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# Impact of Occlusal Interventions using the Messerman Test on Postural and Musculoskeletal Stability in Adult Weightlifters under Static Conditions: Experimental Study

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# INDEX

## 1. ABBREVIATIONS

| | |
|---|---|
| AI | Artificial Intelligence |
| APECS | AI Posture Evaluation and Correction System |
| ASIS | Anterior Superior Iliac Spine |
| CHA | Cervical Horizontal Angle |
| CNS | Central Nervous System |
| CR | Centric Relation |
| CVA | Craniovertebral Angle |
| FHP | Forward Head Posture |
| HKA | Hip-Knee Angle |
| LHP | Lower Horizontal Plane |
| LJ-Me | Lip Junction-Menton Angle |
| MI | Maximum Intercuspation |
| SSP | Scapular Shoulder Position |
| TMJ | Temporomandibular Joint |
| UHP | Upper Horizontal Plane |
| VP | Vertical Plane |

## 2. ABSTRACT

**Introduction:** This study investigates whether occlusal interventions, using the Messerman Test, may improve postural and musculoskeletal stability in adult weightlifters under static conditions compared to natural occlusion. Despite their high level of physical training, athletes often present with postural misalignments. These imbalances may not only affect athletic performance but also predispose athletes to injury. The aim was to determine whether occlusal adjustments could positively impact overall postural alignment, including both upper and lower body regions.

**Materials and methods:** A pre- and post-experimental study was performed to assess static posture before and after the occlusal intervention. Postural evaluation was performed using both the Messerman Test and the APECS system. Variables analyzed included craniovertebral angle (CVA), head and shoulder alignment (CHA), lower body deviations (feet, knees), and spinal alignment.

**Results:** Results showed that prior to the intervention, common postural imbalances were observed. Post-intervention, significant improvements were noted in head-neck alignment and reduced head tilt. However, improvements in body alignment were limited, with slight improvements in feet and knees, but a deterioration in spinal alignment, and balance remained unchanged.

**Conclusion:** The occlusal intervention showed limited effects on overall static postural control in trained weightlifters. While some improvements were observed in craniofacial and lower limb alignment, spinal alignment did not benefit, indicating that occlusal changes alone may not sufficiently address overall postural stability. Further research is needed to explore the interaction between dental occlusion and musculoskeletal alignment in athletes.

## 3. RESUMEN

**Introducción:** Este estudio investiga si las intervenciones oclusales, utilizando el Test de Messerman, pueden mejorar la estabilidad postural y musculoesquelética en halterófilos adultos en condiciones estáticas en comparación con la oclusión natural. A pesar de su alto nivel de entrenamiento físico, los atletas a menudo presentan desalineaciones posturales. Estos desequilibrios no solo pueden afectar el rendimiento atlético, sino también predisponer a los atletas a lesiones. El objetivo fue determinar si los ajustes oclusales podían impactar positivamente en la alineación postural general, incluyendo tanto las regiones superiores como inferior del cuerpo.

**Material y método:** Se realizó un estudio experimental pre y post intervención para evaluar la postura estática antes y después de la intervención oclusal. La evaluación postural se llevó a cabo utilizando tanto el Test de Messerman como el sistema APECS. Las variables analizadas incluyeron el ángulo craneovertebral (CVA), la alineación de la cabeza y los hombros (CHA), las desviaciones en la parte inferior del cuerpo (pies, rodillas) y la alineación espinal.

**Resultados:** Pre-intervención, los resultados evidenciaron desequilibrios posturales comunes, mientras que tras la intervención se observaron mejoras significativas en la alineación cabeza-cuello y una reducción en la inclinación de la cabeza. No obstante, las mejoras en la alineación corporal fueron limitadas, con ligeros avances en la posición de pies y rodillas, pero un empeoramiento en la alineación espinal, y sin cambios en el equilibrio.

**Conclusión:** La intervención oclusal mostró efectos limitados en el control postural estático general en halterófilos entrenados. Aunque se observaron algunas mejoras en la alineación craneofacial y de las extremidades inferiores, la alineación espinal no mostró beneficios significativos, lo que indica que los cambios oclusales por sí solos pueden no ser suficientes para abordar la estabilidad postural general. Se necesitan más investigaciones para explorar la interacción entre la oclusión dental y la alineación musculoesquelética en los atletas.

## 4. KEYWORDS

I. APECS
II. Athlete
III. Athletic performance
IV. Dental occlusion
V. Maximum intercuspation
VI. Messerman Test
VII. Occlusal interferences
VIII. Occlusion
IX. Postural balance
X. Posture
XI. Stomatognathic system
XII. Weightlifting

# 5. INTRODUCTION

Dentistry is undergoing a transformation, moving away from being seen as a field that focuses only on the oral cavity, and instead starting to look at the body as a whole. Increasing evidence exists to suggest that dental occlusion is linked to postural control, and balance. This acknowledgment highlights the importance of a multidisciplinary approach that positions dentistry alongside specialties such as biomechanics, physiotherapy, neurology, and orthodontics. Understanding the human body as a whole is essential for accurate diagnosis and efficient treatment. Research has proven that occlusion is capable of influencing and being influenced by musculoskeletal function and posture. Postural analysis also helps to maintain this perspective, demonstrating that imbalances in foot pressure, spinal alignment, or body balance are often related with dental malocclusions (1).

These findings highlight the need for dentistry to actively participate in interdisciplinary diagnostic and therapeutic approaches, establishing a new era of dental and medical collaboration for a deeper understanding of the human body. Despite growing interest in the occlusion-posture relationship, much of the existing research remains inconclusive or lacks consistency. This study aims to address this gap by investigating the effects of occlusal intervention on posture, particularly in weightlifters, where precise neuromuscular coordination is crucial.

## 5.1 Posture

Posture is the position of the body in space, designed to maintain balance in both static and dynamic conditions (2). It is an unconscious, automatic response to gravity that is realized by a properly coordinated skeletal muscle contraction and neuromuscular adjustments in the integration of the sensory input of the proprioceptive, visual, and vestibular systems at the level of the central nervous system (CNS) (2,3). It guarantees balance with maximum stability, a minimum of energy expenditure, and a minimum stress of anatomical structures, adapting to the environmental and mobility demands (2).

Postural stability relies on the coordination of key muscle groups that regulate head and spinal alignment. According to Brodie´s Theory, the center of gravity of the head is naturally positioned anterior to the atlanto-occipital joints, which is the primary support point on the cervical spine. This forward positioning of the head needs a continuous activation of the cervical extensor muscles to counteract this effect. The sub-occipital muscles play a crucial role in adjusting head positioning, while the sternocleidomastoid and deep cervical flexors stabilize posture through antagonistic interaction. Additionally, the suprahyoid muscles also influence mandibular posture, which directly affects spinal alignment. When these muscles are not in balance, due to occlusal asymmetry or parafunctional habits, they can alter head posture, disrupt cervical alignment, and trigger compensatory activation in deeper postural chains (4).

Maintaining correct body posture is important for overall health, since an ideal upright posture is considered a key indicator of musculoskeletal well-being and proper body alignment. Consequently, deviations from optimal posture may negatively impact health, emphasizing the importance of postural stability and alignment (5).

### 5.1.1 Static and Dynamic Posture

Understanding the role of posture in maintaining balance and stability requires distinguishing between its two primary forms: static and dynamic posture.

In both types of balance, the center of gravity is stabilized by following the body´s anatomical structure, using minimal energy by evenly distributing the weight across the skeleton. Stability is maintained through isometric muscle contractions. Opposing muscles work together to maintain postural tone and keep the body in balance. Good coordination between the muscular and skeletal systems is important in maintaining the body´s equilibrium (2).

Static posture refers to the ability of the body to maintain a stable position, such as sitting or standing, by aligning the spinal column along its natural curvatures In athletes, particularly weightlifters, maintaining static posture is important when performing lifts, since posture can directly influence stability. In contrast, dynamic posture is the maintenance of balance by movements such as walking or performing everyday tasks. It requires coordinated muscle action, joint stability, and skeletal support, regulated by essential systems, such as the CNS, proprioceptors, and the vestibular apparatus, keeping proper alignment and stability (2).

Although this study primarily focuses on static postural assessment, the dynamic nature of athletic performance is important for the understanding of how both static and dynamic postural mechanisms are influenced by occlusal factors.

### 5.1.2 Posturology

Since dental occlusion can affect posture, it's important to understand how posture is studied and evaluated. For this reason, gaining a basic understanding of posturology is important.

Posturology is a scientific and clinical study of posture and balance in humans, with a focus on the function of orthostatic posture (the ability to maintain an upright standing position against gravity) and the factors that influence this function, including pathological conditions, which may otherwise be difficult to recognize (2,3). This discipline analyses the relationship between posture and functional disorders, as well as its impact on chronic conditions such as headaches, fibromyalgia, back pain, and other daily challenges (2).

The three major approaches that posturology is based on, include the neurophysiological model, which focuses on postural tone and balance; the biomechanical model, which considers body alignment and movement in its relation to gravity and reflexes; and the psychosomatic model, considering how psychological or emotional factors interact with posture. By focusing on these aspects, posturology aims to assess how posture reflects general health and to identify the cause of the problem behind postural imbalances (2).

## 5.2 Occlusion

Occlusion, the static relationship between the upper and lower teeth, plays an important role in maintaining both the functional stability of the masticatory system and overall postural alignment (6,7). Ideal occlusion is achieved when all posterior teeth make simultaneous contact, evenly distributing occlusal forces across the dental arches (7).

This dental relationship is closely linked to the function of mandibular and cervical muscles, which not only coordinate jaw movement but also influence head and neck posture. The masseter, temporalis, and lateral pterygoid muscles work together to stabilize the temporomandibular joint (TMJ), with the lateral pterygoid contributing to mandibular translation and proprioceptive input to the CNS. Supporting these actions, the suprahyoid muscles, particularly the digastric and mylohyoid, connect the mandible to the hyoid bone and assist in maintaining mandibular posture and cervical alignment (4,8).

Occlusal conditions can influence a broader network of muscles involved in posture. These include not only the jaw and neck but also trunk and even lower limb stabilizers such as the sternocleidomastoid, erector spinae, and gastrocnemius, all of which may adapt to imbalanced occlusal contact. For instance, asymmetrical occlusion can disrupt the functional relationship between the masseter and sternocleidomastoid, leading to compensatory muscle activity and shifts in postural control (9). Head posture also affects mandibular function, providing that altered head position may change muscle activation patterns and contribute to forward head position (FHP) and neck myalgia (8).

A key component in this system is the trigeminal nerve, which connects the masticatory system with cervical and lumbar motor pathways. Occlusal disturbances can activate this nerve, triggering neuromuscular responses that affect both static and dynamic postural stability. These effects are especially noticeable in athletes, where even small occlusal imbalances can lead to asymmetrical muscle activity, altered pelvic alignment, and decreased postural control, directly impact performance (10).

