

Effects of an 8-week mat Pilates intervention on trunk strength and core endurance in pre-pubertal male soccer players: A randomized controlled trial

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Abstract

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Aim: This study investigated the effects of an 8-week Mat Pilates intervention, performed in addition to regular soccer training, on trunk strength, muscular endurance, and core stability in pre-pubertal male soccer players. **Method:** Forty boys aged 11–13 years were randomly assigned to a Pilates group ($n = 20$) or a control group ($n = 20$). Both groups continued their standard soccer training three times per week, while the Pilates group additionally completed supervised Mat Pilates sessions twice weekly for eight weeks. Maximal isometric back and leg strength was assessed using dynamometry, dynamic abdominal endurance via a sit-up test, and static core stability using the prone plank test before and after the intervention. **Results:** Data were analyzed using a 2×2 mixed-model ANOVA with Bonferroni-adjusted post-hoc analyses. A significant Group \times Time interaction was observed for isometric strength ($p = .018$, $\eta p^2 = 0.184$), with the Pilates group demonstrating a significant increase from pre- to post-test, whereas no meaningful change occurred in the control group. For abdominal endurance, a significant main effect of time was found ($p < .001$), indicating improvements in both groups, but no interaction effect was detected. **Conclusion:** Static core stability showed a positive trend in the Pilates group; however, the interaction did not reach statistical significance.

Introduction

Soccer is a multifaceted team sport that imposes high physiological demands on players, requiring a complex interaction of aerobic capacity, speed, agility, and muscular strength (Stølen et al., 2005). In modern soccer, executing fundamental technical skills such as shooting, passing, and tackling under competitive pressure heavily depends on the biomechanical efficiency of the kinetic chain. The lumbopelvic-hip complex (LPHC), widely referred to as the "core," functions as the anatomical fulcrum of this chain. It facilitates the transfer of torques between the lower and upper extremities while stabilizing the spine against the high rotational forces inherent to the sport (Kibler et al., 2006). Consequently, deficits in core muscle function can impair force transmission and increase mechanical loading on distal joints, thereby elevating the risk of lower extremity injuries (Prieske et al., 2016). Recent reviews have further underscored that optimized core stability is not only injury-protective but also a prerequisite for maximizing physical performance in

youth soccer players (Negra et al., 2021; Yılmaz et al., 2025; Yılmaz et al., 2023).

From a developmental perspective, the pre- and early-pubertal years (ages 11–13) are identified within Long-Term Athletic Development (LTAD) models as a critical "window of opportunity" for establishing fundamental movement patterns and structural strength (Lloyd & Oliver, 2012). While core conditioning is a standard component of youth soccer curricula, the optimal training modality for this specific age group remains a subject of debate. The Pilates method, characterized by its focus on deep muscle recruitment (such as the transversus abdominis and multifidus), controlled breathing, and lumbopelvic stability, offers a distinct alternative to traditional high-volume calisthenics (Wells et al., 2012). Unlike exercises that isolate the rectus abdominis in a single plane, Mat Pilates emphasizes anti-rotation and the dissociation of limb movements from a stable trunk, theoretically aligning well with the unilateral and multi-planar nature of soccer actions (Cruz-Ferreira et al., 2011). Indeed, a systematic review by González-Gálvez et al.

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(2019) highlighted that Pilates interventions in youth populations significantly improve flexibility and muscular endurance, yet called for more sport-specific randomized controlled trials.

Despite the widespread adoption of Pilates in rehabilitation and adult fitness, there is a paucity of experimental research examining its efficacy in youth performance settings. While recent studies have demonstrated positive effects of Pilates on kicking accuracy and dynamic balance in adult or late-adolescent soccer players (Yılmaz et al., 2025), data regarding pre-pubertal cohorts remain scarce. Specifically, it remains unclear whether an 8-week field-based Mat Pilates protocol can induce significant adaptations in maximal isometric strength and core endurance in this specific population.

