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## ENHANCING SOCCER ATHLETES' PERFORMANCE: A KINEMATIC ANALYSIS OF AGILITY TRAINING

**SALVATORE PINELLI ***

*University of Bologna, Department for Life Quality Studies, Corso D'Augusto 237, Rimini, 47921, Italy*

*salvatore.pinelli2@unibo.it, ORCID ID: 0009-0009-1638-1542*

**RAFFAELE ZINNO**

*University of Bologna, Department for Life Quality Studies, Corso D'Augusto 237, Rimini, 47921, Italy*

*raffaele.zinno2@unibo.it, ORCID ID: 0000-0001-6797-6049*

**GIULIO SENESI**

*University of Bologna, Department for Life Quality Studies, Corso D'Augusto 237, Rimini, 47921, Italy*

*giulio.senesi2@unibo.it, ORCID ID: 0009-0005-6954-2689*

**MARIA SCOPPOLINI MASSINI**

*University of Bologna, Department for Life Quality Studies, Corso D'Augusto 237, Rimini, 47921, Italy*

*maria.scoppolini2@unibo.it, ORCID ID: 0009-0007-9644-6048*

**ERIKA PINELLI**

*University of Bologna, Department for Life Quality Studies, Corso D'Augusto 237, Rimini, 47921, Italy*

*erika.pinelli2@unibo.it, ORCID ID: 0000-0001-7451-3739*

**LAURA BRAGONZONI**

*University of Bologna, Department for Life Quality Studies, Corso D'Augusto 237, Rimini, 47921, Italy*

*laura.bragonzoni4@unibo.it, ORCID ID: 0000-0002-4773-2300*

[*]Corresponding authors; e-mail address: salvatore.pinelli2@unibo.it

## Abstract

This study investigates how a targeted training program impacts agility and kinematic performance in soccer players. The Agility T-test was used to measure dynamic movement skills, focusing on execution time and joint movements. Seventeen players performed the test under dominant and non-dominant conditions at two time points—baseline (after summer) and follow-up (after winter). The first change of direction classified trials as dominant or non-dominant. Motion data were captured with Xsens MTw Awinda sensors, and paired t-tests compared baseline and follow-up results.

The analysis showed a clear improvement in performance. Execution times decreased by an average of 1.03 seconds on the dominant side and 0.9 seconds on the non-dominant side. Key kinematic changes included a greater range of motion at the knee during forward running and better hip rotation control on both sides. Interestingly, a reduction in ankle plantar and dorsiflexion range of motion was observed. Significant changes were also noted in knee internal rotation during lateral shufflings.

These findings highlight the program's effectiveness in enhancing agility and movement efficiency through improved lower limb strength and motor coordination developed over the four-month training program.


Keywords: Kinematic analysis, Agility test, Football training.

## 1. Introduction

Understanding the impact of training programs on athletic performance is a key focus in contemporary sports science research.[1,2] In football, which involves frequent high-intensity sprints and abrupt changes of direction, the risk of lower-limb injuries—particularly ACL injuries—is notably high.[3–5] Targeted neuromuscular, strength, and agility training programs have been shown to reduce these risks significantly and simultaneously improve performance, underscoring the importance of investigating their effects.[6,7] In particular, analysing biomechanics and agility offers valuable insights into the effectiveness of various training approaches. Agility, defined as the ability to maintain control of body position while quickly changing direction, play a crucial role in both team sports and individual performance.[8,9] Growing interest surrounds the factors influencing agility and the development of effective testing protocols and training strategies to assess and improve this quality.[10] Hence, research on the impact of targeted training on agility is not only about enhancing performance but also about mitigating injury risk, a key concern in sports like soccer.

To assess agility and movement proficiency, various tests are employed, each with unique strengths and limitations. The Illinois Agility Test [11], the 5-0-5 Agility Test [8], and the Arrowhead Agility Test [12] are among the most commonly used tests in soccer training. Specifically, the Illinois Agility Test evaluates agility through a series of forward and backward runs interspersed with slaloms between cones, making it ideal for measuring changes of direction (COD) at different angles.[11] The 5-0-5 Agility Test focuses on the ability to execute rapid 180° COD, particularly useful for identifying asymmetries between dominant and non-dominant legs.[8] The Arrowhead Agility Test introduces diagonal runs, making it especially useful for replicating the kinds of movements athletes perform in football.[13]

Despite their utility, these tests have limitations, particularly in isolating the contribution of different phases of movement or capturing the relation interplay between speed, coordination, and strength. The Agility T-test[14], another commonly used test to assess agility, addresses many of these limitations by combining linear sprints, lateral movements, and backward runs into a single protocol, offering a holistic evaluation of an athlete's agility.[15,16] Moreover, its straightforward design ensures reproducibility and reliability, making it one of the most widely used tests in sports.[17]

