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The effects of lumbar spinal manipulation on athletes' symmetry: a prospective randomized study*

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Abstract: Objectives: the purpose of this prospective study among healthy athletes was to verify the possible effects of lumbar manipulation on symmetry, analysing the measured outcomes from physical tests. Methods: Young athletes of both genders were selected according to the eligibility criteria, randomly allocated into experimental and control groups. Data were collected with two

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force platforms integrated with motion capture system, to retrieve the bilateral ground reaction forces, to apply the symmetry index. All participants performed three commonly used physical performance tests, including static posture, squat, and vertical jump, before and after the lumbar manipulation and control intervention. Results: In the group 1 pre- to post-lumbar manipulation, statistically significant differences were found in bilateral symmetry. The improvement of symmetry was found in static post-lumbar spinal manipulation. In the group 2 pre- to post-control intervention, no statistically significant differences were found. Conclusions: The athletes from group 1, benefited regarding to the static symmetry after lumbar intervention. These findings suggest that one single lumbar spinal manipulation, actually took place, producing effects on symmetry.

Keywords: Biomechanics phenomena, spinal manipulation, lumbar, ground reaction forces, symmetry index**.**

Summary:

I. INTRODUCTION

The common focus of biomechanics and sports rehabilitation is to enhance individual capabilities in terms of the proficiency and consistency of techniques relative to physical performance tasks that are typically practiced by symptomatic and asymptomatic (1) athletes from different levels and modalities (2). This focus contributes to the controlling and minimizing the intrinsic and extrinsic injury risk factors (3), which affect the quality of movements on daily training and competition routines (4,5), mainly as a result of repetitive biomechanical demands (4,5).

The identification of previous musculoskeletal disorders, such as biomechanical spinal dysfunctions, which may create lower limb asymmetries that predict injuries in athletes, may be the key to treating these conditions (2), even if they are symptomatic or asymptomatic or occur during training or competition, which has been the goal of all involved sports professionals.

Functional asymmetries in athletes may be associated with performing a task asymmetrically, in static and dynamic tests (9–16), as a result of excess training and/or various other factors. Deviations from ideal bilateral symmetry may be interpreted as a signal of a lack of asymmetrical pattern development that influences the normal biomechanics parameters.

Bilateral asymmetry assessment techniques can be employed in commonly used physical performance tests and are often used as indicators of an athlete's performance in sports (2,10,14,17–25). Several authors have calculated the bilateral symmetry through the symmetry index for gait, vertical jumps and other assessments, agreeing that symmetry index values greater than 15% represent an important asymmetry (10,24,26–31). However, these data are important to verify the existence of bilateral asymmetries of physical performance tests (10,11,32) to assess training effectiveness and contribute to prevention/rehabilitation program outcomes (27,32–36).

Spinal manipulation is a safe and considerably effective therapy for musculoskeletal disorders that has increasingly been used in sports (38) in athletes of different levels and modalities; it is applied by clinicians, including chiropractors and physiotherapists, in sports competitions worldwide, such as Olympic game events (17,33,39), as part of the medical services available for teams.

The purpose of spinal manipulation is to correct spinal joint biomechanical dysfunctions using a high-velocity, low-amplitude movement, which is applied in the paraphysiological space beyond the passive joint range of motion (11).

According to the literature, no studies have been performed with athletes integrating knowledge regarding clinical rehabilitation, sports performance and biomechanics, with a focus on symmetry parameters.

Therefore, the objectives of this prospective randomized study was to verify and analyse the measured outcomes pre and post lumbar and control interventions, through the use of three commonly employed physical performance tests in static and dynamic actions.

II. MATERIALS AND METHODS

Based on a previous study sample size (43), twenty athletes (n: 20) from different levels and sports modalities participated in this prospective ramdomized study.

All the participants were volunteers who signed an informed consent form prior to their enrolment. The research protocol was approved by the ethics research committee from university.

III. DATA COLLECTION PROCEDURES

Prior to the acquisition of the kinetic parameters, demographic anthropometric data, including age, body weight and height measurements for each participant, were recorded. The physical performance tests were administered for 5 minutes (pre-and-post therapeutic intervention) for each participant to familiarize them with the tasks and procedures of data collection.

In sequence to collect this type of data were the necessary calibration of the space (force plate area inside the biomechanics laboratory) and the motion capture system utilized to obtain kinetic symmetry through force platforms and optoelectronic systems (44–46), for kinematics. The marker set (47) and model used (figure 1) in this study were based on the calibrated anatomical system technique (CAST).

