which gymnasts reached first.

JPS can be defined as a person's ability to actively or passively reproduce a predetermined joint angle, and has emerged as a reliable and valid mechanism for quantifying proprioceptive abilities (Elshemy & Battecha, 2013). The protocol for this assessment was modified from a JPS test used previously (Ettinger et al., 2017). Joint position was determined using a custom LabVIEW program (National Instruments, USA) using accelerometry data from an iPod (Apple, USA). Changes in the angle of hip extension were measured as the gymnasts were cued to perform arabesque repetitions. An arabesque is a standard position that Level 3 gymnasts must hold on the balance beam, and the angle of hip extension in an arabesque was used for this study. Prior to testing, subjects were familiarized with the protocol and performed several practice trials until comfortable with the equipment and the environment. Eyes were closed to eliminate visual input as a proprioceptive aid for this test.

To initiate the assessment, the application audibly cued extension of the hip into an arabesque with a low constant tone. Real-time feedback of their position was provided with the tone remaining low or changing to high, corresponding to the need to raise and lower their leg, respectively. Subjects, as prompted before testing, knew to memorize the "target" position, which was held for two seconds and pre-set to be either 30˚, 45˚, or 60˚ with allowance for plus or minus 10˚. The command "relax" told subjects to return to the standard anatomical position for two seconds, and was followed three seconds later by a cue to "find target". In silence, subjects repositioned their leg in an arabesque which they felt most closely resembled the one they had completed seconds before. Once still for two seconds, the command "relax" would play again, indicating the end of that trial. Nine trials (three for each target angle range) were completed in a randomized order. Average error was calculated for each joint angle.

Statistical analyses were conducted using SYSTAT 13. Data were tested for assumptions of normality and homogeneity of variance. The independent variable was assessed as the completion of either the balance and proprioception intervention or the control. The dependent variables included the COP path length, SEBT score, BESS score, and JPS score as described above. The difference in training outcomes for each dependent variable between groups was analyzed using a within-subjects mixed ANOVA analysis. Additional post-hoc pair-wise comparisons were run to analyze stage-by-stage differences. Statistical significance was set at $\alpha = 0.05$. Values are presented as mean ± SD.

This study received approval from the Institutional Review Board. Prior to participation, both Child Assent and Parental Consent were obtained.

RESULTS

The COP test did not identify any statistically different changes in the performance of the experimental group when compared to those of the control group. Individual changes of the experimental group's dominant foot path lengths measured for one second following their landing can be seen in Figure 2. The experimental group saw a general decrease in COP across the three timepoints, averaging 0.197±0.07 cm, 0.182±0.04 cm, and 0.165±0.05 cm for the pre, mid, and post sessions, respectively. The change in the control group's COP values varied more across timepoints, averaging 0.199±0.08 cm, 0.210±0.04 cm, and 0.165±.034 cm for the pre, mid, and post sessions, respectively. There was no significant difference between the groups (p=0.676).

This test did not identify any statistically different changes in the performance of the experimental group when compared to those of the control group. For the pre, mid, and post assessment sessions, the experimental group averaged scores of 11.25±2.46 errors, 10.85±3.25 errors, and 10.06±2.83 errors, while the control group scores were 12.83±2.65 error, 11.06±3.43 errors, and 11.56±3.61 errors across the three timepoints respectively (Figure 3).

Gymnasts of the experimental group reaching anteriorly with their dominant foot improved significantly more between the testing session at the end of week 4 and the end of week 8 than those in the control group (p=0.03). On average, the experimental group's scores improved from 59.3±7.7 to 60.5±8.1 cm (23.33±2.9 to 23.8±3.2 in) while the control group's reaching distances decreased from 61.9±6.4 to 58.2±5.1 cm (24.38±2.5 to 22.91±2.0 in) (Figure 4). No other statistically significant improvements were made in reaching distances when comparing the groups.