Moreover, the Agility T-test is particularly valuable to distinguish between performance on dominant and non-dominant sides, an essential factor in sports requiring symmetrical agility. Indeed, during the test, athletes perform directional changes that challenge their ability to coordinate movements bilaterally, reflecting real-game scenarios.[9] Furthermore, this test has been shown to be highly reliable when combined with advanced motion analysis tools, such as inertial measurement units (IMUs), to assess not only execution time but also the kinematics of specific joints.[17,18]

Despite the wide use of agility tests and motion analysis tools, a gap remains in understanding the combined effects of targeted training programs on both agility performance and kinematic changes in specific movements. This study investigated the dual impact of a structured training program on agility performance and the kinematic adaptations of specific movements in young soccer players. By integrating the Agility T-test to measure change-of-direction ability and IMU-based kinematic analysis to capture detailed biomechanical data.

## 2. Materials and Methods

### *2.1. Study design*

This single-arm experimental study analysed the effectiveness of a specific training program on soccer players to improve the agility and generate kinematic changes. All participants met the inclusion criteria: (i) men older than 18 years old, (ii) at least 2 years of experience, (iii) not suffer any lower-limb injury in the last 6 months before the data collection. Prior to data collection, all participants were briefed on the study protocols, including the potential risks involved. This study was approved by the University of Bologna Bioethics Committee (protocol No. 0025861). Informed consent was obtained from each participant prior to their involvement, and all procedures adhered to the approved protocol. In order to maintain the subjects' privacy, all data were anonymized before the analysis, in accordance with the principles of the Declaration of Helsinki.

### *2.2. Participant*

A total of 21 amateur football players from an Italian non-professional league were initially recruited for the study. Four players were excluded: two due to transfers to other teams during the winter transfer window and two for disciplinary reasons that left them out of the squad. Consequently, the final analysis included a cohort of 17 players. Participants were amateur football players with a mean playing experience of 16.0 ± 5.4 years. The study sample comprised participants with a mean age of 27.5 years (SD = 5.3). The mean weight of the participants was 78.2 kg (SD = 7.0). The mean height was 179.9 cm (SD = 5.5).

### *2.3. Training Program*

The training program was conducted over four months during the competitive season to maintain and enhance physical performance while addressing the specific demands of soccer. Athletes trained twice per week (Tuesday and Thursday), with each session lasting approximately 90 minutes. The training program focused on explosive strength, reactive agility, and coordination, incorporating exercises designed to simulate the multidirectional and high-intensity nature of soccer gameplay. The structure of the weekly training sessions is summarized in Table 1.

Table 1. Weekly training structure

| Day | Focus |
|---|---|
| Tuesday | Explosive strength training: Sprint drills with resistance (e.g., sled pushes), plyometric exercises (e.g., drop jumps, bounding), and core stability work (e.g., planks, side planks). Sets were shorter (3–5 repetitions) with 1-minute recovery intervals. |
| Thursday | Reactive agility and tactical preparation: Agility drills incorporating unpredictable directional changes triggered by external cues (e.g., coach's signals) and small-sided games emphasizing decision-making, spatial awareness, and fatigue resistance. |

Each training session was structured into three phases:

1. Warm-up: Dynamic stretching and light jogging to prepare for high-intensity efforts.
2. Central phase: Focused on the day's specific training objective, either explosive strength or reactive agility.
3. Cooldown: Low-intensity running and static stretching to facilitate recovery and reduce muscle soreness.

The explosive strength training included exercises such as sprint drills with resistance (e.g., sled pushes) to enhance lower limb power, plyometric tasks (e.g., drop jumps and bounding) to improve reactive strength, and core exercises (e.g., planks) to stabilize the trunk and support efficient force transmission. The reactive agility sessions incorporated directional changes in response to external cues to replicate match scenarios, while small-sided games combined physical and tactical elements to enhance decision-making and technical execution under fatigue.

### *2.4. Testing Procedures*

The agility was evaluated through an Agility T-test (fig. 1), as described by the National Strength and Conditioning Association.[14] The test was divided into five phases of the movement: forward sprinting, three side shuffling, and backpedaling. The test was considered “dominant” if the first COD (point A in fig.1) between forward and side runs was executed in the direction of the dominant foot, and “non-dominant” otherwise. Each player performed the Agility T-test two times (dominant and non-dominant) per each time points: pre-period training (baseline), conducted at the conclusion of summer conditioning; and post-period training (follow-up), conducted after winter conditioning. All the players were tested the same day and hour and on the same field at both baseline and follow-up. The experimental tests were performed on an outdoor soccer field, and therefore, variations in environmental conditions, including ground surface and weather, could potentially affect participants' performance.