Therefore, the primary objective of this study was to evaluate the effects of an 8-week Mat Pilates intervention, performed in addition to standard soccer training, on strength and endurance parameters in 11–13-year-old male soccer players. To capture a functional profile of the athletes, this study utilized a battery of field-based tests assessing maximal isometric back and leg strength (dynamometry), abdominal endurance (sit-up test), and static core stability (plank test). We hypothesized that the experimental group would demonstrate significantly greater improvements in isometric strength values and endurance hold times/repetitions compared to a control group (CG) performing only standard soccer training.

Methods

Participants

A total of 40 male youth soccer players aged 11–13 years (mean age: 12.0 ± 0.92 years; height: 151.6 ± 8.46 cm; body mass: 44.19 ± 10.5 kg) voluntarily participated in the study. An a priori sample size calculation was performed using G*Power software (version 3.1.9.7), based on a mixed-design analysis of variance (ANOVA) with two groups and two time points. Assuming a medium effect size ($f = 0.25$), an alpha level of 0.05, and a desired statistical power of 0.80, the minimum required sample size was determined to be 34 participants. To compensate for potential attrition and preserve adequate statistical power throughout the study, the sample size was increased, resulting in a total of 40 participants recruited. The players were members of a local competitive youth soccer academy and had a mean training experience of 3.4 ± 1.2 years. Inclusion criteria included a chronological age between 11 and 13

years, regular attendance at soccer training (3 sessions/week) for at least two years, no history of musculoskeletal injury in the previous 6 months, and no prior experience with formal Pilates training. To ensure homogeneity between groups, participants were allocated using a stratified randomization method based on age. Specifically, from the 11-year-old cohort, 10 players were assigned to the PG and 10 to the CG. Similarly, from the 13-year-old cohort, 10 players were assigned to the PG group and 10 to the CG. Consequently, the final sample consisted of 20 participants in the PG and 20 participants in the CG. Written informed consent was obtained from the parents/legal guardians, and the children provided verbal assent. The study protocol was approved by the Bursa Uludağ University Faculty of Medicine Clinical Research Ethics Committee (Protocol No: 2025/724-12/8) and conducted in strict accordance with the Declaration of Helsinki.

Study Design and Randomization

This study used a randomized controlled trial design with a pre-test/post-test structure to investigate the effects of an 8-week Mat Pilates intervention on trunk strength, muscular endurance, and core stability in pre-pubertal soccer players. The experiment lasted 8 weeks. Baseline (pre-test) and post-intervention (post-test) measurements were conducted 48 hours before the first training session and 48 hours after the final session, respectively, to minimize the effects of residual fatigue. To ensure standardization and control for circadian variations, all performance tests were administered at the same time of day (17:00–19:00). The study employed a single-blind design, with the researchers conducting the physical assessments blinded to participants' group allocation to prevent assessor bias. Participants were randomly allocated to either the PG or the CG using a simple randomization procedure. Randomization was performed by an independent researcher using a computer-generated random sequence to ensure allocation concealment.

The allocation sequence was generated using a computer-based random number generator with a simple randomization approach (no blocking or stratification was applied). Allocation concealment was ensured using sealed, opaque, and sequentially numbered envelopes prepared by an independent researcher who was not involved in participant recruitment or assessment. This independent researcher implemented the group assignment after baseline measurements were completed. Outcome assessors

remained blinded to group allocation throughout the study.

Testing Procedures

Before all testing sessions, participants performed a standardized 10-minute warm-up consisting of 5 minutes of low-intensity running and 5 minutes of dynamic stretching targeting the lower limbs and trunk. The testing order was standardized as follows: (1) Plank Test, (2) Sit-up Test, and (3) Back-Leg Dynamometry, with a 5-minute passive recovery interval provided between tests to prevent fatigue accumulation.

