Structural Types of the Foot and Their Influence on Core and Sports Performance in College Athletes

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General Objective:

The objective of this study is to assess the impact of foot arch height and the implementation of a corrective exercise program on foot posture alterations in college athletes. The evaluation will focus on three aspects: postural stability, muscular activity at the center of gravity, and sports performance. This assessment will be conducted using advanced measurement systems such as Surface Electromyography, motion analysis technology, Ergospirometry, and body motion kinematics measurement systems. The findings of this study aim to contribute to the optimization of athlete training and overall performance.

Specific Objectives:

1. Compare the average muscular activity at the center of gravity and both static and dynamic stability among college athletes with low, high, and neutral foot arches. This analysis will employ Surface Electromyography and a 3D motion measurement system. The goal is to determine the potential influence of different foot structural types on core muscle activity and overall stability in athletes.

2. Assess the potential variations in jump force, acceleration, step speed, race time, maximum oxygen consumption, and anaerobic threshold among college athletes with high, low, or neutral foot arches. This investigation will utilize biomechanical analysis technology and Ergospirometry, with the aim of identifying any possible impact of varying foot structural types on athletes' performance capacity.

3. Evaluate the potential changes in terms of center of gravity muscle activity and both static and dynamic stability after a 12-week exercise program designed to correct different foot structural types (high or low) in college athletes. This assessment will employ Surface Electromyography and a 3D motion measurement system, with the objective of establishing the effectiveness of these exercises in improving athletes' body stability.

4. Determine the potential alterations in VO2max, anaerobic threshold, jump force, acceleration, step speed, and race time in college athletes, following a 12-week exercise program aimed at correcting two foot structural types (high or low). This investigation will use Ergospirometry and a 3D motion kinematics assessment system to evaluate possible improvements in sports performance resulting from the exercise program.

Methodology:

Design and Sample: An observational study design was employed to assess the impact of foot structural types on postural stability, activity of core stabilizing muscles, maximum oxygen consumption (VO2max), anaerobic threshold, and lower limb performance in male college athletes over 18 years old from the University of Magdalena, participating in various sports modalities such as rugby, soccer, basketball, volleyball, tennis, table tennis, karate, and cheerleading. For evaluating the effects of a corrective exercise program targeting high or low foot posture alterations on the same variables, an experimental design was used. Stratified random sampling was employed for convenience, and 35 participants with low medial arch, 32 with high arch, and 36 with neutral arch were selected for the observational studies. For the experimental studies, 33, 31, and 33 participants were selected, respectively, from a pool of 230 candidate athletes. G Power 3.1.9.7 software was used to determine the appropriate sample size, considering three independent groups, an alpha level set at 0.05, a power (1-β) of 0.80, and an effect size (f) of 0.40.

Foot Type Evaluation: The Foot Arch Index, which determines the medial arch height by measuring the ratio between the midfoot area and the total foot area (excluding toes), was used to evaluate the foot type. An index less than 0.21 indicated a high-arched foot, an index greater than 0.26 indicated a flat foot, and an index between 0.21 and 0.26 was considered a "neutral" arch. Participants' footprints were obtained using a washable ink pad, and analysis software was used to calculate the Foot Arch Index.

Study Instruments: State-of-the-art equipment was used, including 3D inertial sensors for assessing static and dynamic postural stability (optogate and Gyko, Microgate® Bolzano, Italy), surface electromyography to measure neuromuscular activity of core muscles (Biomec® Newport, United Kingdom), ergospirometry equipment to measure oxygen consumption and anaerobic threshold (Cosmed® K5, Rome, Italy), motion analysis equipment to assess jump power and speed (Gyko, Microgate® Bolzano, Italy), and photocell sensors to measure running speed and times (Witty-Microgate® Bolzano, Italy). Anthropometric measurements were conducted using a bioimpedance equipment (InBody® 970, Seoul, Korea).