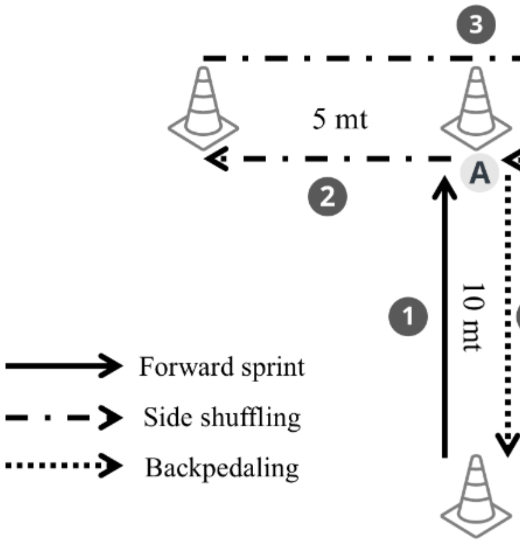


Fig. 1. Schematic illustration of Agility T-test.

### *2.5. Data Collection*

Participants, while performing the Agility T-test, utilized the MVN Biomech Link system (Xsens Technologies BV, Enschede, The Netherlands), a previously validated setup consisting of seven inertial measurement units, a transmission pack, and a battery.[19,20] The sensors were positioned on the feet, lower leg (tibia, near the knee), upper leg (mid-lateral thigh), and sacrum. Calibration required participants to assume the N-pose—a standardized posture characterized by standing upright with relaxed upper limbs parallel to the body, fully extended lower limbs, and feet positioned parallel.[21] Anthropometric measurements were incorporated to scale the proprietary biomechanical model within the Xsens Motion Tracking System. This facilitated motion capture calibration using the Xsens MVN

Analyze software (version 2023.2). The Xsens MVN system has shown fair to excellent accuracy in sagittal plane motion analysis when compared with gold-standard optoelectronic systems. This makes it particularly suitable for capturing sport-specific, on-field movements.[19] During testing, participants wore their own shoes to ensure both comfort and the maintenance of natural movement patterns.

### *2.6. Data Processing*

The running measurements were post-processed using the Xsens MVN Analyze software (v. 2021.0.1), operating in the "High-definition reprocessing" mode under the "no-level" processing scenario. This specific configuration fixes the pelvis segment in space, ensuring that all kinematic parameters are expressed relative to it. This approach is particularly recommended for joint angle analysis in biomechanics due to its reliability in capturing relative motion across body segments.[22,23]

The test movements were divided into five distinct phases and categorized as forward sprinting, shuffling, and backpedaling, as previously described. For each participant, five key moments of the movement were identified and analyzed: 1) the start of the test with a forward sprint, 2) COD at 90° and 3-4) 180°, and 5) the final backward sprint toward the starting line. These phases provided a structured framework for segmenting the movement and analyzing joint kinematics. For each phase, specific frames were extracted using the Xsens MVN Analyze software (v. 2023.2) and compiled into an Excel spreadsheet for all participants. After the segmentation, the range of motion (ROM) for each joint were extracted. The performance metric was the total execution time of the agility test measured with a chronometer.

### *2.7. Statistical analysis*

The statistical analysis was performed in IMB SPSS Statistics version 25.0 (SPSS Inc., Chicago, IL) for the Windows statistical software package. The normality of the data distributions was assessed using the Shapiro–Wilk test. A Wilcoxon signed-rank test was employed to evaluate the differences in all kinematic parameters (e.g., ROM of hip, knee, and ankle joints). Paired t-test was used for performance outcomes (e.g., execution time during the Agility T-test). Kinematic parameters were analyzed for each of the five phases of the Agility T-test, providing a comprehensive evaluation of joint performance during forward runs, lateral movements, and backward runs. The significance threshold was set at $p < 0.05$. Furthermore, beyond reporting p-values, we calculated an overall effect size (ES) and derived its 95% confidence interval (CI) via a bootstrap procedure.[24] ES values of 0.2, 0.5, and 0.8 were considered to be small, moderate, and large differences, respectively.[25]

## 3. Results

The proposed training program resulted in a statistically significant improvement in agility performance, as evidenced by the reduction in execution time of the Agility T-test.