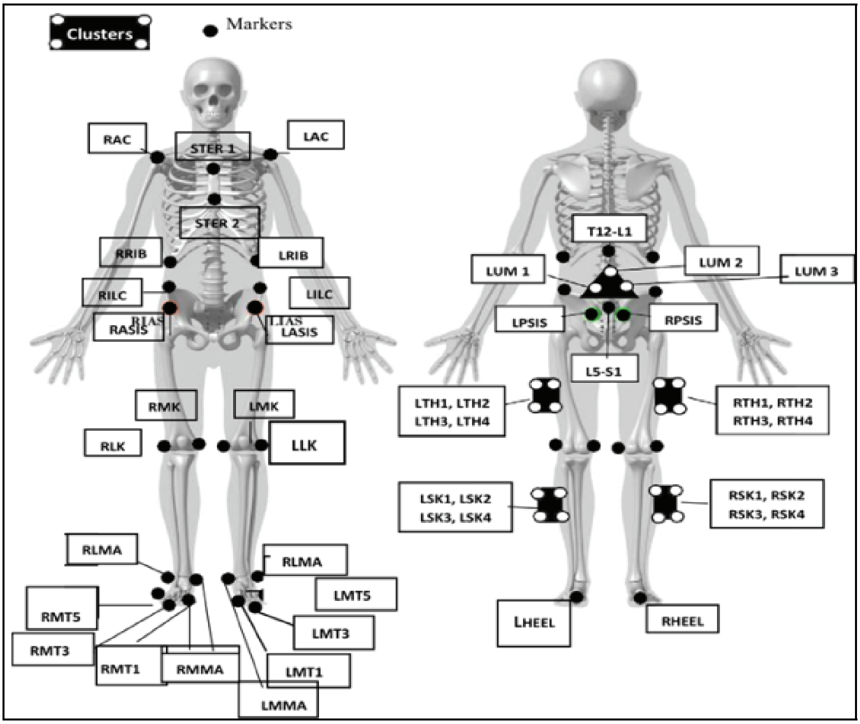


Figure 1 - Marker set-up and biomechanical 3D model. Anterior (left) and posterior (right) views of the 49 marker placement, and 5 rigid clusters (Squares with 4 markers) were placed on the lateral aspect of the thighs and shanks.

The participants were invited to show their performance through performance tests before (pre-test) and after (post-test) the lumbar intervention.

Physical Tests (Pre and Post Interventions) sequence.

Prior to performing the physical tests, the participants were informed of the tasks and were provided with an opportunity to practice for at least 5 minutes, performing two repetitions of each task for familiarization.

The athletes stood on the force platform, with one side in each force platform; starting with the pre-test in three consecutive tasks, the static, squat movement and the vertical jump included 3 repetitions.

After the pre-test, the participants received the interventions lumbar manipulation (group 1) and control intervention (group 2); according to the randomly allocation. For the group 1, the therapeutic intervention was applied according biomechanical dysfunctions on the lumbar spine detected; the athletes subsequently performed the post-test, with the same tasks and sequence of the pre-test according to the study protocol (figure 2).

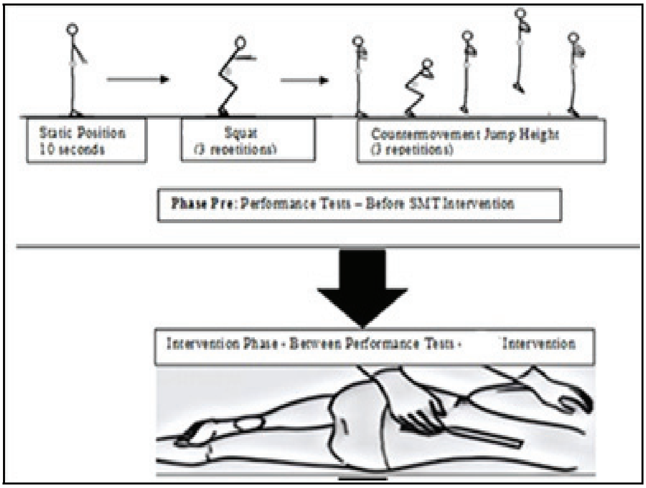


Figure 2 - Physical Tests (Pre and post-tests, static, squat and jump), between lumbar and control interventions.