Measurement of Dependent Variables: This study evaluated the action of core muscles and static and dynamic body stability. Surface electromyography (sEMG) was used to measure muscle activity during functional exercises, such as unstable Bulgarian squats with weights for Rectus Abdominis (RA), front plank with shoulder adduction and posterior pelvic tilt for Internal Oblique (IO), standing unilateral dumbbell press for External Oblique (EO), and deadlift for Spinal Erectors (SE). These postures demonstrated the highest activity in electromyography studies. Core assessment exercises were performed with each muscle group holding an isometric contraction for 5 seconds. Parameters recommended in the literature were used for electrode placement on RA and for SE, IO, and EO. Static postural control tests were conducted with eyes closed to increase changes in somatosensory and muscular components of the postural control system. Athletes remained motionless for 10 seconds with closed eyes, and four measurements were taken for the dominant foot, with 30-second rests between each measurement.

Different parameters such as average distance and speed, anteroposterior distance and speed, mediolateral distance and speed, and covered area were measured. Dynamic postural control was evaluated by performing five single-leg jumps with the dominant foot to obtain data on average power and average displacement to the left/right and forward/backward, as well as covered area. All muscle strength measurements and assessments of static and dynamic postural control were conducted on different days to avoid muscle fatigue.

The measurements were performed during the general preparation stage of each sports semester, with no changes in diet and approximately two hours after the main meal of the day. To evaluate aerobic capacity (VO2max) and anaerobic threshold, participants underwent an incremental treadmill test. The test began with a 3-minute warm-up at a speed of 4.8 km/h, increasing 1.2 km/h every minute while maintaining a constant 3% incline. Then, the main test started at 8.2 km/h with a constant 3% incline, and speed increased by 1.2 km/h every two minutes until exhaustion. The V-Slope method was used to measure VO2 values at the anaerobic threshold. VO2max was estimated based on three criteria: when the participant could not continue the test, when the VCO2/VO2 ratio exceeded 1.1, or when the maximum heart rate was reached with no more than a 10 beats/minute difference. To measure performance capacity, the countermovement jump (CMJ) technique was used, which involved jumping from a kneeling and hip-flexed position. Different parameters, such as maximum force, maximum velocity, maximum power, and level of developed force, were recorded. To assess lower limb speed and acceleration, the 40-meter linear acceleration test was employed, which demonstrated good reliability and validity.

Program of Corrective Foot Posture Exercises: In the experimental studies, the intervention group followed a 12-week exercise program aimed at correcting foot posture alterations, while the control group performed flexibility exercises. The exercises for the intervention group varied based on foot structural type (high or low) and focused on strengthening intrinsic and extrinsic foot muscles. The program was conducted under the supervision of an experienced physiotherapist. For participants with flat feet, exercises focused on strengthening the abductor hallucis, flexor digitorum brevis, and quadratus plantae muscles, with a progressive load over eight weeks. Additionally, myofascial release of the lateral long fibular muscle was performed. For participants with high arches, exercises emphasized improving flexibility of the tibialis posterior and gastrosoleus muscles. Strengthening exercises for the same muscles as in the flat feet group were also performed, with a gradual increase in load.

Statistical Analysis: Data were reported as mean ± standard deviation and analyzed using IBM SPSS Statistics (version 21, IBM Corp., NY, USA). The normality of each variable for different foot types (low, high, or neutral) was checked using the Shapiro-Wilk test. The significance of variables such as age, weight, height, and muscle/fat percentages among the three foot types was evaluated using ANOVA if the variables followed a normal distribution, or the Kruskal-Wallis test if they did not. For descriptive studies, ANOVA was used for normally distributed dependent variables or Kruskal-Wallis for non-normally distributed variables. Levene's test was used to assess homogeneity of variances. Post-hoc analysis with Bonferroni correction was performed to determine differences between groups. Pearson's or Spearman's correlation was used to assess the relationship between variables. For experimental studies, the effects of exercise on dependent variables were assessed using repeated-measures ANOVA or Friedman's test. Levene's test was used for variance homogeneity. Post-hoc analysis with Tukey correction was conducted to assess pre-post exercise significances of dependent variables. Eta-squared (η2p) or Kendall's W concordance coefficient was used to evaluate the effect size of the exercise program on foot types. The significance level for both studies was set at $p \leq 0.05$.