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# EFFECTS OF 360° TITANIUM CORE STRENGTH EXERCISE© ON PHYSICAL PERFORMANCES AND LOW BACK PAIN IN AMATEUR TABLE TENNIS PLAYERS

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**Abstract**
This study investigated the effects of the 360° TitaniUM Core Strength Exercise© on the physical performances of amateur table tennis (TT) players within the Malaysian public sector and its potential to reduce the risk of low back pain (LBP). Twenty participants were recruited from various government departments in Negeri Sembilan. They were randomly assigned to either the core exercise group (CE) or the control group (CON). The CE group underwent a six-week intervention featuring the 360° TitaniUM Core Strength Exercise©, while the CON group followed their usual routine. Physical performances were assessed using isometric endurance, flexibility, strength, balance, and stability tests, whereas LBP was measured through the Visual Analog Scale (VAS). The results exhibited significant improvements in CE group's isometric endurance, flexibility, and strength ($p < .05$), along with notable enhancements in trunk balance and stability. Furthermore, the CE group demonstrated a trend towards reduced LBP risk as indicated by VAS scores ($p < .05$). These findings suggest that the 360° TitaniUM Core Strength Exercise© holds promise for enhancing physical performances and potentially mitigating LBP among amateur TT players in the Malaysian public sector. Further research could explore long-term effects and its potential applications across diverse populations and sports disciplines.

**Keywords:** 360° TitaniUM Core Strength Exercise©, core training, physical performances, low back pain, amateur table tennis players

## Introduction
Table tennis (TT) is a globally popular indoor racket sport enjoyed for leisure, exercise, and competition. Known for its rapid, repetitive movements, quick reflexes, coordination, and agility, TT is considered one of the fastest sports due to its short table distance and high-speed ball (1). During gameplay, players must react quickly to the flying ball, with only a fraction of a second to evaluate each stroke. In order to do so, players often assume a ready position characterized by a kyphotic body posture, involving flexed upper and lower limbs, a leaned-forward torso, and weight placed on the forefoot (2, 3). However, maintaining this position for extended periods of time during matches and training sessions can lead to overuse injuries, particularly in the lower back region.

Despite TT's popularity, previous studies have primarily focused on commonly affected sites such as the shoulders and knees, neglecting the lower back (4, 5). The repetitive nature of TT makes players more susceptible to developing muscle imbalance than non-players (6). The sport's demanding nature involving whole-body coordination, repetitive forearm movements, and prolonged trunk asymmetrical muscle work, significantly loads one side of the body. These motions, including rapid twisting, bending, and turning, generate high-impact force through trunk flexion and extension, which can lead to stress and strain on the lower back muscles (7).

The erector spinae, multifidus, latissimus dorsi, and spinalis muscles in the lower back region and also the obliques and transverse abdominis in the abdominal region play a vital role as a "core" in stabilizing the spine and maintaining proper posture during TT. Overloading or underuse of these muscles can result in musculoskeletal disorders and increase the risk of developing low back pain (LBP) (2). A study by Bankosz and Barczyk-Pawelec (8) discovered that approximately 32% of players experienced frequent or very frequent LBP, often occurring during gameplay or immediately after training. This can be attributed to the excessive workload on the lower back muscles due to prolonged training hours and the need to adopt a forward-inclined trunk position for frequent, repetitive, and intensive torsional movements. Additionally, players of different skill levels, especially amateurs, may employ their unique techniques and patterns, and incorrect techniques can alter joint mechanics and loadings, eventually leading to LBP over time (9).

Previous studies have emphasized the significance of physical conditioning in preventing injuries and enhancing the performance of TT players (1, 10, 11). Kondrič and coworkers (1) recommended integrating physical conditioning into the regular training regimen, particularly focusing on exercises targeting the lower back muscles, core stability, and upper body strength. Given the physical demand of TT which require a good physical capacity, a combination of balance, coordination, endurance, stability, and strength is necessary. Therefore, it is imperative to develop a training program that concurrently improves all these specific aspects of physical conditioning to minimize injuries and optimize performance.

Core exercise is an emerging training modality that addresses the specific needs of TT players by strengthening the core muscles for optimal momentum, power, and kinetic chain stabilization during functional exercises (12, 13). It has been widely applied in other sports where studies have shown that core exercises significantly enhance body control and balance, increase power output from both the core musculature and peripheral muscles such as the shoulders, arms, and legs, ultimately reduce the risk of injury (14, 15). However, there is currently limited research on the use of core exercises to strengthen the core muscles in order to counteract asymmetry or postural defects in TT.

Therefore, the purpose of this study is to investigate the effects of a new sequence of core strengthening exercises, known as the 360° TitaniUM Core Strength Exercise© on physical performances among the amateur TT players. The hypothesis is that a 6-week of comprehensive core strengthening exercises can significantly reduce the risk of LBP (pain score) and improve multiple physical performances (such as endurance, strength, flexibility, and stability) in this population.