JPS did not identify any statistically different changes in the performance of the experimental group at the 30˚, 45˚, or 60˚ angles across the three timepoints when compared to those of the control group when performing the static arabesque skill (p>0.05 for all). The 45˚ target angle had a non-significant trend of improvement for the experimental group (p=0.059) (Figure 5); however, this was not different from the control group (p>0.05).

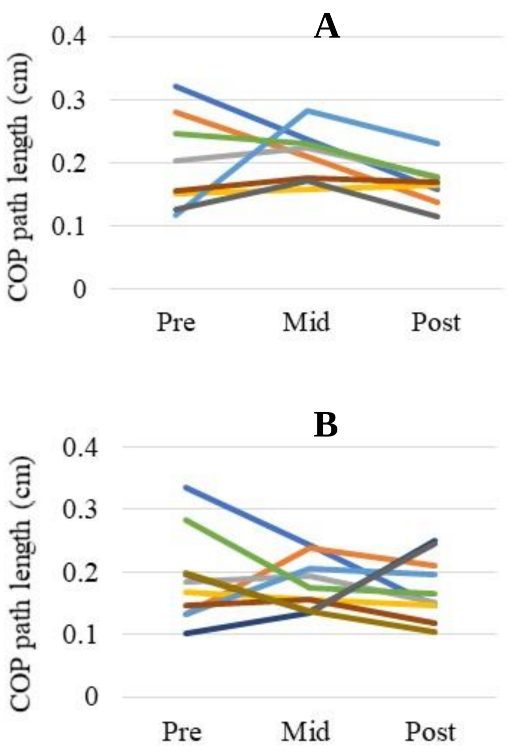

Figure 2. Changes in average COP scores for the experimental (A) and Control (B) groups

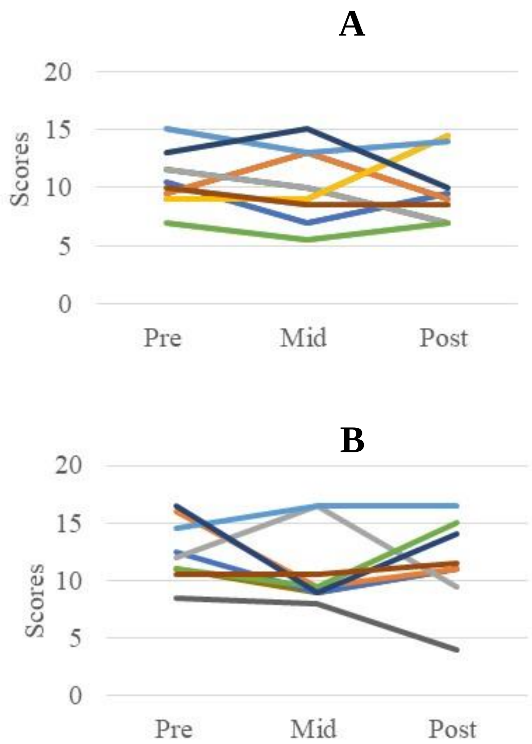

Figure 3. Changes in average BESS scores for the Experimental (A) and Control (B) groups. One subject in the experimental group did not complete her post-training assessment for the BESS test, her data was excluded from the graph, but was used to calculate average scores for the week zero and week four testing sessions.