### 5.2.1 Static and Dynamic Occlusion

Understanding occlusion requires understanding the difference between static and dynamic occlusion, as well as the different types of occlusions, as it helps to identify how occlusal factors affect postural stability.

Static occlusion is the alignment of teeth and the morphological relationship between the upper and lower teeth when they come into contact when the jaw is closed and in a stationary position. In contrast, dynamic occlusion occurs when the teeth make contact during any mandibular movement, such as speaking or chewing. An ideal dynamic occlusion is characterized by the absence of occlusal interferences during these functional movements (11). The different types of occlusions, static, dynamic, and ideal, are all interrelated in understanding how the teeth and jaw interact both at rest and during movement.

Centric relation (CR) is the ideal and stable position of the condyles inside the glenoid cavity, where the masticatory system gains its highest stability and relaxation. This position is independent of tooth contact and is related to the most orthopedically stable position of the TMJ. In contrast, maximum intercuspation (MI) focuses on the tooth contact, representing the most even distribution of occlusal and masticatory loads on the greatest number of teeth with the maximum contact between both arches simultaneously in a very stable position (6).

When CR and MI coincide, they define what is known as ideal occlusion. This represents the optimal functional relationship between the teeth and the TMJ, where the condyles are positioned in a stable CR with the articular discs properly seated in the mandibular fossa, and the teeth close in MI with even contact across all posterior teeth. Anterior contacts are slightly lighter to avoid overload, while posterior teeth receive vertical, axial forces aligned with their long axes to maintain structural integrity. During jaw movements, proper anterior guidance makes sure that non-axial forces are directed away from the posterior teeth, helping to protect them from excessive stress. Although this combination of CR and MI reflects the theoretical standard for occlusal and joint stability, it is rarely found in clinical practice and mainly serves as a reference in dental education (6).

Physiological occlusion, on the other hand, is considered a state of stable occlusal relationship maintained over time without signs of abnormal wear, trauma, or any discomfort. It offers effective anterior guidance compatible with the masticatory range of motion, while comfortable and natural function can be maintained without excessive attrition or occlusal overload. The comfort of the patient and absence of functional disturbances are the main goals in this type of occlusion (6).

### 5.2.2 Dental Interferences

Occlusal or dental interferences are defined as any undesirable tooth contacts that disrupt stable and harmonious occlusion, preventing smooth mandibular movements (12,13). These disturbances can lead to overloading of antagonist surfaces, causing wear facets, fractures, tooth mobility, and continuous microtrauma. Additionally, occlusal interferences may result in orofacial pain, changes in muscle activity, and compensatory mandibular movement patterns as the body attempts to restore functional stability (12).

Whereas some individuals adapt to occlusal interferences, they can alter the mandibular lever system in others and thus contribute to musculoskeletal instability (9,13). Given their potential impact on postural control and musculoskeletal stability, it is important to understand the different types of occlusal interferences and how each one may affect the body.

Centric interference is the first tooth contact that prevents a stable bite when MI and CR do not coincide, causing the mandible to shift. Working-side interference occurs on the same side of the jaw movement, disrupting the smooth movement of the mandible by separating the other teeth on the same side. In contrast, non-working side interference is an undesirable contact on the opposite side of the jaw movement, sifting the fulcrum away from the TMJ, that could potentially lead to instability and excessive tooth loading. Additionally, protrusive interference occurs when posterior teeth contact during forward jaw movement, preventing proper anterior function, causing excessive muscle contraction that disrupts normal protection mechanisms (13).

Occlusal or dental interferences affect postural stability by disrupting alignment, which is why occlusal splints are commonly used to restore this balance and prevent injury. These splints change the position of the mandible and help reduce muscle tension, while occlusal adjustments eliminate interferences that restrict jaw movement and increase the TMJ loading. Orthodontic treatments can also address occlusal interferences, by promoting better postural control (14).

These interferences impact postural control and neuromuscular responses through the temporomandibular system and its connection to the CNS, influencing exercise performance. This occurs due to the proprioceptive feedback transmitted through the trigeminal nerve, which affects muscle coordination, balance, and postural stability. This disruption can lead to compensatory muscle activation and neuromuscular imbalances, ultimately affecting overall stability and performance (15).

### 5.3 Sport Dentistry

Sport dentistry is a new field within dentistry which focuses on dental injuries and oral issues associated with sports and physical activity. It focuses on prevention, diagnosis and management of these conditions. The advancement of sports medicine, including dentistry, has resulted in healthier athletes and improved performance. This field is especially important in this context since it focuses on the illnesses observed in athletes, including temporomandibular disorders, orofacial injuries, and their prevention (16).

The connection between dental occlusion and TMJ function plays an important role in the overall stomatognathic system, which in turn can influence physical performance and injury risk in athletes. Considering the neurology of sports injuries, the stomatognathic system´s impact on posture, strength, and coordination is of increased importance. Collaboration between sports dentistry and medicine can help diagnose and manage occlusal dysfunctions and TMJ disorders, promoting both oral and systemic health in athletes (16).

This aligns with the concept that sports dentistry not only addresses oral injuries but also contributes to overall athletic stability and performance, making it highly relevant to the analysis of occlusal interventions and postural stability in weightlifters (16).

### 5.3.1 Weightlifting

Weightlifting is a sport discipline where athletes try to lift the maximum weight possible through two main lifts: the snatch and the clean and jerk. These lifts produce some of the highest peak power outputs recorded in sports, demanding exceptional postural stability and musculoskeletal coordination to perform these high intensity lifts safely and efficiently. Beyond competition, weightlifting exercises and their derivatives are widely used in athletic training as they improve strength, power and speed. Weightlifters generate power during these lifts, making them stand out from other athletes. Their training structure is often characterized by frequent use of high-intensity exercise movements like jumping and sprinting. In addition to improving abilities, weightlifting also plays a big part in preventing injuries by improving muscle balance and overall performance (17).

Weightlifting injuries often result from bad posture, especially affecting the lower back and neck. A flexed neck posture increases the risk of neck pain, muscle overuse, reduced back strength, and balance issues, while extended neck posture can lead to excessive cervical spine loading and strain (18).

Several of the muscles involved in postural control during weightlifting (such as the sternocleidomastoid, and trapezius), are also directly linked to occlusal function and head positioning. When FHP develops, it causes weakness of the deep neck flexors and rhomboids, and tightness of the pectoralis, upper trapezius, and anterior scalene muscles. This imbalance affects not only pain and limitation of movement but also the diameter of the thoracic cage and lung volumes, leading to dysfunction of respiratory muscles such as the diaphragm and intercostal muscles (19,20).

These outcomes are especially relevant in weightlifters, who rely heavily on coordinated breathing, cervical stability, and neuromuscular control to execute technically demanding lifts like the snatch and clean and jerk (19).

### 5.4 Occlusion and Posture

The occlusion-posture relationship is important for good balance between all anatomical components of the body. Maintaining good posture maintains energy efficiency and ergonomics (21). This relationship is specifically important during dynamic function, such as lifting weights, where strength, power, and speed are essential (19,21).

The connection lies in the interaction between the afferent and efferent signals received by postural receptors, involving the integration of sensory input from the proprioceptive, visual, vestibular, and stomatognathic systems at the level of the CNS (2,21). A key element in this integration is the trigeminal nerve, which provides extensive afferent input from the masticatory system and interacts with cervical motor pathways, facilitating coordinated postural response (9,15). Postural adjustments involve a complex process in which sequences of information are decoded and integrated by these systems to maintain balance and alignment (22).

In everyday life, the occlusion changes, for example, during jaw clenching in weightlifting (23). When these occlusal changes occur, oral cavity proprioception is mediated by receptors located in muscles, periodontal ligaments (PDL), and the TMJ, which send information to the CNS. The CNS processes this information and triggers the necessary muscular responses to adjust and maintain posture (22,23). In this context, the presence of occlusal asymmetry can interfere with the normal proprioceptive signals sent to the CNS, resulting in imbalanced muscle activity. This may lead to compensatory postural adjustments aimed at maintaining stability, potentially affecting overall musculoskeletal balance and stability (9).

This neuromuscular interaction is controlled by a network of mandibular muscles responsible for occlusal function and, indirectly, for postural regulation. These muscles include the masseter and medial pterygoid, which elevate the mandible; the temporalis, which assists in both elevation and retraction; and the lateral pterygoid, which coordinates protrusive and lateral movements through its dual heads. These muscles not only facilitate mandibular movement but also exhibit altered activity under parafunctional conditions such as clenching and bruxism, which can often occur when lifting weights (8).

In addition, muscles like digastric, mylohyoid, suprahyoid and infrahyoid muscle groups link mandibular dynamics to head posture through their connections to the hyoid bone (8). Cervical muscles, particularly the sternocleidomastoid, and trunk stabilizers such as the erector spinae, form part of this functional chain and demonstrate changes in biomechanical properties (tone, stiffness, elasticity) in response to dental occlusion alteration. For instance, occlusal alterations have been shown to increase stiffness in the masseter and erector spinae muscles, suggesting a compensatory effect to maintain postural stability, while a reduction in stiffness is observed in the sternocleidomastoid, reflecting its distinct role in dynamic cervical control (8,9).

### 5.5 Messerman Test

The Messerman Test is a controlled, non-invasive, diagnostic method used to evaluate the relationship between occlusal conditions and upper body posture, as well as to identify any bite misalignments. This is achieved by temporarily altering occlusion by placing two cotton rolls symmetrically between the dental arches in the premolar area, making sure that the mandible is positioned in a stable, unstrained position with no occlusal contact (23,24). In this balanced position, the absence of occlusal contact helps to achieve greater symmetry in the masseter muscle, and lateral gastrocnemius. This even occlusal load that occurs when placing the cotton rolls, helps to reduce the over-activation or under-activation of the muscles on one side, promoting neuromuscular balance (24).

This occurs through the neuromuscular feedback loop, which is triggered by the change in occlusion, by activating trigeminal afferent neurons that relay mandibular input to the CNS. This input integrates with visual, vestibular, and proprioceptive signals, influencing motor responses in cervical and postural muscles (15,23).

This test is widely used in both clinical and research settings to study the impact of occlusal conditions on musculoskeletal stability and overall postural control and is considered an appropriate and reliable tool for postural assessment (23,24).

### 5.6 Postural Analysis Methods

Postural analysis methods can be described as techniques used to assess the mobility, balance, and muscle tone, or deviations from, the normal position of the human body in static and dynamic positions. These methods are clinically applied to evaluate posture-related conditions and optimize movement efficiency (25).

Various methods, ranging from manual examinations to advanced technological approaches can be used. The most common form of postural assessments includes manual approaches such as the visual examination, palpation, and classification systems, like the Kendall´s model. The Kendall´s model categorizes posture into ideal, kyphosis-lordosis, sway-back, and flat-back, based on spinal curvature and pelvic tilt. However, these methods can be supplemented by photographic and silhouette imaging techniques, to improve their efficiency (25).