These performance tests involve since static tasks until dynamic and explosive movements tasks, thus representing the movements typically performed in individuals who have sports practice in daily life because these movements are commonly used in sports and physical activity in general.

Static

- Static (standing position)

The participants were invited to straighten in an orthostatic position (static posture-STT) over two force platforms, (FP1) and (FP2), left and right sides, respectively, with the feet in running shoes on each plate and under a motion capture system, (figure 3) remaining stopped for 10 seconds, to record the kinetic variables. The static posture outcomes measured included the ground reaction forces (GRF) in Newton's (N/Kg), which presents the lower limb reaction force symmetry as a percent (%), calculated by the Symmetry Index (SI), for pre (Static 1) and post (Static 2).

Figure 3 - Picture with posterior view of the participant on data collection session. **Dynamic trials:** (squat movement and vertical jump)

- Squat: The movement started with the athletes standing with the knees and hips in full extension; the athletes were subsequently instructed to squat freely and then return to the original position.

The data were recorded as the pre-test (initial) and post-test (final) intervention Normalized data by the participant's body mass and were utilized in the symmetry index calculations. The data were captured and recorded with a cadence determined of 4 times to go down and 4 times to go up during three repetitions of the squat movement, pre- (initial) and post- (final) intervention.

The outcome measures of the maximal flexion at the 'PB point' between descending and ascending were acquired to obtain the kinetic values to subsequently apply the index in all participants. The ground reaction forces (GRF) values were assessed as the mean and standard deviation to calculate the symmetry index.

- Vertical Jump: athletes were instructed to cross their arms over the chest and perform a maximal vertical jump countermovement.

At the lowest centre of mass at the propulsion phase, the acquired data were used to achieve outcome measures from jumps. The outcome measures of the maximal flexion at the propulsion phase, prior to jump (last instant framed before take-off), represented data acquired to achieve the kinetic values, which was subsequently calculated in the symmetry index for all participants.

IV. LUMBAR SPINAL MANIPULATION INTERVENTION

Group 1 was assigned to the lumbar spinal manipulation intervention with 10 participants. Lumbar intervention was performed by a researcher on the athlete participants using Diversified techniques (42) that aim to correct the vertebral dysfunctional segments identified in the clinical assessments prior to the intervention. Between the physical performance tests, the participants were instructed to lay down prone for the spinal motion palpation analysis. It was performed to evaluate the presence of dysfunction in the vertebral segments of the lumbar spine. Then the intervention was subsequently performed with the athlete laying sideways while a correction was performed contacting the transverse process (mammillary) of the lumbar vertebrae, performing the lumbar roll technique, with a line drive posterior to the anterior force vector, as described by Liekens-Gillet and Bergmann, as well as by Száraz (40,42).

The validated diagnostic criteria used in our previous study performed by the lab team and other clinical study recommendations by the WHO and clinical practice guidelines (48–53) have been established. The safety and efficacy of these diagnoses and treatments for this condition have been demonstrated (54).

Control group intervention – Pre-positioning Lumbar manipulation

Group 2 was assigned to the randomized control group with n:10 participants, who only received the procedure "SHAM" (pre-load positionin, lumbar manipulation). The intervention was performed with the participant's body positioning in the lateral recumbent, as in the lumbar intervention. The researcher followed the participant through the same position, but using the maintenance of the set-up position; however, no manipulative thrust was delivered. The position was maintained for approximately, with 30 seconds on each side. None of the force or researcher's body weight were applied in this procedure; only minimal contact was common to stabilize the set-up position of this type of intervention.

In our study, to complement the measurements and verify the lower limb reaction force symmetry during physical performance tests was applied the symmetry index; moreover, we assessed how it works using multiple events retrieving the biomechanical parameters at a specific point of all cycles of the physical performance test on marked instants.

Symmetry Index (SI)

The SI index is the method most commonly used and cited in publications on gait symmetry or bilateral asymmetry in performance tests. The symmetry measures include the difference between two sides, referred to as the Symmetry Index (SI) (27). The SI is calculated as subsequently expressed, where 0% represents a perfect symmetry and 100% represents a complete asymmetry:

$$SI = \frac{X_R - X_L}{1/2(X_R + X_L)} \,.\, 100\%$$

(eq.1): where X_R is a measure from the right side and X_L is a homologous measure from the left side.

The SI index is a method of assessment of the differences between the lower limbs at the local level (during a marked instant of the specific point of all cycle). This equation was used because the purpose of the study was to assess the local symmetry side by side; it was not to assess whether the dominance of one lower limb over the other interfered.