Specifically, the mean execution time decreased by 1.03 seconds ($p < 0.001$) on the dominant side and 0.9 seconds ($p < 0.001$) on the non-dominant side (Table 2).

Table 2. Execution time comparison pre vs post training program

| Test Side | Pre | Post | P-value | ES | CI |
|---|---|---|---|---|---|
| Dominant | 12.6 ± 0.7 | 11.6 ± 0.6 | **< 0.001*** | **0.76** | **[0.56 – 0.87]** |
| Non-Dominant | 12.6 ± 0.7 | 11.7 ± 0.5 | **< 0.001*** | **0.75** | **[0.49 – 0.87]** |

*Note:* Pre- and post-intervention data are presented as medians and interquartile ranges (IQR). ES denotes the effect size, and CI represents the confidence interval of the effect size. The bold asteric symbol (*) is utilized to highlight significant differences.

Post-training, significant changes in joint range of motion (ROM) were observed across test phases (Tables 3–7). In the forward sprint, robust improvements were observed at the hip and knee. The hip showed significant increases in abduction/adduction (≈8°), flexion/extension (≈14°), and internal/external rotation (≈15°) with high effect sizes (ES ranging from 0.68 to 0.88). Likewise, the knee demonstrated marked enhancements in abduction/adduction (up to 15°) and internal/external rotation (up to 9.6°). A significant reduction in dominant-side ankle dorsiflexion/plantarflexion (≈6°) was also noted.
During lateral shufflings, consistent changes emerged in hip internal/external rotation (e.g., 1st shuffle dominant side: $p = 0.001$, ES = 0.76; 2nd shuffle: $p < 0.001$, ES = 0.82), with fewer modifications at the knee and ankle.
During backpedaling, significant increases were recorded at the hip—in abduction/adduction (≈10° dominant; ≈6° non-dominant), flexion/extension (≈6° dominant; ≈9° non-dominant), and internal/external rotation (≈9° dominant; ≈5° non-dominant)—while a significant reduction in non-dominant ankle dorsiflexion/plantarflexion (≈9°) was observed. All results are detailed in Tables 2 through 7, providing comprehensive data on execution times and kinematic parameters across the different test phases.

Table 3. Forward Sprint comparison ROM pre vs post training program

| Joint | Movement | Test Side | Pre | Post | P-value | ES | CI |
|---|---|---|---|---|---|---|---|
| Hip | Abduction/ Adduction | Dominant | 22.5 (2.4) | 30.6 (11.0) | **0.02*** | **0.56** | **[0.14 - 0.86]** |
| | | Non dominant | 21.1 (4.7) | 28.6 (7.2) | **0.001*** | **0.77** | **[0.53 - 0.88]** |
| | Flexion/ Extension | Dominant | 72.4 (6.0) | 85.9 (8.1) | **0.001*** | **0.77** | **[0.5 - 0.88]** |
| | | Non dominant | 74.7 (11.3) | 89.4 (11.6) | **< 0.001*** | **0.88** | **[0.88 - 0.88]** |
| | Internal/ External Rotation | Dominant | 18.9 (12.4) | 33.9 (9.7) | **0.003*** | **0.68** | **[0.34 - 0.88]** |
| | | Non dominant | 18.3 (4.6) | 32.7 (7.8) | **< 0.001*** | **0.87** | **[0.81 - 0.88]** |
| Knee | Abduction/ Adduction | Dominant | 19.6 (5.9) | 31.4 (17.5) | **< 0.001*** | **0.72** | **[0.55 - 0.84]** |
| | | Non dominant | 17.8 (7.0) | 33.0 (11.1) | **< 0.001*** | **0.74** | **[0.54 - 0.84]** |
| | Flexion/ Extension | Dominant | 81.0 (14.3) | 88.1 (18.1) | 0.145 | 0.36 | [0.03 - 0.72] |
| | | Non dominant | 80.4 (17.1) | 84.3 (14.8) | 0.459 | 0.19 | [0.02 - 0.6] |
| | Internal/ External Rotation | Dominant | 17.2 (5.4) | 23.4 (8.5) | **0.001*** | **0.59** | **[0.33 - 0.78]** |
| | | Non dominant | 17.6 (3.6) | 27.2 (10.4) | **< 0.001*** | **0.83** | **[0.78 - 0.84]** |
| Ankle | Abduction/ Adduction | Dominant | 37.7 (9.2) | 39.0 (15.2) | 0.517 | 0.17 | [0.01 - 0.6] |
| | | Non dominant | 33.5 (4.8) | 35.2 (12.7) | 0.08 | 0.43 | [0.03 - 0.82] |
| | Dorsiflexion/ Plantarflexion | Dominant | 64.2 (5.0) | 58.0 (10.3) | **0.02*** | **0.56** | **[0.14 - 0.84]** |
| | | Non dominant | 66.3 (11.0) | 63.1 (12.3) | 0.057 | 0.46 | [0.07 - 0.84] |
| | Internal/ External Rotation | Dominant | 31.2 (7.2) | 34.3 (15.2) | 0.051 | 0.48 | [0.06 - 0.81] |
| | | Non dominant | 30.2 (7.9) | 29.5 (6.2) | 0.404 | 0.21 | [0.02 - 0.64] |