## Methods

Ethic statement

In accordance with the ethical guidelines, this study obtained approval from the Ethics Committee for Research involving Human Subjects at Universiti Putra Malaysia (Approval No. JKEUPM-2021-845).

Participants

The study specifically focused on individuals affiliated with the Malaysian public sector who showed a moderate level of physical activity according to the International Physical Activity Questionnaire (IPAQ). These participants were also involved in occasional TT activities, making them eligible for inclusion as amateur TT players. The recruitment and testing were conducted during the pre-competition training camp for National Public Services Commission Sport Carnival, held between September and October 2022. Prospective TT players were approached and invited to participate, and those who agreed were included in this study. A total of twenty amateur TT players from various government departments in Negeri Sembilan voluntarily enrolled in this study (Fig. 1). The study employed a parallel design, where participants were randomly assigned to either the core exercise group (CE) or the control group (CON) using a computer-generated randomization list (16). Prior to data collection, participants were provided with comprehensive information regarding the intervention procedures and were required to provide written consent.

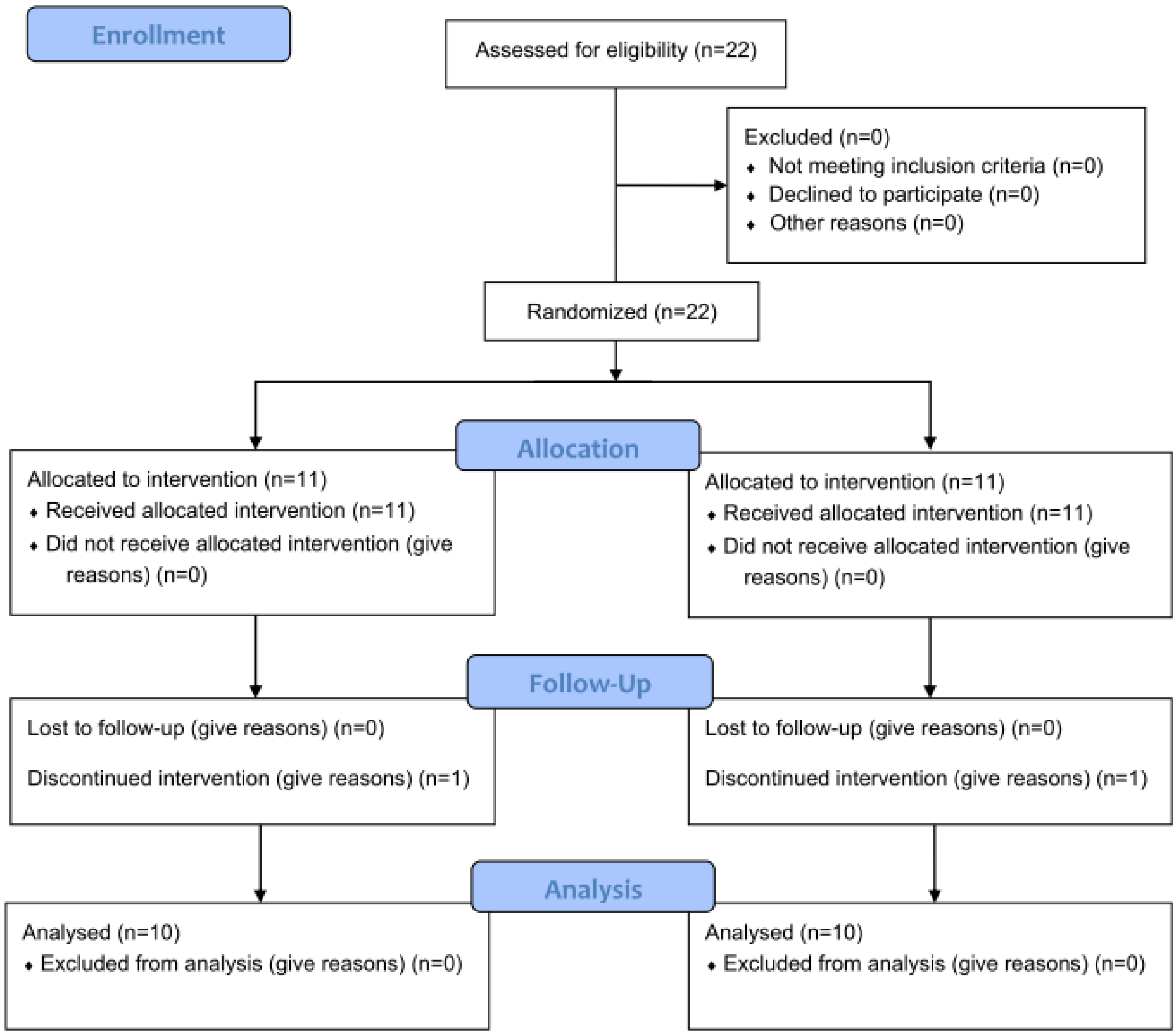



**Fig. 1:** CONSORT participant flow chart.

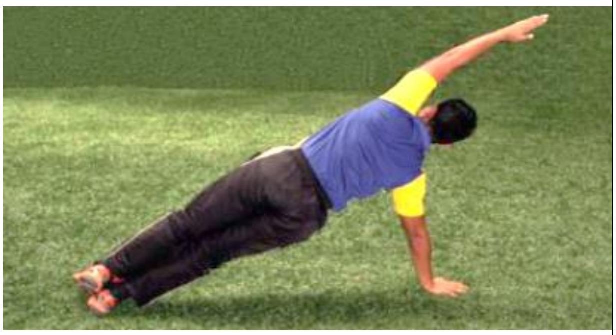
**Overview of procedures**

The testing and intervention procedures were conducted at the Sports Council of Negeri Sembilan. The intervention program carried out for six weeks, with participants engaging in three training sessions per week on Monday, Wednesday, and Friday. Each session lasted approximately 20 minutes, resulting in a total of 18 completed training sessions. All training sessions were conducted in the evening following a warm-up and prior to the commencement of gameplay.

During each training session, participants in the CE engaged in the 360° TitaniUM Core Strength Exercise©, while participants in the CON continued with their regular gameplay. The 360° TitaniUM Core Strength Exercise© was designed to strengthen up 29 pairs of core muscles, including the frontal abdominal muscles (rectus and transverse abdominis, internal and external obliques, adductors), back muscles (paraspinals and gluteals), and deep abdominal muscles (iliopsoas, iliacus, quadratus lumborum). The core exercises comprised of a sequence of twelve isometric exercises, as depicted in

Fig.2: (1) Both elbow prone bridge, (2) Right elbow lateral bridge, (3) Both legs supine bridge, (4) Left elbow lateral bridge, (5) Both hand prone bridge, (6) Right hand lateral bridge, (7) Left leg up supine bridge, (8) Right leg up supine bridge, (9) Left hand lateral bridge, (10) Alternate left hand and right leg, (11) Alternate right hand and left leg, and (12) Superman.