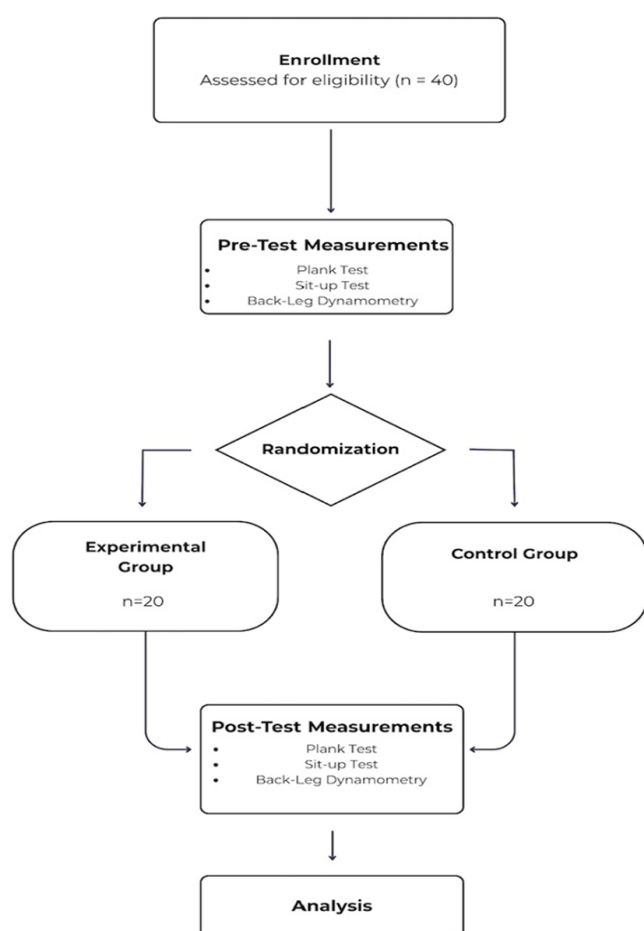


Figure 1. Flowchart of the experimental design.

Static Core Stability

The prone plank test was utilized to assess the static endurance of the anterior core musculature. Participants assumed a prone position with elbows bent at 90°, directly under their shoulders, and forearms flat on the ground. Their feet were hip-width apart. They were instructed to lift their hips to maintain a straight line from the head to the heels, ensuring neutral spine alignment. The stopwatch commenced once the correct position was achieved. The test was terminated when

the participant could no longer maintain the neutral spine position (e.g., hip sagging or lifting greater than 5 cm) or voluntarily collapsed. One verbal warning was given to correct the posture; if the participant failed to correct it immediately, the time was stopped. The total hold time was recorded in seconds.

Dynamic Abdominal Endurance

The sit-up test was performed to evaluate the dynamic muscular endurance of the abdominal flexors. Participants lie supine on a mat with their knees bent at 90°, their feet flat on the floor, and are anchored by a partner, with their hands interlocked behind their head. For the "Go" command, participants curled their trunk up until their elbows touched their knees (concentric phase) and then returned to the starting position, keeping their scapulae on the mat (eccentric phase). The score was recorded as the maximum number of correctly completed repetitions. Repetitions performed with improper form, such as elbows failing to touch the knees or shoulders not returning to the mat, were not counted.

Isometric Back Strength Test

Isometric back strength was assessed using a calibrated Back-Leg-Chest Dynamometer (Takei Back, Leg and Chest Dynamometer, Japan). Participants stood on the dynamometer platform with their feet shoulder-width apart, knees flexed at approximately 130°–140°, their trunk slightly flexed but upright, and their arms hanging straight down, holding the handlebars. The chain length was adjusted for each participant's height to ensure proper biomechanics. On the command "Pull," participants were instructed to extend their knees and hips as forcefully as possible, keeping their arms straight and their back in a neutral position. Participants were asked to avoid jerky movements. Three maximal trials were performed with a 1-minute rest interval between efforts, and the highest value was recorded in kilograms.

Training Intervention

Both groups continued their regular technical and tactical soccer training regimen, which took place 3 days per week for approximately 90 minutes per session. The CG participated only in standard soccer training sessions and did not engage in any additional core or resistance training during the study period. The PG, in addition to standard soccer training, performed a structured Mat Pilates program twice a week for eight weeks. These sessions were conducted on non-soccer training days or at least 4 hours apart from soccer

sessions to ensure movement quality, with a 72-hour interval maintained between Pilates sessions. The experimental group participated in an 8-week Pilates training program in addition to their standard soccer practice. Sessions were conducted twice a week on non-consecutive days, with each session lasting 60 minutes. The protocol consisted of a 10-minute warm-up phase followed by a 50-minute main exercise phase, which included beginner-level Pilates Mat exercises. During each session, participants performed eight specific exercises selected from the planned exercise pool (Table 1). All sessions were supervised by a certified trainer to ensure proper technique and safety. To implement the principle of progressive overload, the training volume was systematically increased throughout the 8-week intervention. Specifically, participants performed six repetitions per exercise during the first two weeks (Weeks 1–2), which were increased to eight in Weeks 3–4, and finally to ten in the remaining period (Weeks 5–8).

