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# The Effects of Different Core Stability Training on Trunk Stability and Athletic Performance in Adolescent Female Basketball Players

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***Purpose:*** Trunk function is not only related to physical fitness performance, but also important for the balance, and stability of the whole body. This study aimed to investigate the effects of 2 training methods on trunk stability and athletic performance in adolescent female basketball players. ***Methods:*** Fifty-one healthy elite female basketball players (age: 14.76 [1.84] y, body mass index: 21.41 [1.96] kg/m$^2$) were assigned to TRX training (n = 17), Swiss ball training (n = 17), or control groups (n = 17). Participants performed a progressive program of unstable core muscle training consisting of 8 different exercises, with each exercise performed in 3 sets, twice a week for 8 weeks. The outcome measures were a plank test, the modified double leg lowering task, and athletic performance including jumping, speed, agility, cardiopulmonary endurance, and the ankle proprioception. ***Results:*** Significant group and time interaction were identified in the modified double leg lowering task ($P = .032$, $\eta^2 = .134$), with post hoc comparisons revealing improvements in the TRX group ($P = .014$). The TRX group (8.6%) improved significantly more than the Swiss ball group (2.9%) when it comes to the modified double leg lowering average change percentage. The plank test also exhibited a significant group and time interaction ($P = .033$, partial $\eta^2 = .133$), with notable improvements in both the Swiss ball ($P = .001$) and the TRX groups ($P = .001$). Athletic performance measures showed no significant differences among groups. ***Conclusions:*** The results indicate that both TRX and Swiss ball training can increase core muscle strength and stability without compromising athletic performance after 8 weeks of training. Furthermore, incorporating core muscle training enhances power transmission capabilities. Nevertheless, considering the goal was to improve speed and ankle proprioception during preseason training, careful consideration must be given to the timing and intensity of any intervention involving unstable core muscle training.

***Keywords:*** suspension training, Swiss ball, core muscle functions, ankle proprioception, physical functions

**Key Points**

- TRX and Swiss ball training enhanced trunk control, with TRX showing a more significant impact on trunk stability.
- Implementing these core training methods within the original training time did not compromise athletic performance in female basketball players, highlighting their value without performance drawbacks.

Basketball is a high-speed, intense, physical game that demands strength, power, speed, balance, coordination, and dribble control. It has been shown that trunk function is not only related to the degree of physical fitness but is also important for the balance and stability of the whole body.[1,2] Moreover, benefits of core stabilization have been studied, from improving athletic performance and preventing injuries to alleviating low back pain.[3–5]

Notably, poor trunk control, particularly among female athletes, correlates to a heightened risk of injuries, especially ACL injuries, compared to those with better trunk stability.[6] Previous researchers have demonstrated that exercise increases the instability in the trunk when the body's center of mass is over an unstable surface and further away from a stable surface.[7–9] An unstable surface can lead to decreases in externally measured force because of the increased stabilizing function of the limb muscles.[10,11] Previous studies have found that unstable core stability training can result in greater activity in the core muscles.[8,12] The most common unstable surface training tools include Swiss balls, BOSU, core discs, and suspension training systems, among others. Studies revealed that Swiss ball training significantly improves core stability, activates specific core muscles more than stable alternatives, and leads to greater gains in trunk balance ability compared with traditional training methods.[13–16] In addition, Swiss ball core muscle training can not only improve core muscle strength, neuromuscular recruitment, and balance ability, but also benefits injury prevention.[17,18]

Furthermore, suspension training, as observed in the study by Mok et al,[16] triggered core muscle activation particularly in stable conditions. This form of training significantly elevates core muscle strength and trunk stability, especially in track and field



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athletes.[16,19] TRX Suspension training has been shown to be an effective device for eliciting increased core muscle endurance, core muscle activation, balance, and proprioception.[20–22]

The dynamic demands of basketball, including the high-intensity, intermittent nature of the game, emphasize the necessity to assess players' physical performance for tailored training programs.[23,24] The basketball's frequent collisions highlight the pivotal role of core stability in injury prevention.[25] Core muscles, extending from the thoracic spine to the hips, play a crucial role in fundamental movements.[26]

To our knowledge, few studies have discussed the effects of different unstable core muscle training methods on trunk muscle abilities. Therefore, the purpose of this study was to investigate the effects of the 2 training methods on trunk stability and other performance-related outcomes in female basketball players during preseason training. Specifically, we examined secondary outcomes, such as jumping ability, speed, agility, cardiopulmonary endurance, balance, and ankle proprioception. Our hypothesis posited that both training methods would enhance trunk stability and athletic performance.