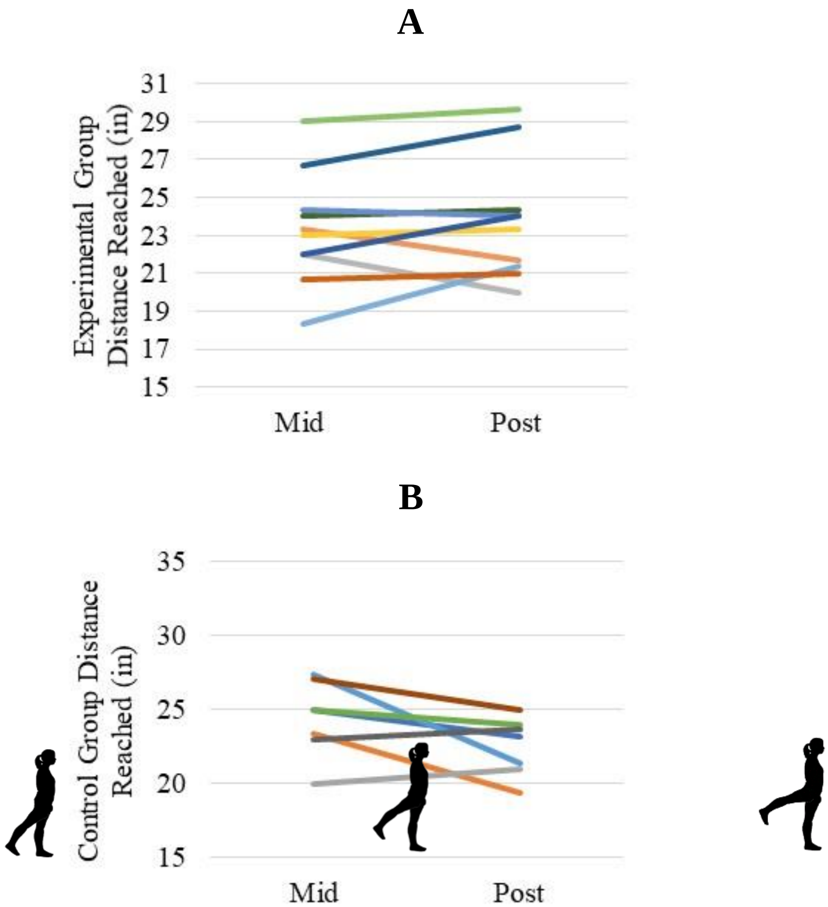

Figure 4. Changes in average dominant anterior SEBT reaching distances for the experimental (A) and Control (B) groups

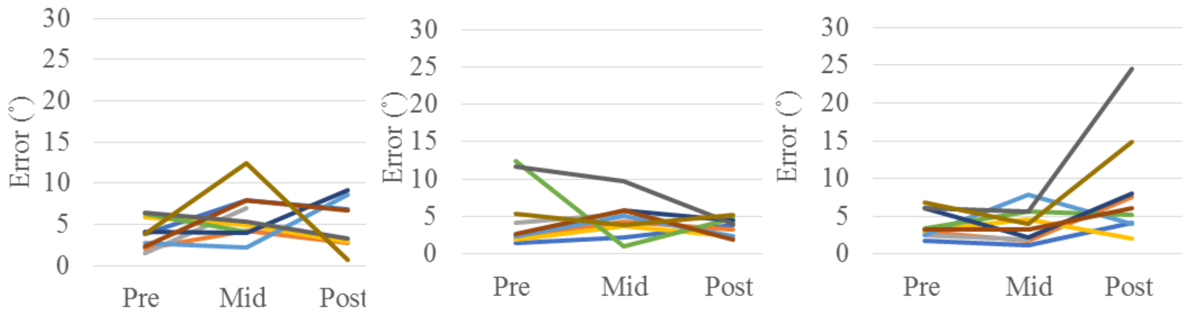

Figure 5. Changes in average JPS constant errors for the experimental group aiming for 30˚ (left), 45˚ (middle), and 60˚ (right).

DISCUSSION

The purpose of this study was to implement and assess the efficacy of a balance training protocol for pre-adolescent JO female gymnasts. Gymnasts who are early in their competitive training, JO Level 3, have the greatest potential for improvement in both their skills and their balance. The training stimuli were designed to improve performance on a sport-specific skill, as well as assessments of dynamic balance, static balance, and proprioception. For the SEBT, in the anterior direction when reaching with the dominant foot, the experimental group improved their scores significantly more than the control group between the assessment at the end of week 4 and at the end of week 8. However, all other assessments did not reveal any statistically significant differences between the groups. While trends towards improvement were apparent, they were not statistically different between the groups.