*Note:* Pre- and post-intervention data are presented as medians and interquartile ranges (IQR). ES denotes the effect size, and CI represents the confidence interval of the effect size. The bold asteric symbol (*) is utilized to highlight significant differences.

Table 4. 1st lateral shuffling comparison ROM pre vs post training program

| Joint | Movement | Test Side | Pre | Post | P-value | ES | CI |
|---|---|---|---|---|---|---|---|
| Hip | Abduction/ Adduction | Dominant | 28.6 (8.5) | 29.6 (3.8) | 0.854 | 0.05 | [0.01 - 0.57] |
| | | Non dominant | 28.1 (8.6) | 28.3 (9.3) | 0.329 | 0.25 | [0.02 - 0.66] |
| | Flexion/ Extension | Dominant | 38.9 (22.2) | 44.4 (14.2) | 0.257 | 0.2 | [0.01 - 0.53] |
| | | Non dominant | 56.5 (21.7) | 56.8 (19.0) | 0.089 | 0.42 | [0.05 - 0.77] |
| | Internal/ External Rotation | Dominant | 21.1 (7.3) | 27.7 (11.0) | **0.001*** | **0.76** | **[0.51 - 0.88]** |
| | | Non dominant | 19.6 (7.5) | 27.0 (9.3) | **0.013*** | **0.59** | **[0.17 - 0.87]** |
| Knee | Abduction/ Adduction | Dominant | 23.7 (9.3) | 26.1 (4.8) | 0.678 | 0.11 | [0.01 - 0.61] |
| | | Non dominant | 23.7 (8.0) | 26.0 (5.2) | 0.305 | 0.18 | [0.01 - 0.51] |
| | Flexion/ Extension | Dominant | 51.5 (7.9) | 60.5 (7.2) | **0.008*** | **0.63** | **[0.27 - 0.84]** |
| | | Non dominant | 60.6 (11.7) | 57.2 (12.8) | 0.579 | 0.14 | [0.01 - 0.6] |
| | Internal/ External Rotation | Dominant | 17.5 (5.6) | 24.4 (8.2) | 0.517 | 0.17 | [0.01 - 0.67] |
| | | Non dominant | 16.4 (7.1) | 20.7 (4.5) | **0.046*** | **0.35** | **[0.04 - 0.65]** |
| Ankle | Abduction/ Adduction | Dominant | 43.5 (6.5) | 48.1 (10.8) | 0.459 | 0.19 | [0.02 - 0.6] |
| | | Non dominant | 47.3 (11.9) | 44.6 (11.0) | 0.579 | 0.14 | [0.01 - 0.59] |
| | Dorsiflexion/ Plantarflexion | Dominant | 42.1 (11.4) | 42.4 (11.0) | 1 | 0.01 | [0.01 - 0.53] |
| | | Non dominant | 44.5 (10.4) | 41.5 (13.2) | 0.579 | 0.14 | [0.02 - 0.61] |
| | Internal/ External Rotation | Dominant | 41.3 (12.2) | 44.3 (16.2) | 0.322 | 0.18 | [0.01 - 0.51] |
| | | Non dominant | 39.8 (9.0) | 43.4 (9.4) | 0.378 | 0.22 | [0.02 - 0.66] |

*Note:* Pre- and post-intervention data are presented as medians and interquartile ranges (IQR). ES denotes the effect size, and CI represents the confidence interval of the effect size. The bold asteric symbol (*) is utilized to highlight significant differences.