Core stability and ankle proprioception are crucial for injury prevention and rehabilitation,[27,28] significantly reducing the risk of lower limb injuries,[29] including ACL injuries.[30,31] Additionally, assessing jumping ability, speed, and agility helps gauge functional improvements that translate to enhanced on-court performance, while indicating improved neuromuscular control and coordination, pivotal for injury prevention.[32] Cardiopulmonary endurance is pivotal for overall fitness and recovery, ensuring athletes maintain high-performance levels and reduce fatigue-related injuries.[33] By addressing these variables, our study aimed to bridge the gap between sport performance and rehabilitation, providing valuable insights for injury prevention and enhancing athletic performance in female basketball players.

This study aimed to provide insights into how these training methods can optimize core stability and athletic performance in female basketball players. Furthermore, the study also aimed to contribute to this underresearched area by focusing on core stability training's impact on performance and injury prevention in this specific population. By doing so, it addresses the unique physiological, hormonal, and injury risk profiles of adolescent female athletes, offering evidence-based strategies to enhance their performance and reduce their injury risks.

# Methods

## Study Design

This study involved an 8-week intervention focusing on core muscle training among adolescent female basketball players. The intervention was conducted during the preseason. Pre- and posttests were conducted to assess core stability, jumping ability, ankle proprioception, speed and agility, and cardiopulmonary endurance. The study was reviewed and approved by the Human Experiment and Ethics Committee of National Cheng Kung University Hospital (No. A-ER-108-537) prior to the recruitment of participants.

## Participants

Fifty-one healthy elite female basketball players (age: 14.76 [1.84] y, body mass index: 21.41 [1.96] kg/m$^2$) were enrolled in the study. Participants were selected from those who ranked among the top 4 in national junior and senior high school basketball tournaments. Exclusion criteria included any musculoskeletal injuries within 3 months prior to the study and a history of vestibular dysfunction or concussion. Participants were matched based on their pretest rankings in various dependent variables and were randomly paired, allocated into 3 groups: a Swiss ball training group (17 individuals undertaking Swiss ball core training), a TRX training group (17 individuals undergoing suspension based TRX core training), and a control group (17 individuals continuing the team's original technical and strengthening training).

The selection of elite adolescent female basketball players for this study was intentional and based on several considerations. Physiologically, female athletes often face different injury risks compared with their male counterparts, particularly in sports involving jumping, pivoting, and rapid changes in direction, such as basketball. For instance, female athletes are at a higher risk for ACL injuries,[34,35] which can have long-term impacts on their athletic careers and overall health. Additionally, hormonal differences, such as those involving estrogen, estradiol, and progesterone, can influence ligament laxity and injury susceptibility.[34,36]

Focusing on this demographic allows us to address specific needs and challenges faced by female athletes in high-performance settings, such as injury prevention and performance enhancement during preseason training. Furthermore, there is a research gap in the literature regarding effective training interventions tailored to this population, making this study particularly relevant.

To ensure that participants were not involved in any other training programs that could have influenced the results, we maintained a controlled training environment where participants in both the intervention and control groups continued their regular team training under the same conditions. During the core training intervention sessions, only the Swiss ball or TRX training programs were administered to the experimental groups, while the control group followed their standard training regimen (ie, skill-specific drills, such as dribbling, shooting, passing, and defensive maneuvers). Particularly, the Swiss ball and TRX core training programs were progressively intensified over the 8-week period, starting with basic stability exercises and advancing to more complex and challenging movements (see Supplementary Materials S1–S3 [available online] for TIDieR checklist and detailed training programs).

Participants were instructed not to engage in any additional training outside the prescribed programs. Pretraining measures were collected prior to group assignment to ensure baseline equivalence across groups. Additionally, investigators conducting the pre and posttest measures were blinded to group assignments to minimize bias. All participants provided informed consent.