Table 1
List of planned Pilates mat exercises.

No	Exercise Name	No	Exercise Name
1	Breathing	13	Double Leg Stretch
2	Imprint and Release	14	Rolling Like a Ball
3	Hip Rolls	15	The Saw
4	Spinal Rotation	16	Roll Up
5	Cat Stretch	17	Spine Stretch
6	Scapula Isolation	18	Leg Pull Down
7	Arm Circles	19	Leg Pull Up
8	The Hundred	20	Push Up
9	The Shoulder Bridge	21	Pelvic Curl
10	Single Leg Circle	22	Side Bend
11	Swimming	23	Side Kick Front
12	One Leg Stretch	24	Side Kick Back

Statistical Analysis

All statistical analyses were performed using JASP software (Version 0.95.4). The normality of data distribution was assessed using the Shapiro–Wilk test, and homogeneity of variances was examined using Levene’s test. Descriptive data are presented as mean \pm standard deviation (SD). A 2×2 mixed-model analysis of variance (ANOVA) (Group [Pilates Group vs. Control Group] \times Time [Pre-test vs. Post-test]) was conducted to examine interaction effects on strength and endurance variables. When a significant Group \times Time interaction was observed, post hoc simple effects

analyses were performed within the ANOVA framework, using the Bonferroni correction to control for multiple comparisons. Effect sizes for interaction effects were reported as partial eta squared (η_p^2) and interpreted as small (0.01), medium (0.06), or large (0.14). The level of statistical significance was set at $p < 0.05$.

Results

The effects of the 8-week Mat Pilates intervention on isometric strength, dynamic abdominal endurance, and static core stability are presented in Table 2.

Isometric Back Strength

A significant Time \times Group interaction was observed for maximal isometric strength ($F_{(1, 38)} = 6.295$, $p = .018$, $\eta_p^2 = 0.184$). This interaction indicates that the change in strength over the 8-week period differed significantly between the two groups. Post-hoc analyses revealed that the PG showed a significant improvement in strength from pre-test (49.57 ± 11.50 kg) to post-test (56.63 ± 13.91 kg, $p = .007$). Conversely, the CG showed no significant change (52.10 ± 7.35 kg to 52.27 ± 9.34 kg, $p = 1.000$). These findings demonstrate that the Pilates intervention was effective in enhancing isometric strength in the back and legs compared to standard soccer training alone.

Dynamic Abdominal Endurance

For the dynamic abdominal endurance test, a significant main effect of Time was found ($F_{(1, 23)} = 45.499$, $p < .001$, $\eta_p^2 = 0.664$), indicating that both groups significantly increased their repetition counts from baseline to post-intervention. However, the Time \times Group interaction was not statistically significant ($F_{(1, 23)} = 0.062$, $p = .805$, $\eta_p^2 = 0.003$), suggesting that the rate of improvement was similar in both groups. Additionally, a significant main effect of Group was observed ($F_{(1, 23)} = 12.11$, $p = .002$), with the CG generally performing a higher number of repetitions than the PG at both time points.

Static Core Stability

Regarding static core stability, the descriptive data showed an increase in hold time for the PG (68.11 ± 21.69 s to 76.56 ± 29.30 s) and a slight decrease for the CG (70.20 ± 17.15 s to 68.87 ± 18.40 s). However, the Time \times Group interaction did not reach statistical significance ($F_{(1, 22)} = 2.999$, $p = .097$, $\eta_p^2 = 0.120$). Similarly, no significant main effects were found for Time ($p = .221$) or Group ($p = .742$). Although the

interaction was not significant, the PG demonstrated a mean improvement of 8.45 seconds, whereas the CG showed a decline of 1.33 seconds.