Stabilometry provides a more objective measurement by analyzing center of pressure (CoP) shifts, oscillation area, and plantar pressure distribution, though it simplifies posture to a single point, limiting its ability to capture complex postural behaviors. Photogrammetry improves precision by identifying anatomical landmarks such as spinal curvature, thorax inclination, and iliac spines to detect deviations. Mobile applications further enhance postural analysis by integrating clinometers for movement tracking and automatic software for detecting misalignments, offering a convenient and accessible alternative. The Fukuda-Unterberger test, on the other hand, evaluates vestibulospinal reflexes under dynamic conditions, providing insights into balance and neurological function (22).

However, newer digital tools such as Kinovea and APECS have emerged as more practical and accessible alternatives for postural assessment compared to technically complex methods (26,27). Kinovea is a free 2D motion analysis software used in sports and clinical research to measure angles and movement from video recordings (26). While APECS is a mobile application that provides a non-radiographic posture assessment, marking and measuring angles to detect misalignments (27).

### 5.6.1 AI Posture Evaluation and Correction System (APECS)

The APECS (AI Posture Evaluation and Correction System) is a non-radiographic mobile application designed for a whole-body posture assessment without the need for radiographs. It uses artificial intelligence (AI) to analyze body posture by marking anatomical landmarks and automatically generating angular measurements. APECS is a safe and reliable alternative to traditional radiographic methods, reducing radiation exposure while still providing accurate skeletal alignment assessments. Its ease of use and dependability makes it a valuable tool for both clinical and research purposes in musculoskeletal health (27).

The APECS system was chosen for this study because it is a safe, accurate, and non-invasive way to assess posture without the need for radiographs. Using AI, it automatically detects key anatomical points and measures body alignment, balance, and stability with accuracy. This makes it a reliable tool for evaluating postural changes before and after occlusal interventions done with the Messerman Test. By incorporating APECS into the research, clear data can be collected on how modifying dental occlusion affects postural stability in weightlifters. This guarantees that the findings are accurate, reproducible, and valuable for both clinical and athletic applications.

# 6. JUSTIFICATIONS AND HYPOTHESIS

## 6.1 Justification

In recent years, there has been increasing interest in how dental occlusion affects body posture and musculoskeletal stability. Several studies have suggested a potential relationship between occlusion and postural control (9). Others, however, report inconclusive findings, emphasizing the need for further investigation using standardized protocols and targeted populations (1,23).

In this context, occlusal intervention methods such as the Messerman Test represent promising tools for exploring functional relationships between the stomatognathic system and postural regulation (23,24). Nevertheless, there is a notable gap in the literature regarding the application of such interventions in strength-based sports such as weightlifting, where postural stability is essential for performance and injury prevention.

The purpose of this study is to assess whether occlusal adjustments using the Messerman Test can improve postural and musculoskeletal stability in adult weightlifters under static conditions, as compared to their natural occlusion. By analyzing and comparing postural data before and after the intervention, we aim to determine the impact on how occlusal adjustments may affect parameters such as balance, alignment, and overall static stability.

This research is based on the Sustainable Development Goals, specifically SDG 3 (good health and well-being) and SDG 8 (decent work and economic growth). This study aligns with SDG 3, since prevention of musculoskeletal disorders and injuries would lead to a reduction in injury (target 3.4). By examining the impact of occlusal interventions on postural stability and balance in weightlifters, it explores a potential non-invasive method for enhancement of physical capacity and reduction of biomechanical imbalances. Understanding how occlusion affects posture may help in developing preventive strategies to improve general well-being.

It also aligns with SDG 8 in terms of postural health in physically demanding professions (target 8.8). While specifically focusing on weightlifting, its applications could extend to workplace ergonomics and injury prevention, providing increased stability, reduction of strain-related injuries, and long-term occupational health. By focusing on the role of occlusion for postural control, this study supports safer and more sustainable working conditions within the fields of sports and those characterized by heavy physical demands.

### 6.2 Hypothesis

The hypothesis of this study is that occlusal interventions using the Messerman Test, which includes changes in occlusion and mandibular position, may improve postural and musculoskeletal stability in adult weightlifters under static conditions, showing a relation between posture and occlusion.

## 7. OBJECTIVES

### General Objectives

1. Evaluate whether occlusal interventions, using the Messerman Test may improve postural and musculoskeletal stability in adult weightlifters under static conditions compared to natural occlusion.

### Specific Objectives

1. Analyze postural alignment and musculoskeletal stability of weightlifters in basal conditions.
2. Determine the relationship between dental occlusion and static posture using the Messerman Test.
3. Quantify the effect of occlusal intervention on static postural control by comparing pre- and post-intervention measurements related to balance, spinal alignment, and weight distribution.

# 8. MATERIALS AND METHODS

## 8.1 Identification of the PICO Question

The search was conducted using Medline Complete (PubMed) and Scopus databases for articles published between 2005 and 2024. In addition to articles, relevant textbooks were also included. This search aims to answer the following question: “For adult weightlifters, does the use of occlusal intervention through the Messerman Test during postural evaluation lead to better postural and musculoskeletal stability in static conditions compared to evaluations conducted under natural occlusion?”

This question was structured according to the PICO framework (Population, Intervention, Comparison, Outcome), as follows:

**Population (P):** Adult athletes involved in weightlifting

**Intervention (I):** Postural evaluation with occlusal intervention through the Messerman Test

**Comparison (C):** Postural evaluation under natural occlusion

**Outcome (O):** Results on postural and musculoskeletal stability in static conditions

The results of this study are expected to provide insights on how dental occlusion is related to posture, specifically in weightlifters. According to the Messerman Test, changes in dental occlusion may improve balance, alignment and stability in static conditions, helping to understand the connection between occlusion and posture during weightlifting.

## 8.2 Materials

### 8.2.1 Study Design and Ethics

This was a non-randomized, within-subject, pre-post experimental study, meaning the same participant underwent two evaluation phases without random group assignment, due to the nature of the intervention. The study was conducted in accordance with the CONSORT 2025 guidelines, available at www.consort-spirit.org (Annex I), in a controlled environment suitable for postural and musculoskeletal assessments. This study was not registered in a clinical trial registry as it is a non-randomized, non-clinical intervention conducted within an academic setting, intended for exploratory purposes in the context of a thesis. Given the study design, allocation concealment was not applicable.

The primary objective was to evaluate the effects of occlusal interventions, using the Messerman Test, on postural and musculoskeletal stability in adult weightlifters under static conditions. The APECS software was used as a non-radiographic, AI-empowered tool to assess changes in postural alignment before and after the intervention.

The study was conducted in compliance with the standards recognized by the Declaration of Helsinki of the World Medical Association (59th General Assembly, Seoul, South Korea, October 2008), as well as the Good Clinical Practice Guidelines and Spanish legislation on biomedical research (Law 14/2007).

The study data was computerized and encoded, ensuring anonymous processing (i.e., each volunteer will be assigned a code to prevent identification). All information obtained was handled in accordance with Article 5 of Law 14/2007 on Biomedical Research, along with the Personal Data Protection Law (Law 15/1999). Additionally, the study complied with Regulation (EU) 2016/679 of the European Parliament and the Council, dated April 27, 2016, regarding the protection of individuals concerning the processing and free movement of personal data. The data decoding file was securely stored by the principal investigator, following the security guarantees established by law. All collected information was used exclusively for scientific purposes, treated confidentially, and protected from unauthorized use. Under no circumstances will the data be shared with third parties. However, health authorities will be allowed to inspect it if required by law. The study files will remain under the custody of the principal investigator, and participants will have the right to access, cancel, or oppose the processing of their data.

The study was approved by the Research Ethics Committee of the European University, on February 7th, 2025, with registration code: 2024-520 (Annex II).

No changes to the study protocol, outcomes, or statistical analysis plan were made after the study had begun.

### 8.2.2 Sample Selection and Size

Participants were recruited from a local CrossFit training club in Valencia, Spain, during March and April 2025. They were contacted and invited via direct communication to voluntarily participate in the study. The participants who met the inclusion criteria, did not fall under the exclusion criteria, and provided informed consent (Annex III) were selected for the study.

**Inclusion criteria**

- > 18 years old
- Actively training weightlifting
- At least 1 year of experience in weightlifting
- Systematically healthy individuals
- Compliance and provided informed consent before the start of the study

**Exclusion criteria**

- > 40 years old
- Pregnant participants
- Poly-medicated or medically compromised
- Undergoing active dental treatment (orthodontics, dental implants, etc.)
- Use of orthopedics insoles or other biomechanical aids
- History of severe injuries
- Current use of intraoral appliances, including splints or mouthguards

### 8.2.4 Materials Used

This study used digital tools to make an accurate postural evaluation, organized data collection, and consistent analysis. Photographs of each participant were taken using an iPhone, following a standardized protocol to guarantee image quality and comparability. The camera was positioned at a fixed height and distance using a tripod. Participants stood barefoot in a neutral standing position to promote consistency and minimize external variables.

In the intervention phase, the Messerman Test was applied by placing cotton rolls bilaterally in the premolar area to achieve posterior disocclusion, to eliminate occlusal contact. This was done to evaluate the immediate impact of occlusal deprogramming on static posture (22,23).

The primary tool for postural assessment was APECS, which is a mobile application that integrates AI and biomechanical analysis. The Pro Plus version was used in this study, enabling access to both the Quick Analysis and Head and Neck analysis modules. APECS is a non-invasive, image-based system that processes standardized photographs and identifies anatomical reference points on the body (27). For this study, three photographic views were used per participant: a frontal view to assess bilateral symmetry of the shoulders, hips, and knees, and right and left lateral views to evaluate head posture and spinal curvatures (30).

APECS detects key anatomical landmarks such as the traigon, acromion, cervicale, and anterior superior iliac spine, among others. A full breakdown of the anatomical reference points and corresponding postural variables can be seen in Table 1. Using these reference points, the system calculated angular deviations using AI, and then automatically generated a report to quantify asymmetries and misalignments (27,30). This report was then used to compare pre- and post-intervention results to assess the impact of occlusal modification using the Messerman Test on static postural and musculoskeletal stability.

Participant sociodemographic data, including age, sex, training history, and health status, were recorded using Microsoft Excel (Table 2**.** This database helped keep track of which participants met the inclusion and exclusion criteria, making it easier to organize and manage participation throughout the study.

Data analysis was performed using IBM SPSS Statistics 29.0 for Windows. Descriptive statistics were obtained using DESCRIPTIVES and EXPLORE procedures, providing measures such as mean, standard deviation, minimum, maximum, median, and standard deviation of the mean. To assess the normality of the data, the Shapiro-Wilk test was used.