Table 5. 2nd lateral shuffling comparison ROM pre vs post training program

| Joint | Movement | Test Side | Pre | Post | P-value | ES | CI |
|---|---|---|---|---|---|---|---|
| Hip | Abduction/ Adduction | Dominant | 32.1 (7.7) | 31.3 (5.6) | 0.854 | 0.05 | [0.01 - 0.57] |
| | | Non dominant | 33.6 (6.1) | 36.1 (9.9) | 0.459 | 0.19 | [0.01 - 0.64] |
| | Flexion/ Extension | Dominant | 61.2 (11.1) | 61.8 (12.4) | 0.378 | 0.22 | [0.02 - 0.69] |
| | | Non dominant | 58.6 (14.1) | 62.3 (15.7) | 0.747 | 0.09 | [0.01 - 0.56] |
| | Internal/ External Rotation | Dominant | 24.1 (6.1) | 32.2 (12.9) | **< 0.001*** | **0.82** | **[0.64 - 0.88]** |
| | | Non dominant | 27.4 (6.3) | 33.6 (13.9) | **0.002*** | **0.72** | **[0.4 - 0.88]** |
| Knee | Abduction/ Adduction | Dominant | 26.2 (5.6) | 28.2 (9.8) | 0.738 | 0.06 | [0 - 0.41] |
| | | Non dominant | 24.9 (5.4) | 26.9 (3.5) | 0.086 | 0.32 | [0.03 - 0.61] |
| | Flexion/ Extension | Dominant | 68.3 (14.8) | 68.1 (8.4) | 0.487 | 0.18 | [0.01 - 0.61] |
| | | Non dominant | 72.1 (15.3) | 69.9 (4.6) | 0.145 | 0.36 | [0.02 - 0.72] |
| | Internal/ External Rotation | Dominant | 17.5 (6.6) | 22.8 (7.4) | **0.006*** | **0.51** | **[0.2 - 0.74]** |
| | | Non dominant | 19.5 (7.0) | 23.5 (3.6) | **0.015*** | **0.45** | **[0.14 - 0.71]** |
| Ankle | Abduction/ Adduction | Dominant | 56.3 (13.8) | 53.3 (10.1) | 0.12 | 0.38 | [0.03 - 0.75] |
| | | Non dominant | 49.7 (13.7) | 45.1 (8.8) | 0.098 | 0.41 | [0.03 - 0.82] |
| | Dorsiflexion/ Plantarflexion | Dominant | 50.6 (5.8) | 50.7 (11.0) | 1 | 0.01 | [0.01 - 0.53] |
| | | Non dominant | 49.2 (11.6) | 47.0 (6.1) | 0.098 | 0.41 | [0.03 - 0.83] |
| | Internal/ External Rotation | Dominant | 46.3 (12.1) | 47.6 (13.3) | 0.927 | 0.03 | [0.01 - 0.55] |
| | | Non dominant | 45.0 (8.5) | 46.1 (13.8) | 0.263 | 0.28 | [0.02 - 0.67] |

*Note:* Pre- and post-intervention data are presented as medians and interquartile ranges (IQR). ES denotes the effect size, and CI represents the confidence interval of the effect size. The bold asteric symbol (*) is utilized to highlight significant differences.

Table 6. 3rd lateral shuffling comparison ROM pre vs post training program

| Joint | Movement | Test Side | Pre | Post | P-value | ES | CI |
|---|---|---|---|---|---|---|---|
| Hip | Abduction/ Adduction | Dominant | 29.9 (8.8) | 32.1 (6.4) | 0.132 | 0.37 | [0.02 - 0.78] |
| | | Non dominant | 27.2 (11.0) | 28.2 (7.1) | 0.963 | 0.02 | [0.01 - 0.52] |
| | Flexion/ Extension | Dominant | 47.6 (11.8) | 51.2 (11.5) | 0.306 | 0.26 | [0.02 - 0.69] |
| | | Non dominant | 37.7 (21.2) | 47.9 (16.1) | **0.04*** | **0.5** | **[0.1 - 0.84]** |
| | Internal/ External Rotation | Dominant | 25.1 (7.6) | 30.9 (5.8) | **0.003*** | **0.69** | **[0.37 - 0.88]** |
| | | Non dominant | 22.9 (9.8) | 31.3 (9.6) | **0.023*** | **0.55** | **[0.12 - 0.88]** |
| Knee | Abduction/ Adduction | Dominant | 26.6 (11.2) | 26.8 (7.2) | 0.597 | 0.1 | [0.01 - 0.44] |
| | | Non dominant | 22.1 (6.8) | 25.7 (11.6) | 0.505 | 0.12 | [0.01 - 0.5] |
| | Flexion/ Extension | Dominant | 59.6 (17.0) | 63.7 (14.3) | 0.579 | 0.14 | [0.01 - 0.64] |
| | | Non dominant | 60.9 (9.8) | 57.1 (8.3) | 0.611 | 0.13 | [0.01 - 0.6] |
| | Internal/ External Rotation | Dominant | 19.8 (6.1) | 28.5 (8.8) | **0.041*** | **0.36** | **[0.04 - 0.68]** |
| | | Non dominant | 19.8 (6.9) | 22.5 (8.9) | 0.439 | 0.14 | [0.01 - 0.46] |
| Ankle | Abduction/ Adduction | Dominant | 44.0 (10.3) | 44.1 (17.8) | 0.678 | 0.11 | [0.01 - 0.55] |
| | | Non dominant | 41.9 (7.9) | 40.9 (13.5) | 0.782 | 0.07 | [0.01 - 0.57] |
| | Dorsiflexion/ Plantarflexion | Dominant | 48.9 (11.4) | 45.0 (10.4) | 0.306 | 0.26 | [0.02 - 0.67] |
| | | Non dominant | 54.5 (10.1) | 46.9 (7.1) | **0.027*** | **0.53** | **[0.11 - 0.82]** |
| | Internal/ External Rotation | Dominant | 40.4 (7.1) | 39.8 (18.9) | 0.306 | 0.26 | [0.02 - 0.69] |
| | | Non dominant | 42.8 (10.4) | 44.3 (10.0) | 0.071 | 0.44 | [0.05 - 0.8] |