| | |
|---|---|
| 1. Both Elbow Prone Bridge<br>Lie on your stomach. Raise your body up so that you are resting on your forearms and elbows. Align your head and neck with your back and place your shoulders directly above your elbows. Tighten the abdominal muscles. | 2. Right Elbow Lateral Bridge<br>Lie on your right side, raising your body resting onto your right elbow and forearm. Rest your right arm along the side of your body. Place your left shoulder and arm directly above your right elbow, keep your shoulders, arm, hips, and knees in alignment. Tighten your abdominal muscles. |
|  |  |
| 3. Both Legs Supine Bridge<br>Lie on your back with your knees bent (45° off ground). Keep your back in a neutral position, not arched and not pressed on the ground. Avoid lifting your hips. Straighten your hands on the ground pointing away from your head. Slowly raise your hips off the ground until your hips are aligned with your knees and shoulders. Tighten the abdominal muscles. | 4. Left Elbow Lateral Bridge<br>Lie on your left side, raising your body resting onto your left elbow and forearm. Rest your left arm along the side of your body. Place your right shoulder and arm directly above your left elbow, keep your shoulders, arm, hips, and knees in alignment. Tighten the abdominal muscles. |
|  |  |

| | |
|---|---|
| 5. Both Hand Prone Bridge<br>Lie on your stomach. Raise your body up so that you are resting on your palms. Align your head and neck with your back and place your shoulders directly above your palms. Tighten your abdominal muscles.<br> | 6. Right Hand Lateral Bridge<br>Lie on your right side. Then, slowly raise and balance yourself supported by your right forearm and arm. Place your left shoulder and arm directly above your right forearm, keeping your left shoulder, arm, hips, and knees in alignment. Tighten your abdominal muscles.<br> |
| 7. Left Leg Up Supine Bridge<br>Lie on your back with your knees bent (45° off ground). Keep your back in a neutral position, not arched and not pressed on the ground. Avoid lifting your hips. Straighten your hands on the ground pointing away from your head. Slowly raise your hips off the ground until your hips are aligned with your knees and shoulders. Tighten your abdominal muscles. Then raise your left leg off the ground in alignment with your head, chest, and hip.<br> | 8. Right Leg Up Supine Bridge<br>Lie on your back with your knees bent (45° off ground). Keep your back in a neutral position, not arched and not pressed on the ground. Avoid lifting your hips. Straighten your hands on the ground pointing away from your head. Slowly raise your hips off the ground until your hips are aligned with your knees and shoulders. Tighten your abdominal muscles. Then raise your right leg off the ground in alignment with your head, chest, and hip.<br> |