The Shapiro-Wilk Test is a statistical method used to determine whether a set of data follows a normal distribution by calculating the statistic (W) to measure how much the data derivates from normality. If the p-value is > 0.05, it indicates that the data is likely normally distributed, meaning we fail to reject the null hypothesis. Controversely, if the p-value is ≤ 0.05, the data derivates from normality, leading to the rejection of the null hypothesis. The Shapiro-Wilk test is useful for small to medium-sized samples, as it is more sensitive compared to other normality tests (31).

For comparing the pre- and post-intervention results, a Related Samples Wilcoxon Signed Rank Test was used. This non-parametric test is appropriate for comparing measurements taken at two different time points from the same participant (32).

The Wilcoxon Signed Rank Test is a non-parametric statistical test used to compare two related samples or paired observations to determine whether their population mean ranks differ. It is often used as an alternative to the paired t-test when the data does not meet the assumption of normality. If the p-value is > 0.05, it indicates that there is no statistically significant difference between the paired samples, so we do not reject the null hypothesis. If the p-value is ≤ 0.05, it means there is a statistically significant difference, leading to the rejection of the null hypothesis. It is useful when you have a small sample size or when you have non-normally distributed data (32).

## 8.3 Methods

### 8.3.1 Procedure

19 adult weightlifters participated in this pre-post-intervention study. The study protocol, including occlusal intervention and postural assessments, was explained to improve participant understanding and cooperation throughout the process.

Each participant underwent two assessment phases to evaluate static postural and musculoskeletal stability using the APECS system. The study followed a within-subject design, meaning that all participants were assessed under two different conditions: first under natural occlusion (without intervention), and then after the occlusal modification (with intervention). In this design, the initial evaluation under natural conditions served as a baseline, functioning similarly to a control condition. The second evaluation, following the Messerman Test, introduced the independent variable allowing for direct comparison within the same participant. This approach eliminates inter-individual variability, making the results more reliable.

- **Pre-intervention phase:** Postural assessments were performed with the participants natural occlusion, under basal conditions (without intervention). Photos were taken following standardized protocols, and postural alignment and stability were measured using APECS.

- **Post-intervention phase:** The Messerman Test was applied to achieve a temporary occlusal modification by placing cotton rolls bilaterally in the premolar area, altering the occlusion temporarily. Then, postural assessments were repeated under the same standardized conditions using APECS to measure any changes in alignment, balance, and musculoskeletal symmetry.

- **Final analysis:** Postural data from both phases were compared to evaluate the effect of the occlusal intervention on postural alignment and stability.

Due to the visual and procedural nature of the occlusal intervention, specifically the placement of the cotton rolls, blinding of participants and evaluators was not possible. Additionally, no adverse events or harm were expected or reported, since this intervention was entirely non-invasive.

### 8.3.2 Data Collection

The data collection followed a standardized, structured approach to guarantee accuracy, reproducibility, and consistency for all participants. The main tool used was the APECS software, which uses AI to analyze postural deviations based on photogenic records. The process followed the following steps:

1. **Image Capture:** Photographs were taken using an iPhone, following standardized protocols to make sure each photograph was taken in the same way:
    a. Participants stood in a neutral standing position, barefoot, with their hair away from the ears, not smiling, and in minimal clothing to better identify the reference points.
    b. Photographs were taken from frontal, right, and left lateral views.
    c. Tripod was used to maintain a consistent height and distance for all participants.
    d. Proper lighting and background contrast were maintained for image clarity.
2. **Postural Assessment with APECS:** Once the photographs were collected, they were analyzed using APECS. The software analyzed the following:
    a. Identified anatomical reference points.
    b. Measured angular deviations and asymmetries.
    c. Generated a postural analysis report indicating potential imbalances.
3. **Sociodemographic Data Collection and Inclusion/Exclusion Criteria:** Participant information, such as age, sex, training history, and health status, were recorded in Microsoft Excel. The same database was used to make sure the participants met the inclusion and exclusion criteria.
4. **Statistical Analysis:** Once all data had been collected, statistical analysis was performed using IBM SPSS Statistics 29.0 for Windows for:

a. Descriptive analysis: Mean, standard deviation, minimum, maximum, median, standard deviation of the mean, and normality test (Shapiro-Wilk Test) was used to summarize the data.

b. The Wilcoxon Signed Rank Test was used to compare pre- and post-intervention results within the same participant.

The use of technological tools in this study guaranteed a structured and reliable evaluation of the impact of occlusal interventions on postural stability in weightlifters under static conditions.

### 8.3.3 Study Variables

The study variables assessed using the APECS system were categorized according to the anatomical plane and landmarks, focusing on identifying postural asymmetries, inclinations, and alignments, in static conditions, as shown in Table 1.

***Table 1:*** *Anatomical Landmarks and Postural Variables Studied with APECS.*

| Plane of the body | Anatomical Landmarks | Postural Variables |
|---|---|---|
| **Anterior (Frontal)** | Head<br>Shoulder<br>Pelvis<br>Knees<br>Feet | Head Tilt<br>Shoulder Alignment<br>Pelvic Tilt<br>Knee Angle<br>Foot Angle<br>Body Alignment |
| **Lateral (Right and Left)** | External Auditory Meatus<br>Cervical Spine<br>Shoulder<br>Pelvis | Craniovertebral Angle (CVA)<br>Cervical Horizontal Angle (CHA)<br>Scapular Shoulder Position (SSP)<br>Body Alignment |
| **Head-Facial (Frontal)** | Eyes<br>Lips<br>Chin<br>Menton | Upper Horizontal Plane (UHP)<br>Lower Horizontal Plane (LHP)<br>Vertical Plane (VP)<br>Lip Junction-Menton Angle (LJ-Me) |

The main independent variable in this study was the occlusal condition, specifically comparing natural occlusion versus occlusal intervention using the Messerman Test.

The dependent variables were specific, measurable indicators of static postural control, generated by the APECS system. The main postural variables included:

1. **Craniovertebral Angle (CVA):** Measures head posture by measuring the angle between a horizontal line passing through the cervicale and a line drawn from the traigon to the cervicale. A reduced CVA angle indicates a forward head posture and misalignment in the upper spine.
2. **Shoulder Alignment:** The shoulder tilt angle assesses bilateral shoulder symmetry by measuring the angular deviation between the right and left acromial process in the frontal plane.
3. **Pelvic Tilt:** Vertical height difference between the right and left anterior superior iliac spines (ASIS). This variable indicates lateral pelvic imbalance.
4. **Body alignment:** Angle measured from the right lateral view between a vertical line and a line drawn through the traigon, cervicale, and lateral malleolus. This indicates the overall forward or backward inclination of the body, including spinal alignment.

These four variables were chosen because they reflect the key components of balance, spinal alignment, and weight distribution. They were measured in all participants, both pre- and post-intervention, to keep the evaluation consistent and easy to compare.

All collected data was recorded using Microsoft Excel.

## 8.4 Patient and Public Involvement

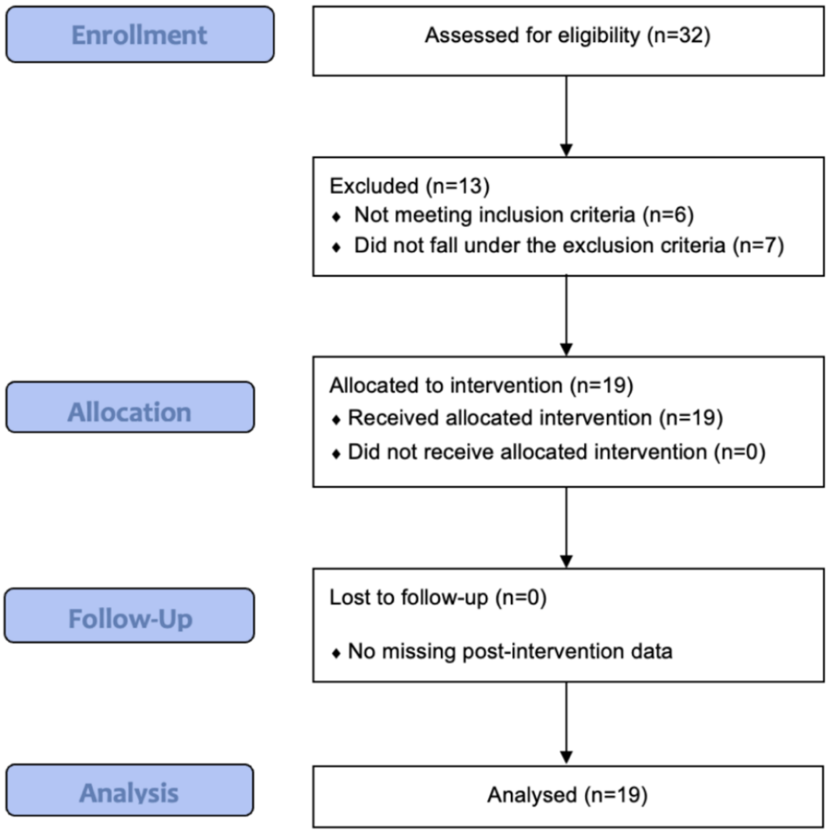
No patients or members of the public were involved in the design, conduct, or reporting of this study.

# 9. RESULTS

## 9.1 Participants and Sociodemographic Data

A total of 32 participants were initially recruited. However, due to the application of the inclusion and exclusion criteria, 19 participants were ultimately selected to complete the study. The recruitment process is detailed in Figure 1, which follows the CONSORT 2025 flow diagram format (Annex IV).

***Figure 1:*** *CONSORT 2025 Flow Diagram Summarizing the Recruitment.*




All participants were adult weightlifters (aged 19-38 years) from a CrossFit training club, with a minimum of one year of experience and in good general health to make sure all participants had a consistent physical background and no medical issues that could interfere with posture or movement. They were regularly training weightlifting at the time of the study. The age limit was selected to include participants who were beyond the growth phase and below the age at which muscle mass typically starts to decline, minimizing physiological variability related to maturation or aging (29).

The exclusion criteria were designed to eliminate factors that could interfere with posture or occlusion. Pregnant participants were excluded due to the natural postural changes that occur during pregnancy. Those who were poly-medicated or medically compromised were excluded to avoid systemic conditions or medications that might influence muscle tone, posture, or balance. Participants undergoing active dental treatment (orthodontics or dental implants), using intraoral appliances (splints or mouthguards), or relying on orthopedic insoles or biomechanical aids were excluded, because these factors could directly alter occlusion or posture independently of the intervention. In addition, participants with a history of severe injuries were excluded to avoid structural compensations or chronic adaptations that could interfere with the assessment of postural changes related to occlusal modifications.

Participation was voluntary, and all participants provided informed consent after being informed about the study´s purpose and procedures. The sample size was selected based on the study´s exploratory nature, sufficient for identifying intra-individual changes, and aligns with similar pilot designs (10,28). There were no dropouts, withdrawals, or missing data throughout the study.