## Procedures

All participants engaged in an 8-week supervised progressive program involving unstable core muscle training sessions or maintained normal training (control group). Each session, conducted twice a week, had a duration of 60 minutes, including a 10-minute warm-up, a 40-minute main exercise session, and a 10-minute cool-down. The core muscle training sessions consisted of 3 sets of 8 exercises, with 40 seconds of workout and 20 seconds of rest between exercises.

The primary outcome measures included a plank test and the modified double leg lowering task (MDLL) assessing trunk stability, alongside athletic performance domains including jumping ability, speed, agility, cardiopulmonary endurance, and ankle proprioception. These parameters were evaluated before and after the 8 weeks of core muscle training.

### *Trunk Stability*

#### MDLL Task.

- Procedure: Participants lay supine with their arms by their sides and legs extended. A stabilizer pressure biofeedback unit

(Stabilizer, Pressure Bio-Feedback Unit, Chattanooga Group Inc)[37–39] was placed under the lumbar spine to monitor and provide feedback on lumbar position and movement. Participants slowly lowered their legs from a vertical position (90°) toward the floor while maintaining contact with the stabilizer unit.

- Measurement: The hip flexion angle was measured using a goniometer at specific points as the legs were lowered. Scores were based on the hip joint angle: 70° to 90° as 5, 60° to 75° as 6, 45° to 60° as 7, 30° to 45° as 8, 15° to 30° as 9, and 0° to 15° as 10. A higher score indicated better trunk stability.

### *The Core Muscle Strength and Stability Test*

**Plank Test.**

- Procedure: The core muscle strength and stability test, which is also known as plank test, consisted of 10 levels, each increasing in difficulty.[40,41] Participants started at level 1, holding a basic plank position for 60 seconds. Subsequent levels introduced challenges, such as lifting 1 arm or leg while maintaining the plank position, with score increases at each level.
- Measurement: The test culminated at level 10, aiming for a score of 100. A higher score indicated superior core muscle strength and stability.

### *Athletic Performance*

The athletic performance included jumping ability measured by a vertical jump, speed ability for a 20-m sprint, a 505-agility test (a test of 180° turning ability), cardiopulmonary endurance ability using a 20-m shuttle run test,[42] and the ankle proprioception tested using a BioSway balance system (Biodex BioSway, Portable, Inc), which is a reliable posturography system for measuring postural sway and detecting changes in center of pressure.[43–45]

Specifically, the BioSway system provides modified Clinical Test of Sensory Integration of Balance protocol.[46] The score recorded as the sway index was calculated by the system. The lower the sway index, the better balance and stability one has. This system detected the anterior–posterior stability (sagittal plane) and the medial–lateral stability (frontal plane), which determines an individual's ankle proprioception.[46]

These selected outcome variables were chosen to comprehensively evaluate both performance and rehabilitation-related benefits.

## Statistical Analyses

Data analysis was performed using SPSS version 18.0. Descriptive statistics were presented as means and standard deviations. A 1-way analysis of variance was employed to assess baseline differences among the groups. We conducted a repeated measures analysis of variance to investigate the impact of core muscle training on both trunk muscle ability and athletic performance. Post hoc comparisons were performed using Scheffe test to assess between-group differences. In the event of significance in these comparisons, the effect size was reported using partial eta-squared. To understand the effectiveness of the training methods in depth, we also compared the differences in the average changes in the MDLL and plank tests. Average change percentages were calculated by taking the posttest scores, minus the pretest scores, dividing that difference by the pretest scores, and then multiplying by 100 to express the change as a percentage. The significance level was set at $P < .05$.

# Results

Fifty-one elite female basketball players with a mean age of 14.76 (1.84) years and a body mass index of 21.41 (1.96) kg/m$^2$ participated in the study, comprising the Swiss ball (n = 17), the TRX (n = 17), and the control groups (n = 17). No significant differences were found in the participants' baseline characteristics. Table 1 shows the participants' baseline characteristics.