| | |
|---|---|
| 9. Left Hand Lateral Bridge<br>Lie on your left side. Then, slowly raise and balance yourself supported by your left forearm and arm. Place your right shoulder and arm directly above your left forearm, keeping your right shoulder, arm, hips, and knees in alignment. Tighten your abdominal muscles. | 10. Alternate Left Hand and Right Leg<br>Start on your hands and knees on the ground. Place your right hand directly below your shoulder and align your head and neck with your back. Raise your right leg off the ground then slowly raise your left arm. Tighten your abdominal muscles. |
|  |  |
| 11. Alternate Right Hand and Left Leg<br>Start on your hands and knees on the ground. Place your left hand directly below your shoulder and align your head and neck with your back. Raise your left leg off the ground then slowly raise your right arm. Tighten your abdominal muscles. | 12. Superman<br>Lie on your stomach. Raise all your limbs i.e., your arms and legs off the floor. Tighten your abdominal muscles. |
|  |  |

**Fig.2**: Sequence of performing the 360° TitaniUM Core Strength Exercise©.

Participants in the CE gradually increased the duration of each exercise from 10 seconds to 20 seconds throughout the course of the intervention period, as specified in Table 1. Close monitoring was maintained during the training sessions to ensure proper technique and timing of each exercise.

Both groups underwent before (pre-) and after (post-) intervention testing to assess the effectiveness of the six-week intervention. The assessment batteries included the Visual Analogue Scale (VAS), Prone Double Straight Leg Raise (PDSLR), Unilateral Hip Bridge Endurance (UHBE), Curl-Up (CU), and Sit-and-Reach (SNR). These measures served as the primary outcomes of the study.

**Table 1:** Schedule of Performing the 360° TitaniUM Core Strength Exercise©

| Intervention Period | Frequency | Duration | Set |
|---|---|---|---|
| Week-1 & week-2 | 3 sessions/week | 10 seconds/exercise | 3 |
| Week-3 & week-4 | 3 sessions/week | 15 seconds/exercise | 3 |
| Week-5 & week-6 | 3 sessions/week | 20 seconds/exercise | 3 |

**Testing protocols**

The testing procedures began with a pain assessment using the VAS, where participants rated their level of LBP on a scale ranging from 0 (no pain) to 10 (unbearable pain) (17).

The PDSLR test was administered to evaluate trunk extensor performance, a reliable and effective measures of isometric endurance in the lower spinal extensor muscles (18). Participants assumed in a prone position with extended hips, placing their hands placed under their forehead, and positioning their forearms perpendicular to the body. They were then raised both legs until knee clearance and held this position for as long as possible while the time was recorded.

Core strength was assessed using the CU test, a straightforward and efficient evaluation method suitable for large groups. Participants laid supine with their knees flexed at a 90-degree angle, ensuring comfortable placement of their feet flat on the floor, approximately 12 inches away from their buttocks. A partner provided assistance by anchoring the participants' feet to the ground. With arms crossed flat over chest, participants raised their trunk to a 30-degree angle, touching their elbows to their thighs, and then slowly lowered their trunk back to the floor until their shoulder blades (upper back) touched the floor (19). The maximum number of correctly performed CU repetitions within a one-minute timeframe was recorded.

Core stability was measured using the UHBE test, a reliable and valid measure commonly employed to evaluate muscle capacity and neuromuscular control in the core region, specifically targeting the lumbar multifidus and erector spinae muscles (20). Participants were instructed to assume a single-leg bridge position with their arms crossed over their chest, while maintaining a neutral hip and pelvic position, for as long as possible while the time was recorded. If a change in alignment exceeding 10 degrees was observed, the test was concluded. The test was repeated once for each leg, and the duration from the two trials was recorded.

The SNR test was implemented to quantify the flexibility of the lower back. In this test, participants assumed a seated position on the floor with their legs extended and their feet positioned against a box. They were instructed to reach forward with their hands as far as possible. The test was performed twice, and the average score from the two attempts was recorded. Clinical research has established a positive association between higher SNR scores and increased lower back extensibility and flexibility (21).

**Data Analysis**

A Split Plot Analysis of Variance (SPANOVA), also referred as a mixed design (within-group between-group ANOVA), was employed to analyze the collected data. Statistical analysis was conducted using the Statistical Package for Social Sciences version 26.0 (SPSS Inc, Chicago, IL, USA). Assumptions of normality, linearity, and homoscedasticity were assessed for all data, and the equality of variances was determined through spread-level plots and Levene's test. The homogeneity of inter-correlations was examined using the Box's M statistic for multivariate tests. Multiple comparisons were adjusted using Bonferroni correction. The effect size of the observed differences was calculated using partial eta-squared ($\eta p2$), which provides a measure of the magnitude and practical significance of the effects (22). The values of $\eta p2$ were interpreted as follows: values ranging from 0.01 to 0.06 indicated a small effect, values from 0.06 to 0.14 indicated a moderate effect, and values of 0.14 or greater indicated a large effect. All tests were two tailed with an alpha significance level of .05. The data were presented as mean±SD.