*Note:* Pre- and post-intervention data are presented as medians and interquartile ranges (IQR). ES denotes the effect size, and CI represents the confidence interval of the effect size. The bold asteric symbol (*) is utilized to highlight significant differences.

Table 7. Backpedaling comparison ROM pre vs post training program

| Joint | Movement | Test Side | Pre | Post | P-value | ES | CI |
|---|---|---|---|---|---|---|---|
| Hip | Abduction/ Adduction | Dominant | 20.2 (3.9) | 30.2 (8.9) | **0.001*** | **0.77** | **[0.53 - 0.88]** |
| | | Non dominant | 20.5 (7.1) | 26.8 (7.6) | **0.015*** | **0.58** | **[0.18 - 0.88]** |
| | Flexion/ Extension | Dominant | 46.5 (6.6) | 52.7 (20.5) | **0.031*** | **0.52** | **[0.11 - 0.82]** |
| | | Non dominant | 49.3 (7.4) | 58.4 (14.7) | **0.02*** | **0.56** | **[0.15 - 0.87]** |
| | Internal/ External Rotation | Dominant | 18.8 (4.8) | 28.2 (8.6) | **0.004*** | **0.67** | **[0.34 - 0.88]** |
| | | Non dominant | 20.7 (5.2) | 26.1 (6.1) | **0.02*** | **0.56** | **[0.13 - 0.83]** |
| Knee | Abduction/ Adduction | Dominant | 15.6 (10.9) | 22.5 (8.4) | 0.132 | 0.37 | [0.03 - 0.74] |
| | | Non dominant | 19.0 (5.7) | 21.1 (6.7) | 0.548 | 0.15 | [0.01 - 0.61] |
| | Flexion/ Extension | Dominant | 75.2 (7.5) | 67.9 (16.5) | 0.611 | 0.13 | [0.01 - 0.61] |
| | | Non dominant | 80.9 (7.1) | 75.7 (6.0) | 0.08 | 0.43 | [0.04 - 0.8] |
| | Internal/ External Rotation | Dominant | 16.7 (4.4) | 22.9 (5.3) | 0.487 | 0.18 | [0.01 - 0.68] |
| | | Non dominant | 19.0 (5.5) | 23.1 (6.3) | 0.459 | 0.19 | [0.01 - 0.66] |
| Ankle | Abduction/ Adduction | Dominant | 44.1 (16.3) | 45.8 (13.1) | 0.174 | 0.34 | [0.02 - 0.75] |
| | | Non dominant | 39.2 (10.7) | 41.7 (15.2) | 0.517 | 0.17 | [0.01 - 0.59] |
| | Dorsiflexion/ Plantarflexion | Dominant | 49.8 (11.4) | 45.4 (15.7) | 0.132 | 0.37 | [0.03 - 0.76] |
| | | Non dominant | 57.8 (7.5) | 49.1 (14.4) | **0.015*** | **0.58** | **[0.17 - 0.87]** |
| | Internal/ External Rotation | Dominant | 26.7 (7.2) | 30.1 (5.5) | 0.263 | 0.28 | [0.02 - 0.66] |
| | | Non dominant | 27.3 (7.0) | 29.5 (8.6) | 0.284 | 0.27 | [0.02 - 0.67] |

*Note:* Pre- and post-intervention data are presented as medians and interquartile ranges (IQR). ES denotes the effect size, and CI represents the confidence interval of the effect size. The bold asteric symbol (*) is utilized to highlight significant differences.