Table 2 summarizes the pretest and posttest MDLL and plank scores, along with the interaction effects, partial eta-squared values, and post hoc comparison $P$ values across Swiss ball, TRX, and control groups. For the MDLL, a significant group and time interaction was observed ($P = .032$, partial $\eta^2 = .134$). Post hoc comparisons revealed a significant improvement in the TRX group ($P = .014$) compared with the Control group, with mean increases from 5.35 (0.61) to 5.76 (0.44), indicating that after the 8-week training period the TRX group exhibited a significant increase in MDLL compared with the other groups. There were no significant differences observed in the Swiss ball or control groups. In terms of the average change percentages, significant differences were found between groups ($P = .038$), with the TRX group (8.6%) improving more than the Swiss ball group (2.9%).

Similarly, the plank test demonstrated a significant group and time interaction ($P = .033$, partial $\eta^2 = .133$). Post hoc comparisons revealed significant improvements in the Swiss ball ($P = .001$) and the TRX groups ($P = .001$), with mean scores changing from 45.59 (32.49) to 81.76 (28.12) and 43.53 (33.58) to 78.24 (31.67), respectively. This suggests that both Swiss ball and TRX training led to a statistically significant increase in plank test scores compared with the control group. The control group did not show statistically significant changes. In addition, no significant differences were found between TRX and Swiss ball groups. Regarding the average change percentages, no significant differences were found between the 3 groups.

Regarding athletic performance, no significant differences were found in jumping ability, speed, agility, cardiopulmonary endurance, and ankle proprioception among all participants across the Swiss ball, TRX, and control groups. Table 3 indicates that both

**Table 1 Participant Characteristics**

| | Swiss ball (n = 17) | TRX (n = 17) | Control (n = 17) | P |
|---|---|---|---|---|
| Age, y | 14.65 (1.69) | 14.88 (2.03) | 14.18 (1.63) | .289 |
| Height, cm | 164.06 (5.92) | 165.65 (5.79) | 166.35 (7.41) | .636 |
| Weight, kg | 56.06 (6.49) | 60.65 (7.79) | 57.29 (7.74) | .667 |
| BMI, kg/cm$^2$ | 20.78 (1.76) | 22.04 (2.00) | 20.63 (1.76) | .960 |
| Training years | 4.71 (2.37) | 5.76 (1.99) | 4.29 (2.01) | .086 |

Abbreviations: ANOVA, analysis of variance; BMI, body mass index. Note: Values are presented as mean (SD). A 1-way ANOVA was employed to assess baseline differences between the 3 groups. Statistical significance was set at $P < .05$.

**Table 2 Statistical Results—Trunk Stability**

| Test | Group | Pretest | Posttest | Average change percentage | $P^‡$ | Interaction $P$ | Partial $\eta^2$ | $P^†$ |
|---|---|---|---|---|---|---|---|---|
| MDLL, level | Swiss ball | 5.47 (0.62) | 5.24 (0.44) | −2.9% | .038* | .032* | .134 | |
| | TRX | 5.35 (0.61) | 5.76 (0.44) | 8.6% | | | | .014* |
| | Control | 5.24 (0.44) | 5.41 (0.62) | 3.5% | | | | |
| Plank test, score | Swiss ball | 45.59 (32.49) | 81.76 (28.12) | 182% | .073 | .033* | .133 | .001* |
| | TRX | 43.53 (33.58) | 78.24 (31.67) | 168% | | | | .001* |
| | Control | 42.65 (29.75) | 50.59 (33.44) | 45% | | | | |

Abbreviation: MDLL, the modified double leg lowering task. Note: Values are presented as mean (SD). Interaction effects are based on group × time. *Significance level was set at $P < .05$. †$P$ value refers to post hoc comparisons among interventions versus the control group. ‡$P$ value refers to the average change percentage between groups.