Table 2
Descriptive statistics, within-group changes, and between-group differences at post-test.

Variables	Pilates Group		Control Group		ANOVA Effects F / p / η_p^2
	Pre Mean \pm SD	Post Mean \pm SD	Pre Mean \pm SD	Post Mean \pm SD	
Dynamic Abdominal Endurance (reps)	25.6 \pm 11.1	40.7 \pm 6.9	36.4 \pm 8.6	50.4 \pm 9.4	Time: 45.50 / <.001* / .664 Group: 12.11 / .002* / .345 T x G: 0.06 / .805 / .003
Within-Group Change		$\Delta+15.1^*$ (d=2.83)		$\Delta+14.0^*$ (d=2.72)	
Between-Group Diff			Control +9.7 reps (p=.041, d=1.07) *		
Isometric Back Strength (kg)	49.6 \pm 11.5	56.6 \pm 13.9	52.1 \pm 7.4	52.3 \pm 9.3	Time: 6.92 / .014* / .198 Group: 0.06 / .806 / .002 T x G: 6.30 / .018* / .184
Within-Group Change		$\Delta+7.1^*$ (d=1.22)		$\Delta+0.2$ (d=0.02)	
Between-Group Diff			Pilates +4.3 kg (p=1.00)		
Static Core Stability (s)	68.1 \pm 21.7	76.6 \pm 29.3	70.2 \pm 17.2	68.9 \pm 18.4	Time: 1.59 / .221 / .067 Group: 0.11 / .742 / .005 T x G: 3.00 / .097 / .120
Within-Group Change		$\Delta+8.4$ (d=0.40)		$\Delta-1.3$ (d=0.06)	

Δ represents the mean difference (Pre - Post). TxG = Time x Group Interaction. Effect sizes are reported as partial eta squared (η_p^2) for ANOVA and Cohen's d for pairwise comparisons. Diff= Difference, Reps= Repetitions, s=second, kg= kilogram *Significant difference at $p < .05$.