## 4. Discussion

The present study provides preliminary evidence suggesting that a targeted training program may positively influence agility performance and joint kinematics in soccer players. These findings are in alignment with existing literature emphasizing the critical role of multidirectional movement proficiency in sports like soccer.[17] By analyzing the performance in the Agility T-test, we observed statistically significant improvements in test execution time for both the dominant (-1.0 s; $p < 0.001$) and non-dominant sides (-0.9 s; $p < 0.001$), supporting prior research that links improvements in agility to optimized coordination and lower limb strength.[26,27]

A detailed analysis of joint kinematics revealed that the training program induced meaningful changes in the ROM across key joints involved in the test. For instance, the hip joint exhibited increased internal and external rotation ROM for both the dominant and non-dominant sides, suggesting enhanced control and flexibility. Similarly, improvements in knee joint ROM during forward and lateral phases underscore the importance of dynamic strength and proprioceptive training in augmenting functional joint mobility.[28] However, a notable decrease in ankle plantar/dorsiflexion ROM ($p = 0.001$) was observed, likely reflecting the adaptation to specific movement patterns during agility drills.[29]

The observed enhancements can be attributed to the structured training program, which incorporated exercises targeting strength, coordination, and proprioception. According to Seitz et al.[30], lower limb strength is directly associated with improved sprint and agility performance. This relationship appears to be supported by our findings, as players showed improvements in both time-based performance and joint kinematics. Additionally, exercises designed to stimulate reactive agility, such as tagging and directional changes, contributed to the observed gains in lateral movement efficiency.[8]

One interesting aspect of this study is the differential response between the dominant and non-dominant sides. While both sides demonstrated significant improvements, the slightly larger gains observed on the dominant side may reflect its preexisting biomechanical advantage or greater neural efficiency in executing sport-specific movements.[31] This finding highlights the potential need for further training adaptations that address asymmetries in functional performance.

Despite these promising results, several limitations should be acknowledged. First, this study was designed as a preliminary feasibility investigation, and thus involved a relatively small sample of 17 healthy male amateur athletes, limiting the generalizability of findings. Additionally, no formal power analysis was conducted prior to the study. Another significant limitation is the absence of a control group, which restricts the ability to isolate the effects of the targeted training from potential confounding factors such as environmental conditions and changes in the participants' training state between testing periods. Future studies would benefit from controlled experimental designs that include a control group to better evaluate the specific impacts of the proposed training protocols. Furthermore, environmental conditions differed between baseline and follow-up assessments, with cooler temperatures during the post-test potentially affecting muscle function and joint mechanics. Another limitation is the exclusive focus on the lower limbs. Incorporating total-body kinematic analysis could provide insights into the coordination between upper and lower body segments and its contribution to agility performance.[32] Furthermore, the segmentation of movements, particularly during the Change of Direction (COD) phase, was not performed. Segmenting and analyzing the COD separately could provide deeper insights into specific biomechanical adaptations and performance improvements in this critical phase of agility tasks.

## 5. Conclusion

In conclusion, the findings of this preliminary study suggest that targeted training programs integrating strength, coordination, and proprioceptive exercises can positively influence joint kinematics, potentially enhancing agility and athletic performance in soccer players. Nevertheless, given the methodological limitations, including lack of a control group and variable environmental conditions, these results should be interpreted cautiously.

Future research should investigate the longitudinal impact of such training across an entire season, particularly its role in injury prevention and overall athletic development. Incorporating surface-specific training programs and whole-body kinematic analyses could provide deeper insights into the biomechanical mechanisms underlying agility and performance improvements. This work lays a first step for advancing our understanding of targeted training's impact on athletic performance and joint functionality.

**Author Contributions**

Conceptualization, Salvatore Pinelli, Raffaele Zinno and Laura Bragonzoni; Data curation, Salvatore Pinelli; Formal analysis, Raffaele Zinno; Investigation, Giulio Senesi and Maria Scoppolini Massini; Methodology, Raffaele Zinno and Salvatore Pinelli ; Validation, Giulio Senesi, Erika Pinelli, Maria Scoppolini Massini; Visualization, Salvatore Pinelli; Writing - original draft, Salvatore Pinelli, Giulio Senesi, Maria Scoppolini Massini; Writing - review & editing, Erika Pinelli, Raffaele Zinno and Laura Bragonzoni

**Ethical Compliance**

Research experiments conducted in this article with humans were approved by the Bioethical Committee and responsible authorities of our research organization(s) following all guidelines, regulations, legal, and ethical standards as required for humans or animals.

**Conflicts of Interest**

There are no conflicts to declare.

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