**Table 3 Statistical Results—Athletic Performance**

| Test | Group | Pretest | Posttest | Interaction $P$ |
|---|---|---|---|---|
| Vertical jump, cm | Swiss ball | 35.53 (4.32) | 38.47 (4.43) | .629 |
| | TRX | 36.06 (4.08) | 39.35 (4.21) | |
| | Control | 35.59 (3.94) | 37.88 (3.69) | |
| 20 m sprint, s | Swiss ball | 3.71 (0.19) | 3.67 (0.16) | .871 |
| | TRX | 3.73 (0.18) | 3.71 (0.15) | |
| | Control | 3.77 (0.17) | 3.76 (0.19) | |
| Agility, s | Swiss ball | 2.65 (0.12) | 2.55 (0.10) | .860 |
| | TRX | 2.69 (0.14) | 2.60 (0.96) | |
| | Control | 2.74 (0.13) | 2.63 (0.17) | |
| Cardiopulmonary endurance, ml/kg/min | Swiss ball | 53.89 (4.26) | 56.82 (2.73) | .984 |
| | TRX | 52.73 (3.93) | 55.48 (1.92) | |
| | Control | 52.73 (3.93) | 55.48 (1.92) | |
| Ankle proprioception, score | Swiss ball | 0.44 (0.16) | 0.54 (0.35) | .280 |
| | TRX | 0.52 (0.27) | 0.5 (0.2) | |
| | Control | 0.54 (0.21) | 0.49 (0.1) | |

Note: Values are presented as mean (SD). Interaction effects are based on group × time. Statistical significance was set at $P < .05$.

the experimental interventions and the daily training in the control group yielded similar effects on athletic performance.

## Discussion

Preseason training is important for bridging the gap between offseason conditioning and in-season performance. It focuses on refining sports-specific skills, enhancing overall fitness, and implementing injury prevention strategies to ensure athletes are well-prepared and less susceptible to injuries during the competitive season. The study aimed to investigate the effects of Swiss ball core muscle training and TRX suspension training on trunk stability and athletic performance in adolescent female basketball players during preseason training.

This study addresses key gaps in the literature regarding effective training interventions for elite adolescent female basketball players. Our research uniquely compared the effects of Swiss ball and TRX suspension training on multiple performance outcomes within the same cohort of Taiwanese athletes, which is a novel approach in this demographic. Functional training methods, such as unstable surface training, and suspension training have not been widely adopted in this demographic, highlighting the need for evidence-based strategies tailored to their specific requirements.

The findings contribute to a broader understanding of how these training methods can enhance core stability, athletic performance, and injury prevention. By focusing on female athletes during preseason training, this study provides targeted insights that align with the physiological, hormonal, and injury risk profiles of adolescent female athletes. While previous studies have explored various core training programs,[47] the novelty of this research lies in its direct comparison of these 2 methods within a single cohort. The results offer practical relevance for coaches and trainers seeking to optimize performance and reduce injury risks in this population.

Previous research has indicated the MDLL task score as a representation of spine maintenance in a neutral position.[48,49] The study's primary outcomes reveal that TRX training had a specific positive impact on MDLL, while both Swiss ball and TRX training led to improvements in the plank test. The control group, which did not undergo specific core muscle training, did not show significant changes. Indeed, trunk stability (MDLL task score) significantly increased in the TRX group, suggesting that TRX core muscle training may have a more pronounced effect on trunk control ability and muscle activation compared with Swiss ball core muscle training and in the control condition.[16]

While the differences between the Swiss ball and TRX groups were insignificant in the plank test, which is commonly used to assess superficial core muscle abilities,[50] the evaluation of deep core muscle stability using the MDLL test showed significant differences, favoring the TRX group's greater improvement. A potential reason for this discrepancy could be that during Swiss ball training, some participants' limbs are supported by the ball, potentially reducing core muscle activation due to the loading of body weight on the ball surface. Conversely, TRX training utilizes gravity as resistance, reducing the base of support and potentially enhancing muscle engagement thereby increasing muscle stability in the long term.[51]

Moreover, this study also found that both TRX and Swiss ball training increased core muscle strength and stability, as supported by the plank test. Several studies have suggested the effective activation of superficial core muscles through plank exercises.[16,50,52] This aligns with our findings, indicating that both TRX and Swiss ball training effectively enhance superficial core muscle capabilities. However, further research integrating electromyography could provide insights into deep versus superficial core muscle activation during different exercise modalities, warranting further exploration.

Additionally, the inclusion of average change percentages provided valuable insights into the magnitude of improvements. Notably, the TRX group demonstrated a substantially higher average change percentage in MDLL compared with the Swiss ball group. This indicates that TRX suspension training resulted in a more distinct enhancement in trunk stability over the training period. Such quantitative measures offer a nuanced understanding of the differential impacts of training methods.