## Results

Eleven participants were assigned to the CE group, and 11 participants were assigned to the CON group, resulting in a total of 22 participants. However, a total of 20 participants completed the study, resulting in a successful completion rate of 90%. Two participants withdrew from the study, one from the CE group due to a busy work schedule and one from the CON group who was admitted to the hospital for appendicitis. The participants demographic characteristic is summarized in Table 2.

**Table 2**: Demographic data of participants (CE, n=10; CON, n=10).

| Descriptions | CE (Mean±SD) | CON (Mean±SD) | *p*-value |
|---|---|---|---|
| Age (years) | 44.20±10.89 | 47.80±10.04 | .863 |
| Sport experience (years) | 18.10±10.70 | 29.60±11.90 | .902 |
| Height (cm) | 160.70±7.04 | 168.60±5.06 | .457 |
| Weight (kg) | 72.89±17.71 | 88.95±12.18 | .136 |
| Body mass index (kg/m$^2$) | 28.27±7.20 | 31.40±4.95 | .256 |
| IPAQ (MET.min.wk$^{-1}$) | 1935.6±2035.85 | 800.7±1758.32 | .399 |

Prior to the intervention, there were no statistically significant differences between the CE and CON groups in most of the test parameters ($p > .05$), except for the VAS and SNR, which exhibited significant group differences ($p < .05$). Following the intervention, a significant within-group interaction effect was observed for the PDSLR test, in which the CE group demonstrated a substantial 91.13% improvement in PDSLR time compared to a more modest increase of 34.56% in the CON group, with a large effect size ($\eta 2 = 0.322$).

Although post-hoc analysis indicated improvements in the CE group for SNR (10.87%), UHBE (31.29%), and CU (16.51%), these changes were not statistically significant, and no significant interaction effects were observed ($p > .05$). However, the effect sizes for these findings were moderate to large, indicating meaningful practical significance despite the lack of statistical significance. The results for the performance outcomes following the 6-week intervention in the CE and CON groups are presented in Table 3 and 4, respectively. Visually comparisons of performances between the groups before and after the interventions are illustrated in Fig. 3 to Fig. 7.

**Table 3:** Pretest and posttest results for physical performance following 6-week of intervention in the CE group (n = 10) and the CON group (n = 10).

| | Group | Pre-test (Mean±SD) | Post-test (Mean±SD) | % of change |
|---|---|---|---|---|
| VAS | EX | 1.40±1.66 | 0.30±0.42 | -78.57 |
| | CON | 1.00±1.27 | 1.80±2.14 | 80 |
| SNR | EX | 25.03±7.68 | 27.75±7.30 | 10.87 |
| | CON | 21.41±4.81 | 20.77±4.57 | -2.99 |
| PDSLR | EX | 43.96±30.17 | 84.02±65.70 | 91.13 |
| | CON | 38.40±26.72 | 51.67±32.04 | 34.56 |
| UHBE | EX | 47.37±22.85 | 62.19±30.51 | 31.29 |
| | CON | 51.95±34.33 | 61.25±48.75 | 17.90 |
| CU | EX | 21.80±9.99 | 25.40±13.11 | 16.51 |
| | CON | 22.70±6.83 | 20.20±10.58 | -11.01 |

**Table 4:** The SPANOVA results for physical performance following 6-week of intervention in the CE group (n = 10) and the CON group (n = 10).

| Test | Predictor | Wilks' lambda | *F* | *p* | η2 |
|---|---|---|---|---|---|
| VAS | Time (pre-test vs. post-test) | 0.988 | 0.216 | .648 | 0.012 |
| | Time*group (intervention vs. control) | 0.675 | 8.664 | < .05 | 0.325* |
| SNR | Time (pre-test vs. post-test) | 0.878 | 2.502 | .131 | 0.122 |
| | Time*group (intervention vs. control) | 0.734 | 6.507 | < .05 | 0.266* |
| PDSLR | Time (pre-test vs. post-test) | 0.678 | 8.548 | < .05 | 0.322** |
| | Time*group (intervention vs. control) | 0.893 | 2.156 | .159 | 0.107 |
| UHBE | Time (pre-test vs. post-test) | 0.814 | 4.12 | .057 | 0.186 |
| | Time*group (intervention vs. control) | 0.988 | 0.216 | .648 | 0.012 |
| CU | Time (pre-test vs. post-test) | 0.995 | 0.093 | .763 | 0.005 |

| | | | | | |
|---|---|---|---|---|---|
| | Time*group (intervention vs. control) | 0.862 | 2.875 | .107 | 0.138 |

η2, effect size measured by partial eta squared.
*Significant difference between groups.
**Significant interaction within group.