Data processing

Data were recorded in the pre and post phases, thus obtaining outcome measures of the ground reaction forces (GRF). After these data were obtained, the values were normalized by the mass to apply the equations (eq.1) for the symmetry index (SI) calculations, as well as the statistical analysis for kinetic parameters at the local level in all participants.

After data collection with the athlete participants, the reflective markers and ground reaction forces (GRF) recorded were identified by *Qualisys QTM software (Gothenburg, Sweden)* and were exported as c3d. archived in file (CMO) format to be processed and analysed. Using this *software,* the biomechanics model created was used on static and dynamic movements, reconstructed body segments, filtered and calculated kinetic data through measured outcomes (GRF).

Statistical Analysis

All statistical analyses were performed using *SPSS (Version 24: IBM, Chicago, IL), Microsoft Office Excel.* A two-way random model, was utilized in *SPSS software* for calculations of the discrete and continuous data measured outcomes from the physical performance tests symmetry.

The Student's t test was employed, whereas for data with a non-normal distribution, a nonparametric test was used for the comparisons between the two groups. Moreover, linear regression bivariate and ANOVA models were employed for all included variables. Moreover, *Microsoft Office Software Excel* was used to calculate the remaining statistical data.

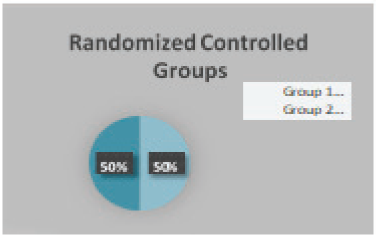
Results

Relative to the baseline athlete participants' characteristics, the table 1, shows the mean and standard deviation for the age, body mass and height of all study participants.

Participants characteristics	Age years old	Weight / Kg	Height / m
Mean	23,47	66,54	1,70
SD	4,4	9,35	0,062

Table 1 - Demographic data: Baseline anthropometric characteristics of all athletes' participants (n:20). The Mean (M) and Standard Deviation (SD) of age, body mass and height of all participants represented.

In this study, all twenty participants were randomly divided in two groups and completed the study protocol. No participants left the study or had complaints and/or injuries during the data collection procedures. Moreover, there were no related side effects or negative interference on the training performance or daily life post study participation.



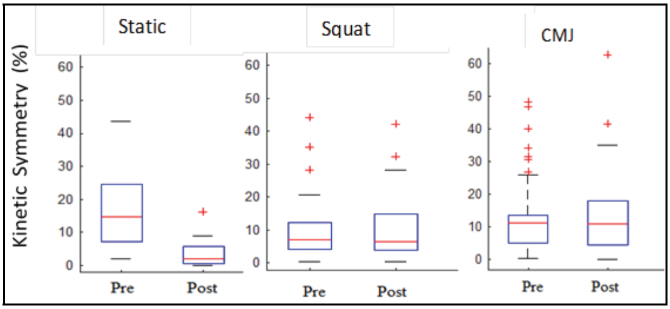
Graphic 1 - Demographic data distribution of the group of athletes' participants.

Group 1 - Lumbar spinal manipulation and control, intervention groups

- Static (standing position): The outcome measures related to the symmetry index were calculated using $P<0.05$ statistical significance. The mean and standard deviation were calculated pre and post, respectively. The outcome measures of the symmetry index (SI) on the pre phase mean were (M) 22% and standard deviation (SD) ± 12.4, with a post phase (M) 7.7% and (SD) ± 4.18. There was an increase in the lower limb reaction force symmetry on the static after the lumbar intervention.

- Squat: The outcome measures related to the symmetry index were calculated using $P<0.05$ statistical significance. The mean and standard deviation were calculated pre and post, respectively. The pre phase mean was (M) 10.37% and Standard Deviation (SD) ± 5.52, with a post phase (M) 13.47% and (SD) ± 6.77. There were no statistically significant differences.

- Vertical Jump (CMJ): The outcome measures related to the symmetry index were calculated using $P<0.05$ statistical significance. The mean and standard deviation were calculated pre and post, respectively. The pre phase mean was (M) 14.9% and (SD) ± 8.6, with a post phase mean (M) 17.8% and (SD) ± 8.8. There were no statistically significant differences.



Graphic 2 - Visual Representation of variability values by symmetry index, shows the percentage values of mean bilateral symmetry for all participants (n=20). Measured outcomes of test-retest physical performance tests. The blue box, red line and red cross signal as outliers, represents total variability values from kinetic symmetry by used index.