Previous research indicates that core muscle training on unstable surfaces enhances core strength, supporting our current findings on the efficacy of Swiss ball and TRX training in enhancing core stability. These interventions are crucial in ensuring trunk stability, refining movement dynamics, and reducing injury risks during athletic activities.[13,15,21] Specifically, studies employing Swiss ball training programs have shown significant enhancements in core stability.[13,17,18] Similarly, studies focusing on suspension training methods, particularly TRX training, reported improvements in core muscle abilities, such as the MDLL task score, and plank endurance.[12,53] These findings are aligned with current work, highlighting the need for core muscle intervention training during the preseason to potentially elevate fitness levels and enhance athletic performance. Nevertheless, it would be valuable to explore the retention effects in the future.

The study showed no significant improvement in speed and ankle proprioception after 8 weeks of training. This aligns with previous research indicating that while core stability improved, it did not immediately transfer to speed or other athletic capabilities.[54,55] Additionally, several studies have found that core stability training often involves low-load, slow-motion exercises, differing from high-load, high-speed actions typical in sports training.[56] As such, the immediate translation of core stability improvements to athletic abilities might be limited.[57]

Furthermore, exploring the impact on ankle proprioception had minimal improvements, suggesting that core muscles might not have a direct influence on ankle balance control in the short time, especially where ankles are more distal from the core.[58] Future research could delve into exploring hip muscle activation patterns or joint biomechanics to potentially enhance this specific capability as hips are closer to the core compared with ankles.

Finally, it is important to acknowledge certain limitations of the study, such as the relatively short intervention period and the focus on specific athletic performance measures. Future research could explore the long-term effects of these training methods and consider a broader range of performance indicators. Furthermore, our study primarily assessed core strength and stability using the plank test and did not directly measure core strength through force production or using electromyography. Future research could incorporate direct measurements of core strength to provide a more comprehensive understanding of the effects. Future research could also explore the impact of core stability interventions on reducing injury rates to comprehensively assess their benefits. Moreover, we did not specifically assess lower limb strength and explosive power in this study. Even though our focus was on trunk stability, and core muscle training, and their effects on overall athletic performance, future research could incorporate direct measurements of these variables to provide a more comprehensive evaluation. Additionally, our findings may have limitations in generalizing to broader basketball populations. Nevertheless, the findings contribute valuable information on the effects of core stability training in elite adolescent female basketball players. Future research can explore similar interventions across diverse athlete demographics to compare outcomes and expand the understanding of these training methods' efficacy.

Indeed, in high-intensity group sports like basketball, which demand strength, speed, and coordination, effective strategies to enhance athletic performance and prevent injuries are crucial. Core stabilization, integral to maintaining balance and stability, offers benefits that extend beyond physical fitness, including injury prevention and performance enhancement. Based on the findings, we suggest that coaches could incorporate Swiss ball and TRX suspension training into preseason regimens to enhance trunk stability and may potentially improve overall athletic performance. These methods can be particularly effective in high-performance settings where injury prevention is critical. To maximize benefits, training programs should balance core stability exercises with traditional technical and high-speed drills to ensure improvements in core strength translate to better performance on the court. Emphasizing core stability and ankle proprioception in training can reduce the risk of lower limb injuries, including ACL injuries, which are prevalent among basketball players. Regular assessment of trunk stability and other performance-related outcomes using tools, such as the MDLL, and plank tests could help track progress and adjust training interventions for optimal results. Given the specific needs of elite athletes, tailored programs that address both performance enhancement and injury prevention are essential. This study provides a useful strategy for developing such programs and highlights the potential of core muscle training to optimize performance and reduce injury risks in adolescent female basketball players.

## Conclusions

This study demonstrates that both TRX and Swiss ball core muscle training methods enhance trunk control in elite female basketball players. Understanding these training methods can inform tailored preseason programs emphasizing core stability for injury prevention and performance enhancement. Importantly, no negative impact on athletic performance was observed, suggesting potential benefits from reallocating training time to core exercises without compromising performance. Incorporating these unstable core muscle training methods may enhance power transmission and injury prevention for players. Careful consideration of timing and intensity is recommended for preseason training focused on physical function and ankle proprioception.

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