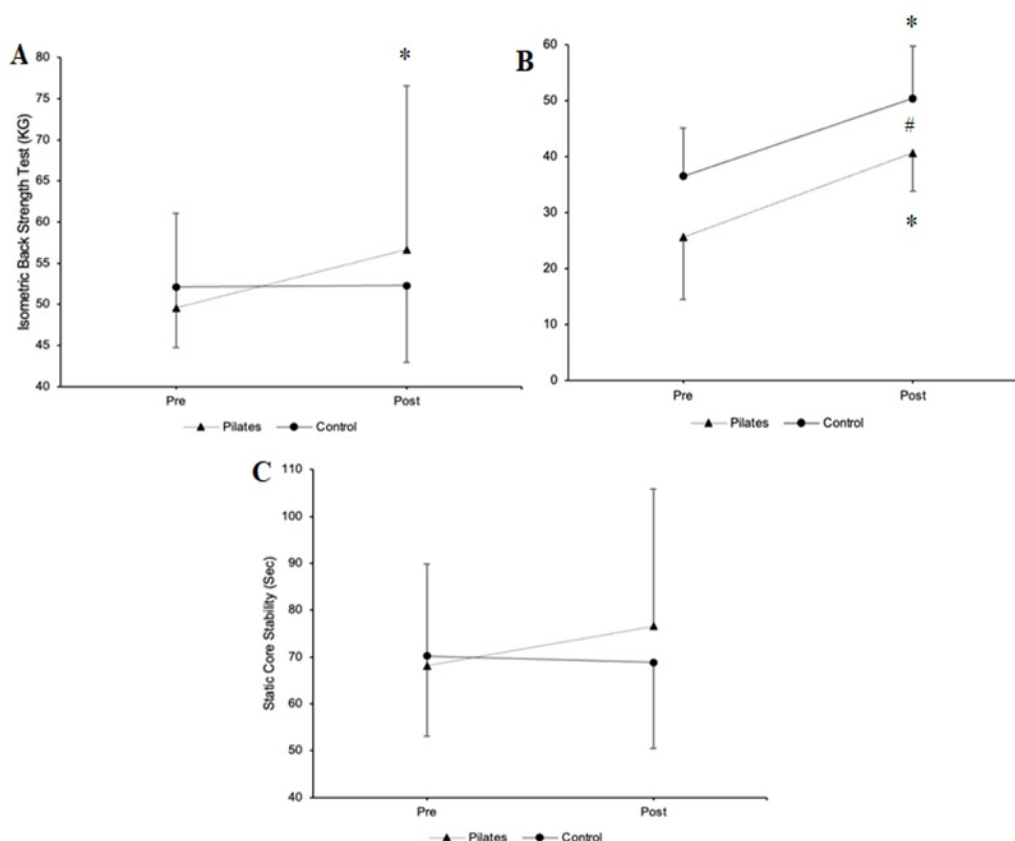


Figure 3. Pre-test and post-test comparisons between the Pilates and Control groups for (A) Isometric Back Strength, (B) Dynamic Abdominal Endurance, and (C) Static Core Stability. * denotes a significant difference compared to pre-test values ($p < .05$). # denotes a significant difference between the Pilates and Control groups ($p < .05$). KG=Kilogram, Reps= Repetition, Sec= Seconds.

Discussions

The present findings highlight the selective nature of physical adaptations induced by Pilates training in young football players, particularly in trunk muscle groups that are insufficiently stimulated by regular football practice. The most significant finding was a clear divergence in back extensor strength. While the CG showed no significant change over the training period, the PG demonstrated a substantial improvement ($d = 1.22$). This finding supports the observation that standard football training, which typically involves high-intensity running and kicking, predominantly stresses the lower extremities and anterior muscle chains (e.g., quadriceps, hip flexors) but often provides insufficient loading to the posterior trunk musculature (Lees et al., 2010; Reilly et al., 2000). By incorporating prone extension exercises, such as the Swimming and Swan, the Pilates intervention provided a targeted stimulus to the erector spinae and multifidus muscles that regular football practice did not offer. This aligns with the "axial elongation" principle described by Latey (2001) and confirms empirical research by Sekendiz et al. (2007) and Kloubec (2010), suggesting that specific isolation exercises are necessary to correct agonist-antagonist imbalances in athletes. Although the observed effect size was large, it should be interpreted in light of the low baseline trunk loading typically observed in pre-pubertal football players, which may allow for rapid initial adaptations when a novel, targeted stimulus is introduced.

Regarding abdominal endurance (sit-ups), both groups demonstrated significant improvements, with no statistically significant difference between them. This result suggests that regular football training is as effective as Pilates for dynamic trunk flexion. This makes sense biomechanically; actions such as sprinting and striking the ball require forceful contraction of the hip flexors and rectus abdominis to control limb angular momentum (Nunome et al., 2002; Inoue et al., 2014). Therefore, the CG was effectively conditioning the prime movers of the sit-up test during their daily football sessions. Furthermore, as noted in foundational texts by Kendall et al. (2005) and confirmed by EMG studies (Juker et al., 1998), standard sit-up tests are heavily reliant on hip flexor strength. Since football acts as a potent stimulus for hip flexor development, the improvement in the CG was physiological. It is highly likely that a "learning effect," which is common in pediatric testing, contributed to the improved scores in

both groups as participants became familiar with the test mechanics (Hopkins, 2000; Tomkinson et al., 2018).

The results of the static core stability (plank) test presented a challenge often seen in pediatric exercise science. Although the PG showed a positive trend (12.4% improvement) compared to a slight decline in the CG, the difference was not statistically significant. This is likely due to the high inter-individual variability among boys aged 11-13. As authoritatively described by Malina et al. (2004), this age group undergoes rapid somatic growth and maturation (Peak Height Velocity). This period is often associated with "adolescent awkwardness," characterized by temporary regressions in balance and motor coordination resulting from changes in limb lengths and centers of mass (Philippaerts et al., 2006). Additionally, isometric tests like the plank require high levels of volitional drive, which can fluctuate significantly in young populations (Tong et al., 2014). While statistical significance was obscured by this variability, the divergence in mean scores suggests that Pilates may serve as a neuromuscular anchor to maintain stability during this critical growth phase, as supported by core stability reviews in athletic populations (Granacher et al., 2013).