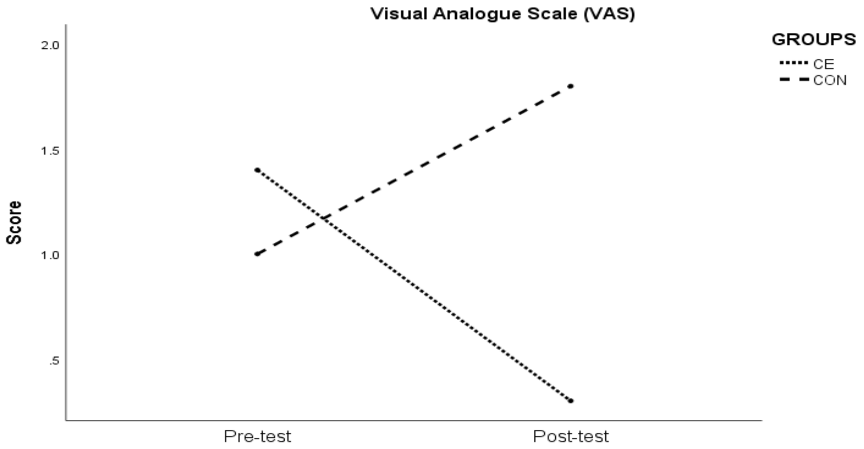



**Fig.3:** The VAS results, CE, core exercise group; CON, control group.

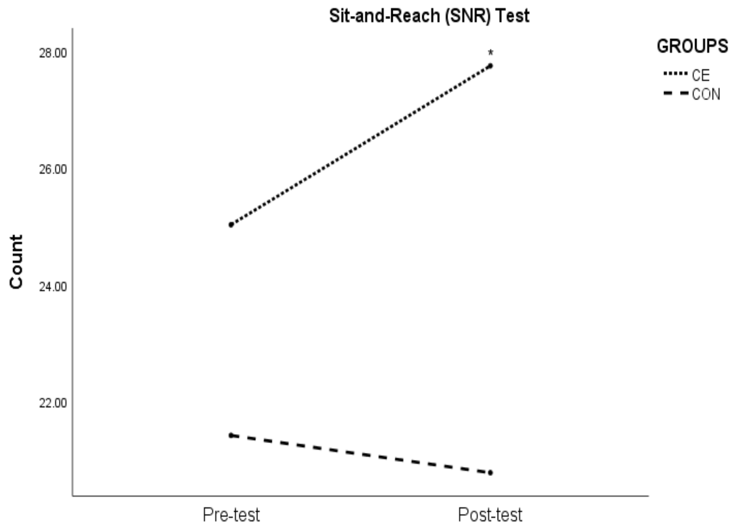



**Fig.4:** The SNR test results, CE, core exercise group; CON, control group.
*Significant difference between baseline and post training.

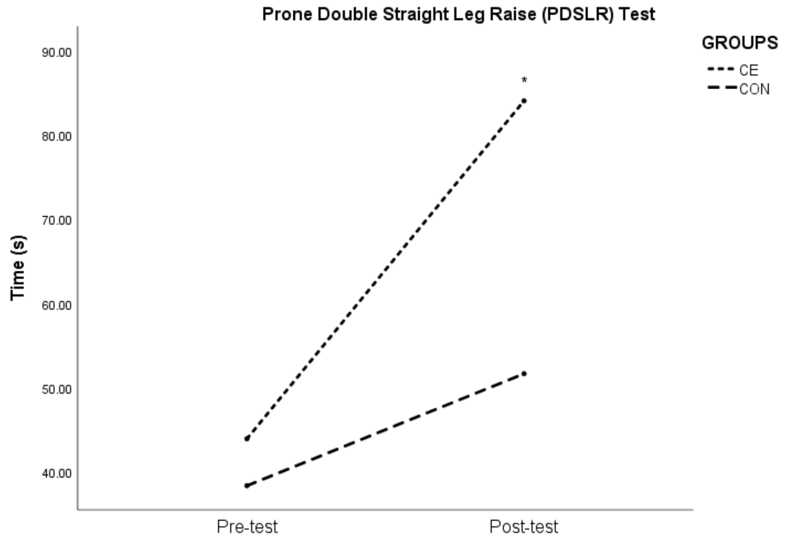



**Fig.5:** The PDSLR test results, CE, core exercise group; CON, control group.
*Significant difference between baseline and post training.