Discussions

Firstly, we discuss the results assuming that this prospective study aimed to verify and analyse the continuous and discrete variables, focusing on the athletes' symmetry over time data's (test-retest), and, if are or not influenced by spinal manipulation.

Because we did not find studies with the same or at least similar protocol in the literature with which to compare our results, we tried to bring important data from this study, and, from several studies find in the literature, that separately developed similar protocols.

The results regarding the ground reaction forces showed altered effects in the bilateral asymmetry on the static tests in the asymptomatic athletes' participants. There was an immediate increase in the bilateral symmetry on the static posture. The values presented a difference of 15% pre and post on the lower limb reaction force symmetry post lumbar manipulation; after this intervention, the percentage of lower limb reaction force symmetry was reduced, thus becoming more symmetrical. However, our results appear to indicate that single lumbar manipulation may significantly improve symmetry, becoming more balanced relative to the bilateral weight distribution (ground reaction forces) in the static position in athletes.

This may be representative of the immediate effects of lumbar SMT in bilateral symmetry in static posture for clinical and sportive contexts, which more symmetrical could enhance the functional performance on posture maintenance, becoming more balanced relative at the weight distribution over the force platform, thus reducing the possibility of biomechanics joint stress and injuries (33,64).

The postural behaviour of healthy and asymptomatic subjects may be characterized in terms of postural static performance, segmental and neural strategies. According to Bizzini et al (28), neuromuscular control is the interaction of systems that integrate different aspects of muscle actions (static, dynamic, and reactive), muscle activation (eccentric and concentric), inter- and intramuscular coordination, core stabilization, balance, and body posture. In this sense, we speculate that these decreases in the percentage of asymmetry on performance tests immediately after lumbar intervention in athletes, may be related to the changes in the neuro-musculoskeletal system described in the literature (43,44,68,69), particularly because the postural control is an important factor for evaluating physical performance and it depends of many other factors, including neurologic, orthopaedic and functional factors, as well as age and gender.

Therefore, this findings suggest a therapeutic strategy of correcting the lumbar vertebral dysfunctions through spinal manipulation application, which influences the biomechanics parameters such as symmetry in physical tests (65,66,74), which affect the musculoskeletal system, namely, on postural muscles and anti-gravitational ones.

In terms of clinical and sportive relevance, we can verify the greater improvement of bilateral symmetry in asymptomatic athlete participants. However, these changes may interfere with the physical performance of many functional static tasks (in the begin, middle and end of movements). Tomkinson, et al (75) suggested that individuals who are functionally symmetric also have improved physical performance.

In this study, relative to dynamic actions, lumbar intervention did not significantly alter kinetic symmetry in dynamic movements, namely, squat and jump. According to the therapeutic intervention literature, there is limited evidence that spinal manipulation may be beneficial in dynamic movements. Our findings are in line, in part, with study performed by Shier et al (76), who measured jump height by applying single thoracolumbar SMT and metatarsal adjustment; no changes were observed in terms of improvement; no symmetry index calculations were applied.

Relative of pre- to post-SHAM intervention, no statistically significant immediate differences were found in bilateral asymmetry namely on kinetic effects of static and dynamic actions of physical performance tests, between (pre-positioning manipulation) in athletes.

Focusing on quantitative measurements of athletes' symmetry, this study expects to contributes to scientific, sportive and clinical communities with information's regarding the randomized study results in terms of lumbar spinal manipulation intervention on symmetry parameters.

The main findings are that only in static, lumbar manipulation was better. Most of the kinetic outcomes showed to be better pre than post phase between lumbar intervention on physical tests relative to symmetry. Thus, these results may not could suggest that athletes with bilateral asymmetry conditions who commonly present with functional joint/spinal dysfunctions exhibiting a unilateral or bilateral decrease in biomechanical parameters during movements, decrease bilateral asymmetries in terms of physical tests, immediately after lumbar intervention.

Given the addition of the randomized study performed regarding the symmetry parameters in physical tests influenced by lumbar intervention, was expect to contribute an important step for further studies contributing with the clinical, academic and sportive contexts, but more randomized and cohort studies are needed to complement the gaps about this theme.

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Graphic:

Graphic 2: Box-plot; visual representation of variability values by symmetry index, shows the percentage values of bilateral symmetry for all participants.

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Not applicable.

Declarations:

Study protocol approved by Ethic Committee (University of Lisbon).

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