The present study has some limitations. First, the assessment relied on field-based tests rather than laboratory gold standards (e.g., isokinetic dynamometry). While field tests offer ecological validity, they have a higher margin of error and lower sensitivity in detecting subtle neuromuscular changes compared to laboratory measures. Second, although chronological age was controlled, biological maturation (e.g., peak height velocity offset) was not assessed; thus, individual developmental differences may have influenced physical performance, particularly in stability tasks. Third, the sample was restricted to male players aged 11–13 years, limiting the generalizability of the findings to female athletes or other age categories. Fourth, the intervention was strictly limited to Mat Pilates; therefore, the results cannot be extrapolated to apparatus-based Pilates (e.g., Reformer) or other core training modalities. Future research should utilize laboratory-based measures to validate these field findings and control for biological maturation to better understand the interaction between growth and training adaptations. Additionally, comparative studies investigating different Pilates modalities (Mat vs. Reformer) and their effects on female youth players would provide a more comprehensive understanding of core training in youth sports.

Conclusion

This study provides novel evidence suggesting that Pilates training may be associated with improvements in back extensor strength in pre-pubertal male football players. While the sport-specific demands of football appear to be sufficient to maintain dynamic abdominal endurance, they may not adequately stimulate the posterior trunk musculature. From a practical perspective, integrating short-duration Pilates sessions into youth training programs could help address trunk strength imbalances during a critical developmental period, without negatively affecting regular football practice.

Authors' Contribution

Study Design: HT, CÇ; Data Collection: HT, CÇ; Statistical Analysis: HT; Manuscript Preparation: HT; Funds Collection: HT, CÇ.

Ethical Approval

The study was approved by the Bursa Uludağ University Faculty of Medicine Clinical Research Ethics Committee (Protocol No: 2025/724-12/8) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