The final sample (n=19) had almost an equal gender distribution (58% men, 42% women), and participants ranging in the age from 19-38 years.

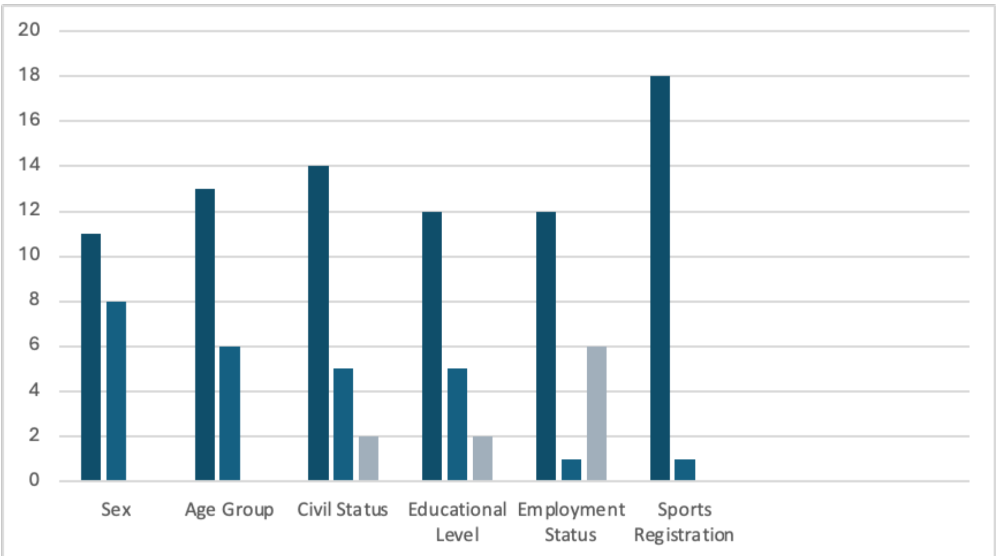
In terms of civil status, 74% were single, and 26% were in a relationship. Regarding education, 63% had a university degree, with the rest having vocational (26%) or secondary education (11%). Most participants (63%) were employed by others, 32% were students (either exclusively or combined with work), and 5% were self-employed. In terms of sports registration, 95% were federated athletes, with only one participant (5%) training at a non-federated club.

A full breakdown of the sociodemographic data is shown in Table 2. Additionally, Figure 2 provides a visual representation of the distribution.

***Table 2:*** *Sociodemographic Characteristics of the Participants.*

| Variable | Category | n (%) |
|---|---|---|
| **Sex** | Male | 11 (58%) |
| | Female | 8 (42%) |
| **Age Group** | 19-29 years | 13 (68%) |
| | 30-38 years | 6 (32%) |
| **Civil Status** | Single | 14 (74%) |
| | In a relationship (married/partner) | 5 (26%) |
| **Educational Level** | University degree | 12 (63%) |
| | Vocational training | 5 (26%) |
| | Secondary education | 2 (11%) |
| **Employment Status** | Employed | 12 (63%) |
| | Self-employed | 1 (5%) |
| | Student (only or combined) | 6 (32%) |
| **Sports Registration** | Federated athlete | 18 (95%) |
| | Non-federated (club/gym) | 1 (5%) |

***Figure 2:*** *Sociodemographic Distribution of Participants by Category.*




## 9.2 Evaluation of the Distribution of Postural Variables

The normality of the data was assessed using the Shapiro-Wilk Test. The results are presented in **Table 3**.

**Table 3:** Test of Normality for Pre-, Post-, and Δ Conditions (Shapiro-Wilk Test)

| | Statistic | df | Sig. |
|---|---|---|---|
| **CVA Pre** | 0,926 | 19 | 0,144 |
| **CVA Post** | 0,963 | 19 | 0,640 |
| **CVA Δ** | 0,892 | 19 | 0,035 |
| **CHA Pre** | 0,946 | 19 | 0,336 |
| **CHA Post** | 0,943 | 19 | 0,302 |
| **CHA Δ** | 0,842 | 19 | 0,005 |
| **SSP Pre** | 0,902 | 19 | 0,053 |
| **SSP Post** | 0,914 | 19 | 0,088 |
| **SSP Δ** | 0,814 | 19 | 0,002 |
| **UHP Pre** | 0,832 | 19 | 0,004 |
| **UHP Post** | 0,842 | 19 | 0,005 |
| **UHP Δ** | 0,919 | 19 | 0,109 |
| **LHP Pre** | 0,844 | 19 | 0,005 |
| **LHP Post** | 0,850 | 19 | 0,007 |
| **LHP Δ** | 0,959 | 19 | 0,561 |
| **VP Pre** | 0,859 | 19 | 0,009 |
| **VP Post** | 0,877 | 19 | 0,019 |
| **VP Δ** | 0,959 | 19 | 0,558 |
| **LJ-Me Pre** | 0,884 | 19 | 0,025 |
| **LJ-Me Post** | 0,715 | 19 | <0,001 |
| **LJ-Me Δ** | 0,864 | 19 | 0,011 |
| **Head Tilt Pre** | 0,894 | 19 | 0,037 |
| **Head Tilt Post** | 0,844 | 19 | 0,005 |
| **Head Tilt Δ** | 0,793 | 19 | <0,001 |
| **Shoulder Alignment Pre** | 0,818 | 19 | 0,002 |
| **Shoulder Alignment Post** | 0,882 | 19 | 0,023 |
| **Shoulder Alignment Δ** | 0,823 | 19 | 0,003 |
| **Pelvic Tilt Pre** | 0,753 | 19 | <0,001 |
| **Pelvic Tilt Post** | 0,715 | 19 | <0,001 |
| **Pelvic Tilt Δ** | 0,949 | 19 | 0,376 |
| **Knees Pre** | 0,831 | 19 | 0,003 |
| **Knees Post** | 0,713 | 19 | <0,001 |
| **Knees Δ** | 0,883 | 19 | 0,025 |
| **Feet Pre** | 0,836 | 19 | 0,004 |
| **Feet Post** | 0,764 | 19 | <0,001 |
| **Feet Δ** | 0,918 | 19 | 0,106 |
| **Body Alignment (Frontal) Pre** | 0,616 | 19 | <0,001 |
| **Body Alignment (Frontal) Post** | 0,751 | 19 | <0,001 |
| **Body Alignment (Frontal) Δ** | 0,507 | 19 | <0,001 |

| | | | |
|---|---|---|---|
| **Body Alignment (Sagittal) Pre** | 0,612 | 19 | <0,001 |
| **Body Alignment (Sagittal) Post** | 0,716 | 19 | <0,001 |
| **Body Alignment (Sagittal) Δ** | 0,568 | 19 | <0,001 |
| ***. This is a lower bound of the true significance.** | | | |
| **a. Lilliefors Significance Correction** | | | |

The test revealed that a large proportion of the variables, particularly Head Tilt, Knee/Foot Angles, and Body Alignment (frontal and sagittal), were not normally distributed ($p < 0.05$). The test rejected the null hypothesis of normality for these variables, indicating that the data is likely not normally distributed. Only a few variables such as CVA, CHA, and some difference (Δ) values met the normality assumption.

Due to the presence of non-normality distributed data, a non-parametric method was used for statistical comparison, specifically using the Wilcoxon Signed Rank Test.

## 9.3 Changes Related to the Occlusal Intervention

Descriptive statistics were calculated for each postural variable under pre- and post-intervention conditions, as well as for the Δ values, which represents the individual change between time points. The results, presented in **Table 4**, offer a comprehensive overview of each variables distribution and the degree of change following the intervention.

***Table 4:*** *Descriptive Statistics for Pre-, Post-, and Δ Conditions*

| | Valid N | Mean | Standard Deviation | Median | Percentile 25 | Percentile 75 | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| **CVA Pre** | 19 | 57,50 | 3,14 | 58,00 | 55,00 | 60,00 | 53,00 | 63,00 |
| **CVA Post** | 19 | 56,89 | 2,78 | 56,50 | 55,50 | 58,50 | 52,00 | 62,00 |
| **CVA Δ** | 19 | -0,61 | 1,90 | -0,50 | -2,00 | 1,00 | -3,50 | 2,00 |
| **CHA Pre** | 19 | 10,11 | 7,20 | 10,00 | 3,00 | 15,00 | 0,00 | 24,00 |
| **CHA Post** | 19 | 11,50 | 6,18 | 11,00 | 6,00 | 15,00 | 2,00 | 22,00 |
| **CHA Δ** | 19 | 1,39 | 4,49 | 2,00 | -0,50 | 4,00 | -13,00 | 7,00 |
| **SSP Pre** | 19 | 9,97 | 6,89 | 9,50 | 5,00 | 13,50 | 1,00 | 25,00 |
| **SSP Post** | 19 | 10,71 | 8,26 | 9,00 | 3,00 | 18,00 | 1,00 | 26,00 |
| **SSP Δ** | 19 | 0,74 | 5,82 | -2,00 | -3,00 | 3,00 | -6,00 | 15,50 |
| **UHP Pre** | 19 | 1,26 | 1,33 | 1,00 | 0,00 | 2,00 | 0,00 | 5,00 |
| **UHP Post** | 19 | 1,42 | 1,39 | 1,00 | 0,00 | 3,00 | 0,00 | 4,00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **UHP Δ** | 19 | 0,16 | 1,17 | 0,00 | -1,00 | 1,00 | -2,00 | 2,00 |
| **LHP Pre** | 19 | 1,42 | 1,57 | 1,00 | 0,00 | 3,00 | 0,00 | 5,00 |
| **LHP Post** | 19 | 1,00 | 0,94 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **LHP Δ** | 19 | -0,42 | 2,12 | 0,00 | -2,00 | 1,00 | -5,00 | 3,00 |
| **VP Pre** | 19 | 2,11 | 2,26 | 1,00 | 0,00 | 4,00 | 0,00 | 7,00 |
| **VP Post** | 19 | 2,74 | 1,97 | 3,00 | 1,00 | 3,00 | 0,00 | 7,00 |
| **VP Δ** | 19 | 0,63 | 2,81 | 0,00 | -1,00 | 3,00 | -4,00 | 6,00 |
| **LJ-Me Pre** | 19 | 1,47 | 1,31 | 1,00 | 0,00 | 2,00 | 0,00 | 4,00 |
| **LJ-Me Post** | 19 | 0,74 | 1,10 | 0,00 | 0,00 | 1,00 | 0,00 | 4,00 |
| **LJ-Me Δ** | 19 | -0,74 | 1,10 | -1,00 | -2,00 | 0,00 | -2,00 | 1,00 |
| **Head Tilt Pre** | 19 | 1,58 | 1,39 | 1,00 | 0,00 | 3,00 | 0,00 | 5,00 |
| **Head Tilt Post** | 19 | 1,16 | 1,12 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Head Tilt Δ** | 19 | -0,42 | 1,43 | 0,00 | -1,00 | 1,00 | -5,00 | 1,00 |
| **Shoulder Alignment Pre** | 19 | 1,37 | 1,50 | 1,00 | 0,00 | 2,00 | 0,00 | 4,00 |
| **Shoulder Alignment Post** | 19 | 1,53 | 1,43 | 1,00 | 0,00 | 2,00 | 0,00 | 5,00 |
| **Shoulder Alignment Δ** | 19 | 0,16 | 0,90 | 0,00 | 0,00 | 1,00 | -2,00 | 1,00 |
| **Pelvic Tilt Pre** | 19 | 0,89 | 1,15 | 0,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Pelvic Tilt Post** | 19 | 0,89 | 1,29 | 0,00 | 0,00 | 1,00 | 0,00 | 4,00 |
| **Pelvic Tilt Δ** | 19 | 0,00 | 1,70 | 0,00 | -1,00 | 1,00 | -3,00 | 3,00 |
| **Knees Pre** | 19 | 0,89 | 0,94 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Knees Post** | 19 | 0,47 | 0,61 | 0,00 | 0,00 | 1,00 | 0,00 | 2,00 |
| **Knees Δ** | 19 | -0,42 | 1,02 | 0,00 | -1,00 | 0,00 | -2,00 | 2,00 |
| **Feet Pre** | 19 | 1,11 | 1,10 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Feet Post** | 19 | 0,68 | 0,89 | 0,00 | 0,00 | 1,00 | 0,00 | 3,00 |
| **Feet Δ** | 19 | -0,42 | 1,30 | 0,00 | -1,00 | 0,00 | -3,00 | 3,00 |
| **Body Alignment (Frontal) Pre** | 19 | 0,37 | 0,50 | 0,00 | 0,00 | 1,00 | 0,00 | 1,00 |
| **Body Alignment (Frontal) Post** | 19 | 0,58 | 0,69 | 0,00 | 0,00 | 1,00 | 0,00 | 2,00 |
| **Body Alignment (Frontal) Δ** | 19 | 0,21 | 0,42 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 |
| **Body Alignment (Sagittal) Pre** | 19 | 1,89 | 3,33 | 1,00 | 0,00 | 2,00 | 0,00 | 14,00 |
| **Body Alignment (Sagittal) Post** | 19 | 3,26 | 4,58 | 2,00 | 0,00 | 4,00 | 0,00 | 17,00 |
| **Body Alignment (Sagittal) Δ** | 19 | 1,37 | 3,11 | 0,00 | 0,00 | 2,00 | -1,00 | 13,00 |