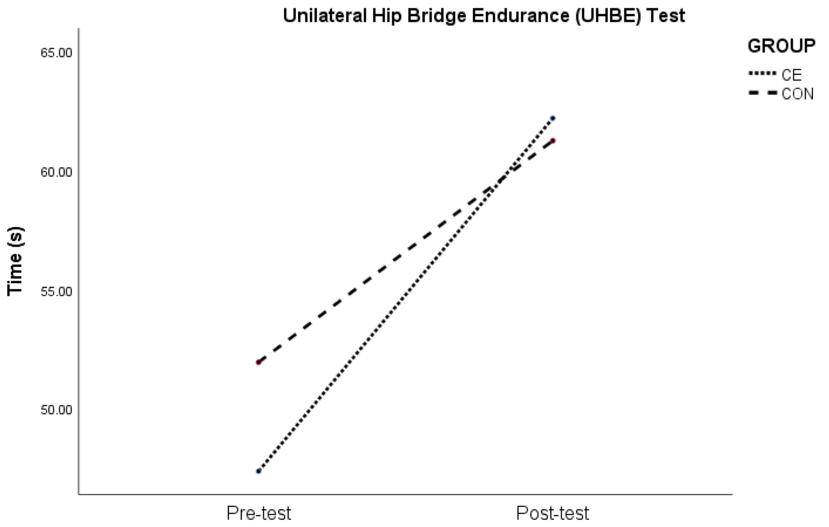



**Fig.6:** The UHBE test results, CE, core exercise group; CON, control group.

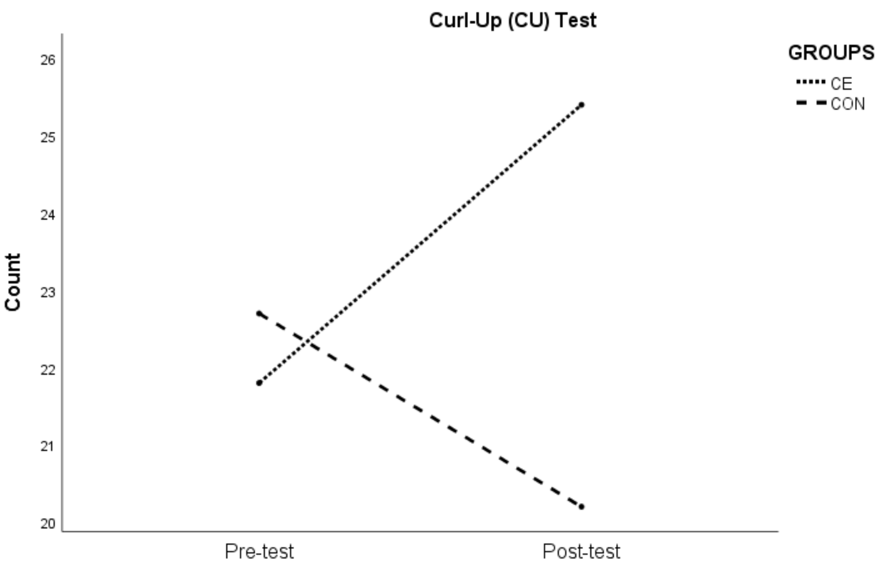


**Fig.7:** The CU test results, CE, core exercise group; CON, control group.

**Discussion**

This study represents a novel exploration of the effects of a newly designed sequence of core strengthening exercises, known as the 360° TitaniUM Core Strength Exercise©, on the physical performance of amateur TT players. To date, no prior research has delved into the specific repercussions of this exercise regimen on TT players. The 360° TitaniUM Core Strength Exercise© introduces as an emerging core training modality that intricately targets 29 pairs of core region muscles, eliciting a more profound augmentation of muscle mass, particularly emphasizing the deep stabilizing muscles, in contrast to conventional exercise modalities (23).

The outcomes obtained from this study offer valuable insights and, in part, lend credence to our hypothesis. The findings underscore the noteworthy potential of the 360° TitaniUM Core Strength Exercise© that significantly mitigating the risk of LBP while concurrently enhancing the endurance, flexibility, and strength attributes of players. This assertion is substantiated by the discernible improvements observed in the VAS, SNR, and PDSLR test results. These outcomes are in line with a recent study conducted by Meng and Bu (13), which discovered that TT players who underwent core strengthening exercises exhibited significant performance improvements following a 9-week training regimen, in comparison to those without any specific training. Our study shares similarities with this prior study, in terms of the application of core exercises such as the prone elbow bridge and lateral elbow bridge. These exercises not only fortify the deep stabilizing muscles but also synergize to enhance overall core muscle capability. This comprehensive approach augments the harmonious integration of the local, single-joint, and multi-joint muscles, fostering an enhanced ability to exert motor control by stabilizing the center of gravity. This, in turn, enables robust power transmission during dynamic movements in TT.

Our findings find further validation in the study conducted by Luo and team (24), which demonstrated the efficacy of core training in strengthening core muscles across various sports, leading to improvements in muscle strength, endurance, balance, stability, and coordination. The core assumes a pivotal role in optimizing the coordinated and efficient transmission of strength, resulting in powerful and effective movements. Additionally, strong core muscles contribute to the reduction of stress on the spine by distributing it uniformly, particularly when compared to activities involving swinging motions. Notably, the abdominal muscles, including the transverse abdominis, rectus abdominis, external oblique, internal oblique, erector spinae, quadratus lumborum, and latissimus dorsi, significantly contribute to rotational movements and the control of external forces that induce spinal rotation. As central hubs in the biological motor chain, robust core muscles facilitate limb strength and foster seamless cohesion, transmission, and integration of movements between upper and lower limbs. Hence, core training presents as a valuable approach to enhance athletic performance by fortifying the core region to improve overall physical capabilities.