References

- Cruz-Ferreira, A., Fernandes, J., Laranjo, L., Bernardo, L. M., & Silva, A. (2011). A systematic review of the effects of pilates method of exercise in healthy people. *Arch Phys Med Rehabil*, 92(12), 2071–2081. <https://doi.org/10.1016/j.apmr.2011.06.018>
- González-Gálvez, N., Gea-García, G. M., & Marcos-Pardo, P. J. (2019). Effects of exercise programs on kyphosis and lordosis angle: A systematic review and meta-analysis. *PLoS One*, 14(4), e0216180. <https://doi.org/10.1371/journal.pone.0216180>
- Granacher, U., Gollhofer, A., Hortobágyi, T., Kressig, R. W., & Muehlbauer, T. (2013). The importance of trunk muscle strength for balance, functional performance, and fall prevention in the elderly: A systematic review. *Sports Med*, 43(7), 627–641. <https://doi.org/10.1007/s40279-013-0041-1>
- Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Med*, 30(1), 1–15. <https://doi.org/10.2165/00007256-200030010-00001>
- Inoue, K., Nunome, H., Sterzing, T., Shinkai, H., & Ikegami, Y. (2014). Dynamics of the support leg in soccer kicking. *J Sports Sci*, 32(11), 1023–1032. <https://doi.org/10.1080/02640414.2014.886126>
- Juker, D., McGill, S. M., Kropf, P., & Steffen, T. (1998). Quantitative intramuscular myoelectric analysis of abdominal wall muscles during different exercises. *Medicine & Science in Sports & Exercise*, 30(6), 952–963. <https://doi.org/10.1097/00005768-199802000-00020>
- Kendall, F. P., McCreary, E. K., Provance, P. G., Rodgers, M. M., & Romani, W. A. (2005). *Muscles: Testing and function, with posture and pain* (5th ed.). Lippincott Williams & Wilkins.
- Kibler, W. B., Press, J., & Sciascia, A. (2006). The role of core stability in athletic function. *Sports Medicine*, 36(3), 189–198.
- Kloubec, J. A. (2010). Pilates for improvement of muscle endurance, flexibility, balance, and posture. *J Strength Cond Res*, 24(3), 661–667. <https://doi.org/10.1519/JSC.0b013e3181c277a6>
- Latey, P. (2001). The Pilates method: History and philosophy. *J Bodyw Mov Ther*, 5(4), 275–282. <https://doi.org/10.1054/jbmt.2001.0237>
- Lees, A., Asai, T., Andersen, T. B., Nunome, H., & Sterzing, T. (2010). The biomechanics of kicking in soccer: A review. *J Sports Sci*, 28(8), 805–817. <https://doi.org/10.1080/02640414.2010.481305>
- Lloyd, R. S., & Oliver, J. L. (2012). The youth physical development model: A new approach to long-term athletic development. *Strength Condit J*, 34(3), 61–72. <https://doi.org/10.1519/SSC.0b013e31825760ea>
- Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity* (2nd ed.). Human Kinetics.
- Negra, Y., Chaabene, H., Sammoud, S., Bouguezzi, R., Mkaouer, B., Hachana, Y., & Granacher, U. (2017). Effects of plyometric training on components of physical fitness in prepubertal male soccer athletes: the role of surface instability. *J Strength Cond Res*, 31(12), 3295–3304. <https://doi.org/10.1519/jsc.0000000000002262>
- Nunome, H., Ikegami, Y., Kozakai, R., Apriantono, T., & Sano, S. (2006). Segmental dynamics of the soccer kick with the instep and side-foot. *Journal of Sports Sciences*, 20(6), 485–485. <https://doi.org/10.1080/02640410500298024>
- Philippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., ... & Malina, R. M. (2006). The relationship between peak height velocity and physical performance in youth soccer players. *J Sports Sci*, 24(3), 221–230. <https://doi.org/10.1080/02640410500189371>
- Prieske, O., Muehlbauer, T., & Granacher, U. (2016). The role of trunk muscle strength for physical fitness and athletic performance in trained individuals: A systematic review and meta-analysis. *Sports Med*, 46(3), 401–419. <https://doi.org/10.1007/s40279-015-0426-4>
- Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *J Sports Sci*, 18(9), 669–683. <https://doi.org/10.1080/02640410050120050>
- Sekendiz, B., Altun, Ö., Korkusuz, F., & Akın, S. (2007). Effects of Pilates exercise on trunk strength, endurance and flexibility in sedentary adult females. *J Bodyw Mov*

- Ther*, 11(4), 318–326. <https://doi.org/10.1016/j.jbmt.2006.12.002>
- Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Med*, 35(6), 501–536. <https://doi.org/10.2165/00007256-200535060-00004>
- Tomkinson, G. R., Carver, K. D., Atkinson, F., Daniell, N. D., Lewis, L. K., Fitzgerald, J. S., ... & Ortega, F. B. (2018). European normative values for physical fitness in children and adolescents aged 9–17 years: Results from 2 779 165 Eurofit performances representing 30 countries. *Br J Sports Med*, 52(22), 1445–1456. <https://doi.org/10.1136/bjsports-2017-098253>
- Tong, T. K., Wu, S., Nie, J., Baker, J. S., & Lin, H. (2014). The occurrence of core muscle fatigue during high-intensity running exercise and its limitation to performance: The role of respiratory work. *J Sports Sci Med*, 13(2), 244–251.
- Wells, C., Kolt, G. S., & Bialocerkowski, A. (2012). Defining Pilates exercise: A systematic review. *Complement Ther Med*, 20(4), 253–262. <https://doi.org/10.1016/j.ctim.2012.02.005>
- Yılmaz, O., Kaplan, T., & Batalik, L. (2025). Randomised controlled study on the effects of Pilates exercises in soccer: Comparing mat and reformer methods on physical and technical performance. *PLoS One*, 20(5), e0324129. <https://doi.org/10.1371/journal.pone.0324129>
- Yılmaz, O., Soylu, Y., Kaplan, T., & Taşkın, M. (2023). How Pilates exercises affect sports performance? a systematic review. *Turk J Physiother Rehabil*, 34(3), 367–373. <https://doi.org/10.21653/tjpr.1211347>