Most variables showed small mean changes between conditions, with a few showing more notable shifts. Among the most relevant findings, the CHA showed a statistically significant increase post-intervention ($p = 0.042$), with a mean change of +1.39° and a median of 2. The LJ-Me angle significantly decreased ($p = 0.012$), with a mean -0.74° and a median of 1. In terms of Body Alignment, a significant increase was observed in the frontal plane ($p = 0.046$), with a mean difference of +0.21°, and with a median of 0. The sagittal plane also showed a statistically significant increase ($p = 0.024$), with a mean change of +1.37°, although the median remained at 0.

### 9.4 Comparison of Pre- and Post-Intervention Variables

To evaluate the effect of occlusal intervention on postural alignment, the Wilcoxon Signed Rank Test was used to compare pre- and post-intervention measurements. The test showed notable changes in a few variables, including a significant increase in the Cervical Horizontal Angle (CHA) ($p = 0.042$), a significant decrease in the Lip-Menton Angle (LJ-Me) ($p = 0.012$), and a significant increase in Body Alignment, both frontal and sagittal (Frontal: $p = 0.046$; Sagittal: $p = 0.024$).

As shown in **Figure 3**, the chart visually represents the pre- and post-intervention values for these variables, clearly indicating the magnitude of changes observed. The light bars represent pre-intervention values, and the dark bars represent post-intervention values. The values demonstrate the statistical significance of the differences. The numbers displayed on the left side correspond to the mean value of that same variable, providing a quantitative reference for comparison.

All other variables (CVA, SSP, UHP, LHP, Head Tilt, Shoulder Alignment, Pelvic Tilt, Knees, Feet) showed no statistically significant differences ($p \geq 0.05$). These results suggest that while the occlusal intervention did not significantly affect all postural parameters, it did produce notable changes in craniofacial and global alignment, particularly in sagittal and frontal postural planes.

The following tables summarize the main and additional postural variables. **Table 5** highlights the main postural variables, presenting the mean values before and after the intervention, the corresponding p-values, and an interpretation of the changes. In addition, Table 6 presents the additional postural variables, following the same structure. This presentation allows for a clear comparison between pre- and post-intervention measurements.

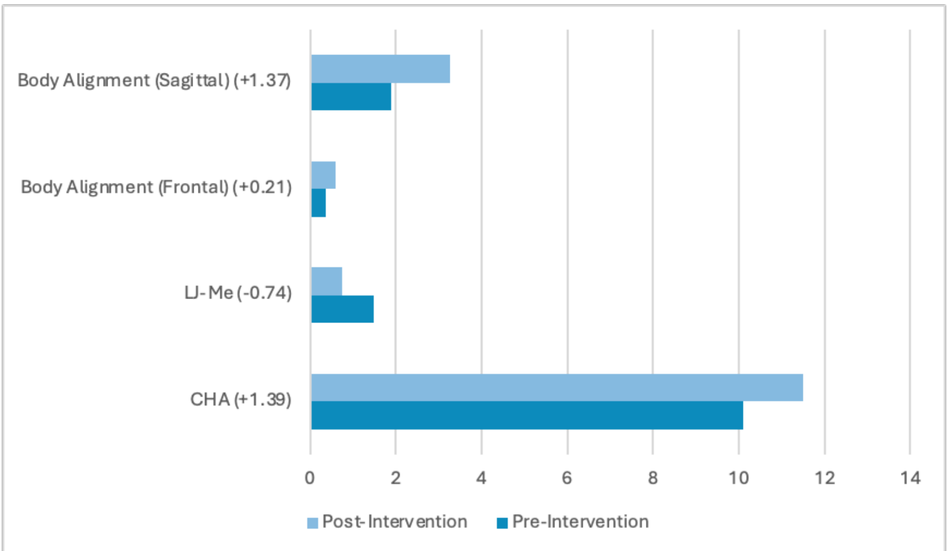
***Table 5:*** *Summarized Results of Main Postural Variables (Pre- and Post-Intervention).*

| Variable | Pre-Intervention Mean (SD) | Post-Intervention Mean (SD) | p-value | Interpretation |
|---|---|---|---|---|
| **Craniovertebral Angle (CVA)** | 57.50° (3.14) | 56.89° (2.78) | 0.160 | No significant change, slight improvement |
| **Shoulder Alignment** | 1.37° (1.50) | 1.53° (1.43) | 0.439 | No significant change, minor increase |
| **Pelvic Tilt** | 0.89° (1.70) | 0.89° (1.70) | 0.972 | No change, stable alignment |
| **Body Alignment (Frontal)** | 0.58° (0.50) | 0.58° (0.69) | 0.046 | Significant change, deviation |
| **Body Alignment (Sagittal)** | 1.89° (4.58) | 3.26° (3.11) | 0.024 | Significant change deviation |

***Table 6:*** *Summarized Results of Additional Postural Variables (Pre- and Post-Intervention).*

| Variable | Pre-Intervention Mean (SD) | Post-Intervention Mean (SD) | p-value | Interpretation |
|---|---|---|---|---|
| **Lower Jaw-Menton (LJ-Me)** | 1.47° (1.31) | 0.74° (1.10) | 0.012 | Significant change, improved alignment |
| **Head Tilt** | 1.58° (1.39( | 1.16° (1.12) | 0.244 | No significant change, slight improvement |
| **Lower Horizontal Plane (LHP)** | 1.42° (1.57) | 1.00° (0.94) | 0.463 | No significant change, slight improvement |
| **Knee Alignment** | 0.89° (0.94) | 0.47° (0.61) | 0.103 | No significant change, slight improvement |
| **Foot Alignment** | 1.11° (1.10) | 0.68° (0.89) | 0.133 | No significant change, slight improvement |

***Figure 3:*** *Comparison of Pre- and Post-Intervention Values for Significant Postural Variables.*



## 10. DISCUSSION

The present study aimed to compare static posture and musculoskeletal stability in adult weightlifters before and after an occlusal intervention using the Messerman Test. The findings suggest that occlusal intervention leads to measurable changes in several postural variables, suggesting a correlation between dental occlusion and posture under static conditions. However, individual variations were also identified, meaning that not everyone responded to the intervention in the same way. While many participants showed improvements in their posture, others experienced only slight changes, and a few even showed slight worsening. These individual changes could be due to natural variations in body alignment, or the way their muscles have adapted over time, especially in athletes that are used to compensate for imbalances.

All variables tested in this study were carefully selected based on their relevance to assessing postural stability, symmetry, and musculoskeletal alignment in weightlifters. These variables, as listed in Table 1, give an overview of the anatomical landmarks measured using the APECS software.

### 10.1 Sociodemographic Data

The sociodemographic characteristics of the participants provide important information for interpreting the effects of occlusal interventions on postural and musculoskeletal stability. Since all participants were adults beyond the growth phase and below the age at which muscle mass typically begins to decline, variability related to skeletal development and early muscle loss is minimized (33). Additionally, the near-equal gender distribution allows for balanced representation, enhancing the generalizability of the findings across male and female weightlifters.

Civil status reflects differences in lifestyle, social support, and stress levels, which can indirectly influence musculoskeletal alignment. Educational level may relate to participants understanding of body awareness, and biomechanics. Additionally, their occupational status, including those who are students, employed, or both, may reflect different levels of physical, and mental stress, and workload, which can indirectly affect musculoskeletal alignment and postural tone (33).

The fact that 95% of the participants were federated athletes indicates a high level of training experience, body control, and postural stability (17). This consistency among participants strengthens the study´s reliability by reducing variability due to differences in training experience.

Overall, these factors help gain a clearer picture of the group being studied, a relatively uniform, sport-specific sample of trained weightlifters. This adds strength to the conclusions about how occlusion might affect posture in this population.

### 10.2 Main Postural Variables

To evaluate postural changes, four main postural variables were selected due to their relevance in detecting important features of postural balance, symmetry, and spinal alignment. These variables include the Craniovertebral Angle (CVA), Shoulder Alignment, Pelvic Tilt, and Body Alignment (Frontal and Sagittal Planes).

*Craniovertebral Angle (CVA)*

A normal CVA typically ranges from 48-50°, indicating an upright and aligned head posture. Values below this range indicate a FHP, characterized by increased extension of the upper cervical spine and increased flexion of the lower cervical spine and upper thoracic region (34).