The literature consistently highlights the crucial role of robust core muscles in mitigating the risk of LBP (25). Weak core muscles contribute to a diminished anticipatory capacity within the hip and trunk muscles, thereby compromising segmental protective function, and increasing the risk of LBP. This notion gains further support from the study by Narouei *et al.* (26), wherein individuals with LBP engaged in a core exercise program experienced significant reductions in both LBP and disability. Notably, these individuals exhibited an increase in activity and thickness of key core muscles, including the transversus abdominis, multifidus, and gluteus maximus. These findings highlighted the effectiveness of core exercises in strengthening both the trunk and hip muscles, thereby amplifying the capacity of segmental muscles to furnish structural support and stability to the lumbar region. As a consequence, this improvement directly correlates with a reduced risk of LBP and heightened physical performances.

The CE group exhibited significant enhancements in isometric endurance, flexibility, and strength, suggesting a plausible mechanism for mitigating the risk of LBP, as indicated by the VAS. These positive improvements can be attributed to the targeted reinforcement of core muscle mass through the innovative 360° TitaniUM Core Strength Exercise©, where this exercise regimen engages and promotes the integrity and function of 29 pairs of core region muscles, contributing to a reduced susceptibility to LBP. These findings harmonize with recent research by Gil-Gutiérrez *et al.* (27), highlighting the positive correlation between muscle mass and pain reduction. Increased muscle mass inherently enhances muscle strength and provides natural support to surrounding tissues and structures, thereby diminishing strain and the potential for injury. Moreover, the strengthening of core muscles aids in the distribution of forces and the maintenance of proper spinal alignment, effectively alleviating strain on the lower back, and consequently diminishing the risk of discomfort or injury. This perspective also finds further reinforcement from our preceding study, where individuals afflicted with LBP and engaged in the 360° TitaniUM Core Strength Exercise© displayed a significant improvement in both pain intensity and trunk extensor performances (28).

In this study, although the UHBE and CU tests did not demonstrate statistically significant improvements following the core exercise training, it is important to highlight the substantial performance enhancements observed in both measures – a notable 31.29% improvement in UHBE and a commendable 16.51% enhancement in CU performance following the intervention period. These findings evoke intriguing parallels with a study conducted by Lim *et al.* (23), which demonstrated significant progress in balance and stability among adolescents after a 12-week regimen featuring the 360° TitaniUM Core Strength Exercise©. The outcomes highlight the intricate interplay between core strength, balance, and stability. The prevailing body of evidence points to the significance of a strong core in maintaining dynamic stability. Weakness in the trunk muscles has been associated with muscle fatigue and compromised dynamic stability within the core region, potentially leading to compromised balance and impaired motor control of the trunk (29). The observed improvements in the UHBE and CU performance, even in the absence of statistical significance, may serve as indicators of a promising trend towards enhanced core stability and motor control, aligning harmoniously with the findings of the study by Lim *et al*. These observations suggest that while statistical significance may not have been attained, the practical implications of these performance enhancements could have meaningful implications for the functional capacities, balance, and overall movement control for the players.

Despite the valuable insights gained from this study, it is essential to acknowledge several limitations. Firstly, the intervention period of this study was limited to six weeks, which, while sufficient to observe significant improvements, may not fully capture the potential long-term effects or sustainability of the observed enhancements over an extended timeframe. Moreover, although various outcome measures were used to evaluate the intervention's effects, the inclusion of additional lab-based biomechanical measures, such as electromyography or isokinetic dynamometer assessments, could offer deeper insights into the physiological and functional changes resulting from the core training. Such in-depth analyses would provide a more comprehensive understanding of the underlying mechanisms contributing to the observed improvements. Lastly, it is important to recognize that the outcomes observed among amateur players in this study may not directly translate to elite athlete. Elite players often undergo distinct and rigorous training regimens, and they possess varying levels of physical conditioning and skill proficiency. As a result, the findings of this study may be more applicable and offer practical insights and guidance to recreational practitioners and individuals engaged in amateur sport.

## Conclusion

This study provides valuable insights into the effects of the 360° TitaniUM Core Strength Exercise© on amateur TT players' physical performances. The core exercise training demonstrated significant improvements in isometric endurance, flexibility, and strength, complemented by notable enhancements in trunk balance and stability. These positive outcomes suggest that strengthening core muscle mass through this comprehensive exercise regimen could serve as a potential mechanism for reducing the risk of LBP in this population. The observed enhancements in overall muscular integrity and function, underscore the significance of core training as an effective approach to optimize physical performance and potentially mitigate the vulnerability to LBP. Looking ahead, future research should explore the applicability of this exercise regimen to diverse populations and across various athletic disciplines. Investigating the long-term effects of this training modality would also provide a more comprehensive understanding of its potential impact on physical performance and injury prevention.

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