Despite support in the literature for the theoretical implementation of balance training with lower level (compulsory) gymnasts (Cohen et al., 2002), to our knowledge, this is the first study to investigate a balance or proprioception training intervention in young female gymnasts, particularly at a novice competitive level such as JO Level 3. When comparing to non-elite young females training in other sports we see that Filipa, et al. (2010) saw an improvement in SEBT with an 8-week neuromuscular training program which included core muscle training and balance stimuli twice per week in high-school competitive soccer players. Similarly, Valovich, et al. found an improvement in BESS and SEBT scores among female high school basketball players after a 6-week training intervention twice per week, including balance training. Holm, et al. (2004), similarly found improvements in balance and proprioception after a 5 to 7-week intervention, three days per week. However, this study utilized elite-level handball players. As compared to the present study, each of these studies implemented similar balance interventions across an equivalent duration of training. The focus of these studies was on older and more highly trained ball-sport athletes. These athletes were at a higher level of physical and sports-specific development than the younger and more novice gymnast in the present study. This difference in age and development may have affected the difference in results, specifically BESS and SEBT.

JO Level 3 gymnasts were chosen for this study because Level 3 is often the first level of competition, and therefore competitive training. Among the competitive levels, these gymnasts have the greatest potential for improvement and were, therefore, the focus of this study. Ultimately, this sample selection may have confounded the results. We believe that our balance training stimulus was not a sufficient overload beyond overload stimulus presented by standard practice in this early stage of training. Gymnastics training alone has been found to improve balance in young (4-6 years) children with no previous training (Akın, 2013). In the present study, for example: the COP path length outcome measure represented a sport-specific skill that could be improved through the training stimuli implemented. However, a split leap is a common focus of training at this level, so all subjects (both control and experimental) had ample practice in this skill throughout the study duration. The BESS test and SEBT are reliable and valid assessments that quantify improvements in static and dynamic balance, respectively. Drills on the balance beam involved a combination of static and dynamic balance, and gymnasts had about 45 minutes of training on the balance beam in each practice. Therefore, the training of the gymnasts could have specifically confounded these three outcome measures.

This study had a minimum of 50% attendance for inclusion in the final analysis; actual attendance exceeded 88%

of all sessions with at least one session per week. This requirement was based on past research utilizing only one training session per week for a period of 8 weeks or less (Heitkamp et al., 2001). Given that the gymnasts at this level only practice two days per week, and the gymnasts were just beginning competitive level training in JO Level 3, the balance training stimulus may have been insufficient to differentiate between the groups. Future research using similar balance training protocols could be conducted with subjects at higher JO levels, ensuring a distinctly different balance stimulus from their standard training.

A potential confounder to our results may be the orderly implementation of our multiple tests. As described above, at each testing timepoint athletes completed all tests in a randomized order, progressing immediately from one test to the next. Anecdotally, we observed that there may be an acute balance stimulus effect, which may confound the longitudinal measurements. The design of the dynamic and static balance portion of the training regimen allowed a comparison of the leap landing before and after the static balance training. While this study was not designed to observe acute effects, it was observed by coaches and researchers that the gymnasts performed subjectively better on their leaps following the static training when compared to their leaps performed prior to the static challenge. Similarly, coaches reported improved performance during balance beam practice immediately after gymnasts returned from balance training. These are biased and subjective reports, so future research should investigate an acute training effect. Currently, we are unaware of evidence in the literature that has specifically investigated the effects of an acute balance stimulus in athletes. In healthy young adults, however, a dynamic warm-up has been shown to improve SEBT scores as compared to a more static warm-up (Erkut et al., 2017). Should some acute effect exist, this may be a confounding factor in measuring longitudinal balance training effects. Establishing the existence of an acute effect would be interesting to consider as a pre-competition exercise for gymnasts, and therefore of interest in future research.

CONCLUSIONS

The selected balance training protocol was generally not a sufficient mechanism for improving young female gymnasts' balance beyond their performance gains acquired through regular JO Level 3 gymnastics practices. Additional research should be conducted on more well-trained gymnasts in an attempt to improve their balance, and the potential acute effect should be investigated.

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