The results showed that the mean CVA decreased from 57.50° (SD = 3.14) pre-intervention to 56.89° (SD = 2.78) post-intervention, with a mean change of -0.61°. Even though the change was not statistically significant ($p = 0.160$), the direction of the change indicates slight improvement, bringing the head posture of the participants closer to the ideal value. This suggests that the occlusal intervention may have had a slight positive effect on the cervical alignment.

These findings align with the evidence that cervical posture influences trunk muscle activation and lumbar spine alignment during weightlifting. A study made on FHP demonstrated that a retracted neck posture, compared to a freestyle or extended posture, reduces lumbar spine flexion and increases activation of stabilizing muscles, including the sternocleidomastoid and lumbar erector spinae. In the context of weightlifting, maintaining an optimal CVA is important, as FHP not only disrupts cervical alignment but may also compromise lumbar stability, increasing the risk of musculoskeletal strain. The observed decrease in CVA following the occlusal intervention, although not statistically significant, suggests a trend towards improved alignment. This could indicate that the intervention supports safer lifting mechanics by reducing cervical flexion and improving sternocleidomastoid activation, promoting a more upright head posture (18).

*Shoulder Alignment*

Perfect shoulder alignment is when the shoulders are at the same level, indicating symmetry. Any deviation from this horizontal line is measured as the shoulder tilt angle, indicating asymmetry between the shoulders (35).

Pre-intervention, the mean value was 1.37° (SD = 1.50) and post-intervention it increased slightly to 1.53° (SD = 1.43), with a change of +0.16°. This minor increase did not reach statistical significance ($p = 0.439$), indicating that occlusal modifications did not significantly affect shoulder symmetry.

These results do not entirely align with evidence suggesting that occlusal interventions may positively influence muscle activation patterns related to shoulder symmetry. According to a study made on occlusal intervention in relation to exercise performance, changes in jaw position using occlusal splints, can improve shoulder muscular strength, likely due to the connection between the temporomandibular system and the neuromuscular system through the CNS. Adjustments in jaw position may alter proprioceptive feedback from the masticatory system to the accessory nerve nucleus, affecting the sternocleidomastoid and upper limb muscles, including the trapezius. This mechanism supports the hypothesis that occlusal interventions could influence upper-body alignment and shoulder symmetry (15).

However, in this study, the minor increase in the shoulder tilt angle observed post-intervention, although not statistically significant ($p = 0.439$), could be due to individual variability rather than a consistent effect of the intervention. This small, nonsignificant change might reflect natural fluctuations in postural alignment rather than a true effect of the occlusal modification.

*Pelvic Tilt*

The goal is to have the right and left ASIS at the same height (36). In this study, the pelvic tilt remained unchanged. Both pre- and post-intervention means were 0.89° (SD = 1.70) and no statistically significant change ($p = 0.972$).

The unchanged pelvic tilt observed in this study, despite the occlusal intervention, may indicate the stability and strong postural control typically developed in weightlifters. According to a study done on weightlifting regarding strength, power, and speed, weightlifting is associated with improvements in strength, power, and stability, which can increase musculoskeletal alignment and reduce asymmetries during static and dynamic conditions (17). Furthermore, another study emphasizes that maintaining a balanced pelvic position is important in weightlifting as asymmetries can lead to compensatory movements and increased risk of lower back pain (18). The fact that the pelvic tilt remained consistent pre- and post-intervention, suggests that the occlusal intervention did not disrupt the established postural control, possibly due to the adaptive strength and neuromuscular coordination characteristics of trained weightlifters (17,18).

*Body Alignment*

The most notable change observed in this study was in the body alignment, where participants demonstrated a statistically significant increase in deviation following the occlusal intervention ($p = 0.046$ for frontal, $p = 0.024$ for sagittal), indicating a movement away from the ideal value. In the frontal plane, the mean deviation increased from 0.37° to 0.58°, and in the sagittal plane, the change was even more pronounced, with a mean deviation increase from 1.89° to 3.26°.

The observed increase in body alignment deviation following the occlusal intervention may be explained by the complex relationship between dental occlusion and postural control. A study about how dental occlusion affects athletic performance demonstrated that disturbances in dental occlusion could significantly impact postural stability, particularly in athletes, due to changes in muscle activation and coordination. This aligns with the idea that altering mandibular position can influence the body´s vertical alignment through neuromuscular pathways, particularly those involving the trigeminal nerve and the cervical spine (10). Furthermore, another study emphasized the importance of maintaining balanced body alignment during lifting to reduce lumbar strain and improve trunk stability. The observed increase in body deviation in both the frontal and sagittal planes, despite being statistically significant, may indicate a short-term destabilizing effect as the musculoskeletal system adapts to the new occlusal conditions (18). This finding suggests that the occlusal intervention might temporarily disrupt the established postural balance, especially in trained weightlifters who typically exhibit strong neuromuscular compensation and stability (10,18).

### 10.3 Additional Postural Variables

In addition to the primary postural variables analyzed, several other variables showed slight but consistent improvements following the occlusal intervention.

Most notably, a statistically significant reduction was observed in the Lower Jaw-Menton Angle (LJ-Me) ($\Delta = -0.74$, $p = 0.012$). According to a study about dental occlusion on athletic performance, occlusal disturbances can negatively impact body posture and muscular coordination, especially in athletes. In the study, changes in occlusal alignment were associated with asymmetric muscle contractions and altered postural stability. The observed reduction in the LJ-Me angle might indicate that correcting mandibular position through occlusal intervention helped restore more symmetrical muscle activation and improved postural control, potentially reducing strain on the craniofacial and cervical structures (10).

This finding aligns with evidence suggesting that improved mandibular alignment may reduce compensatory muscle activity and enhance stability, which is particularly relevant for athletes who rely on optimal postural and muscular balance (15).

Other variables such as head tilt (Δ = -0.42), lower horizontal plane (Δ = -0.42), knee alignment (Δ = -0.42), and foot alignment (Δ = -0.42), did not show a statistical significance. However, they did show a small and consistent decrease in deviation, indicating movement toward the ideal values following the occlusal intervention. Even though these changes were not statistically significant on their own, the small and consistent improvement may suggest that the body began to adjust its posture in response to the occlusal modifications. This could reflect a mild neuromuscular response, where muscles and joints slowly adapted to the occlusal modifications, helping to improve balance and alignment.

These results align with previous research indicating that individual variability plays a significant role in how postural adjustments are made following occlusal changes, particularly in athletes (22).

The interaction between dental occlusion and postural alignment can be explained by the connection between the stomatognathic system and the CNS, where afferent signals from the trigeminal nerve and proprioceptors in the masticatory muscles, PDL, and TMJ integrate with postural control centers in the CNS. Modifications in occlusion may alter trigeminal input, leading to changes in cervical muscle tone and head posture as observed in the present study. The CNS continuously modulates motor responses based on sensory feedback from the stomatognathic system, which explains why some participants showed positive alignment changes while others did not. Additionally, the role of cervical muscles, such as the sternocleidomastoid and trapezius, is crucial in maintaining head stability during static conditions, and occlusal modifications might influence their tone, affecting craniovertebral alignment (21).

Improvements observed in the knees and feet, while not statistically significant, changes in occlusal alignment can still influence lower body posture and balance by affecting neuromuscular coordination through the trigeminal-cervical system, suggesting that even minor improvements in alignment may support better postural control during weightlifting tasks (15).

These findings support the idea that occlusal modifications, even as a short-term intervention, can produce effects not only in the mandible, but across multiple regions of the body. The statistically significant improvement in LJ-Me, along with slight improvements in the CVA, head tilt, LHP, knees and feet, supports the hypothesis that dental occlusion plays a role in the regulation of static postural control by influencing neuromuscular balance and alignment across multiple regions of the body.

### 10.4 Strengths, Limitations, and Future Directions

One of the main strengths of this study is its within-subject design. This is a major advantage because it reduces variability between participants, such as differences in anatomy, training level, or baseline posture, that could potentially affect the results. By using each participant as their own reference point, the study was able to isolate the effects of the occlusal intervention (28).

Secondly, by using a standardized occlusal intervention like the Messerman Test to temporarily modify the occlusion, the intervention is made simple, safe, and consistent within all participants. This makes sure that any observed changes were linked to changes in occlusion rather than inconsistencies in how the test was applied (22,23).

The study also benefited from using a tool like APECS, a non-invasive digital tool for accurate and reproducible measurements of posture, avoiding the need for more invasive techniques, such as radiographs, while still providing reliable measurements of postural alignment and musculoskeletal balance (27).

Additionally, the study applied clear and strict inclusion and exclusion criteria, which made sure that the participants were relatively similar in terms of health status and physical condition. This reduces the change of external factors (such as underlying injuries, orthodontic treatment, or the use of supportive devices) affecting the results, since they can influence occlusion and posture.

However, several limitations should be considered. The small sample size (n=19) makes it almost impossible to generalize the results to a wider athletic population. In addition, the lack of control group makes it difficult to distinguish whether the observed changes were specifically due to the occlusal intervention or influenced by other variables such as normal daily changes in posture. The photographs were also taken at different moments, with some participants being at the beginning of their training, some in the middle, some post-training, and some after a competition. This variability may have influenced the results, as physical condition and fatigue levels can vary significantly depending on the training phase or competition status (18).

Blinding was not possible due to the nature of the intervention (cotton rolls placed in the premolar area), which means that the participants, evaluators, or both were aware of the intervention being applied. This may have introduced some performance bias, where participants unconsciously adjust their posture knowing they are being tested, or observer bias, where the evaluators interpret data with expectations of improvement.

To address the limitations mentioned above, future research should aim to include a larger and more diverse sample of participants, ideally athletes from different types of sports, as postural and muscular patterns can vary depending on the activity performed.

Using a randomized controlled trial design would be ideal to increase the strength and reliability of the findings. Adding a control group would also make it easier to determine if the changes in posture are truly due to occlusal intervention or just part of normal individual variation. Introducing a placebo effect, using an object that mimics the feel of an intervention without affecting the occlusion could also help reduce performance and observer bias because if the participants and the evaluators know which condition is being tested, they may adjust their posture, even unintentionally.

Another key area for improvement would be to introduce evaluator blinding, or even blinding during data analysis, which would make the outcome assessment more objective and reduce expectation-driven errors.

## 11. CONCLUSION

Regarding the primary objective, the findings indicate that while the occlusal interventions can lead to measurable changes in some postural variables, their overall impact on postural stability is limited.

The baseline assessment revealed that even well-trained weightlifters can present postural imbalances under static conditions.

The study demonstrated that occlusal interventions using the Messerman Test can positively affect upper body alignment but the effect on spinal alignment is less favorable.

Additionally, occlusal intervention showed a limited positive effect on balance, but no improvement in weight distribution, and a negative effect on spinal posture.

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# 13. ANNEX

## ANNEX I

## CONSORT 2025 Checklist Item Description

| Section/topic | No | CONSORT 2025 checklist item description | Reported on page no. |
|---|---|---|---|
| **Title and abstract** | | | |
| Title and structured abstract | 1a | Identification as a randomized trial | - |
| | 1b | Structured summary of the trial design, methods, results, and conclusions | 7 & 9 |
| **Open science** | | | |
| Trial registration | 2 | Name of trial registry, identifying number (with URL) and date of registration | - |
| Protocol and statistical analysis plan | 3 | Where the trial protocol and statistical analysis plan can be accessed | 36-38 |
| Data sharing | 4 | Where and how the individual de-identified participant data (including data dictionary), statistical code and any other materials can be accessed | - |
| Funding and conflicts of interest | 5a | Sources of funding and other support (eg, supply of drugs), and role of funders in the design, conduct, analysis and reporting of the trial | 67 |
| | 5b | Financial and other conflicts of interest of the manuscript authors | - |
| **Introduction** | | | |
| Background and rationale | 6 | Scientific background and rationale | 13 |
| Objectives | 7 | Specific objectives related to benefits and harms | 29 |
| **Methods** | | | |
| Patient and public involvement | 8 | Details of patient or public involvement in the design, conduct and reporting of the trial | 39 |
| Trial design | 9 | Description of trial design including type of trial (eg, parallel group, crossover), allocation ratio, and framework (eg, superiority, equivalence, non-inferiority, exploratory) | 31-32 |
| Changes to trial protocol | 10 | Important changes to the trial after it commenced including any outcomes or analyses that were not prespecified, with reason | 33 |
| Trial setting | 11 | Settings (eg, community, hospital) and locations (eg, countries, sites) where the trial was conducted | 33 |
| Eligibility criteria | 12a | Eligibility criteria for participants | 33 |
| | 12b | If applicable, eligibility criteria for sites and for individuals delivering the interventions (eg, surgeons, physiotherapists) | - |
| Intervention and comparator | 13 | Intervention and comparator with sufficient details to allow replication. If relevant, where additional materials describing the intervention and comparator (eg, intervention manual) can be accessed | 36 |
| Outcomes | 14 | Prespecified primary and secondary outcomes, including the specific measurement variable (eg, systolic blood pressure), analysis metric (eg, change from baseline, final value, time to event), method of aggregation (eg, median, proportion), and time point for each outcome | 38-39 |
| Harms | 15 | How harms were defined and assessed (eg, systematically, non-systematically) | 36 |
| Sample size | 16a | How sample size was determined, including all assumptions supporting the sample size calculation | 33 |
| | 16b | Explanation of any interim analyses and stopping guidelines | - |
| Randomization: | | | |
| Sequence generation | 17a | Who generated the random allocation sequence and the method used | - |
| | 17b | Type of randomization and details of any restriction (eg, stratification, blocking and block size) | - |
| Allocation concealment mechanism | 18 | Mechanism used to implement the random allocation sequence (eg, central computer/telephone; sequentially numbered, opaque, sealed containers), describing any steps to conceal the sequence until interventions were assigned | - |
| Implementation | 19 | Whether the personnel who enrolled and those who assigned participants to the interventions had access to the random allocation sequence | - |
| Blinding | 20a | Who was blinded after assignment to interventions (eg, participants, care providers, outcome assessors, data analysts) | 36 |
| | 20b | If blinded, how blinding was achieved and description of the similarity of interventions | - |
| Statistical methods | 21a | Statistical methods used to compare groups for primary and secondary outcomes, including harms | 35 |
| | 21b | Definition of who is included in each analysis (eg, all randomized participants), and in which group | 42 |
| | 21c | How missing data were handled in the analysis | 42 |
| | 21d | Methods for any additional analyses (eg, subgroup and sensitivity analyses), distinguishing prespecified from post hoc | - |
| **Results** | | | |
| Participant flow, including flow diagram | 22a | For each group, the numbers of participants who were randomly assigned, received intended intervention, and were analyzed for the primary outcome | 41-42 |
| | 22b | For each group, losses and exclusions after randomization, together with reasons | 41-42 |
| Recruitment | 23a | Dates defining the periods of recruitment and follow-up for outcomes of benefits and harms | 33 |
| | 23b | If relevant, why the trial ended or was stopped | - |
| Intervention and comparator delivery | 24a | Intervention and comparator as they were actually administered (eg, where appropriate, who delivered the intervention/comparator, how participants adhered, whether they were delivered as intended (fidelity)) | 36 |
| | 24b | Concomitant care received during the trial for each group | - |
| Baseline data | 25 | A table showing baseline demographic and clinical characteristics for each group | 43 |
| Numbers analysed, outcomes and estimation | 26 | For each primary and secondary outcome, by group:<br>● the number of participants included in the analysis<br>● the number of participants with available data at the outcome time point<br>● result for each group, and the estimated effect size and its precision (such as 95% confidence interval)<br>● for binary outcomes, presentation of both absolute and relative effect size | 45-48 |
| Harms | 27 | All harms or unintended events in each group | 36 |
| Ancillary analyses | 28 | Any other analyses performed, including subgroup and sensitivity analyses, distinguishing pre-specified from post hoc | - |
| **Discussion** | | | |
| Interpretation | 29 | Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence | 51-56 |
| Limitations | 30 | Trial limitations, addressing sources of potential bias, imprecision, generalizability, and, if relevant, multiplicity of analyses | 56 |

# ANNEX II

## Ethics Committee

Universidad Europea

**Comisión de Investigación**

Villaviciosa de Odón, 7 de febrero de 2025

Estimado/a investigador/a,

La Comisión de Investigación de la Escuela de Doctorado e Investigación, una vez revisada la documentación e información, remitida por el investigador responsable con fecha 31/01/2024 9:55:28, relativa al proyecto abajo indicado, autoriza su desarrollo en la Universidad Europea.

| | |
|---|---|
| **Título del proyecto:** | Influencia de la modificación de la oclusión y la postura sobre el rendimiento deportivo. |
| **Tipo de proyecto:** | Proyecto-SIN financiación |
| **Investigador/a responsable:** | FERRER SERENA- MARIA DEL CARMEN |

| | |
|---|---|
| **Código CI:** | 2024-520 |
| **Código OTRI:** | Sin especificar |
| **Código Departamento:** | Sin especificar |
| **Dictamen:** | APROBADO |

Atentamente,

Universidad Europea
ESCUELA DE DOCTORADO E INVESTIGACIÓN

**Fdo. Óscar García López**

*Director de la Escuela de Doctorado e Investigación*

# ANNEX III

## Informed Consent

**CONSENTIMIENTO INFORMADO:**

D./Dª. ______________________________________________________, de____ años, con DNI________________ y domicilio en _____________________________________, he recibido una explicación satisfactoria sobre el procedimiento del estudio, su finalidad, riesgos, beneficios y alternativas.

He quedado satisfecho/a con la información recibida, la he comprendido, se me han respondido todas mis dudas y comprendo que mi participación es voluntaria.

Presto mi consentimiento para el procedimiento propuesto y conozco mi derecho a retirarlo cuando lo desee, con la única obligación de informar sobre mi decisión al médico responsable del estudio.

En Valencia, a día______ de _______________ de _______.

________________________________ ______________________

Firma y Nº de colegiado del investigador Firma y Nº de DNI del paciente

*En casos de menores entre 12 y 18 años, debe hacerse una hoja por duplicado: una para el menor (con el texto informativo adaptado a la comprensión y el trato correspondientes a un adolescente) y otra para el representante legal de ese menor. En caso de menores de 12 años, solo firma el consentimiento el representante legal. El modelo para ambos casos varía en la primera línea y en la firma, del siguiente modo:

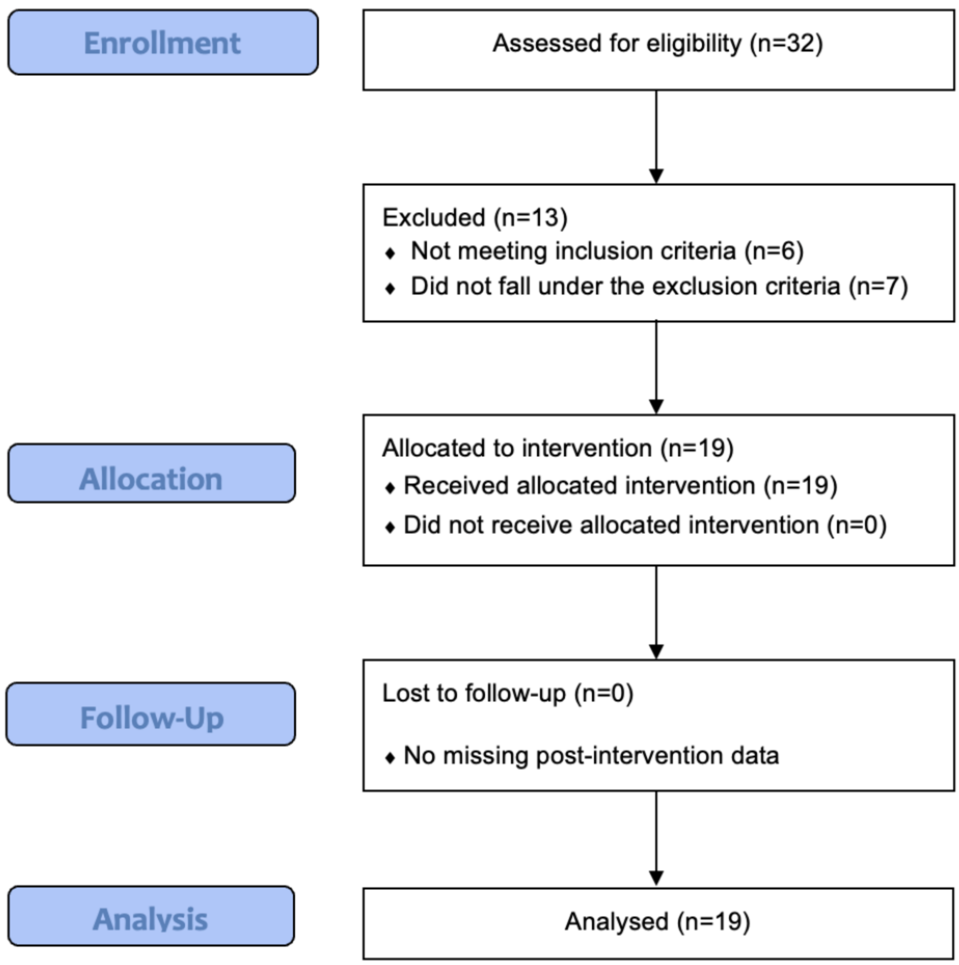
D./Dª. __________________________, de____ años, con DNI________, representante legal de D./Dª. ___________________, de____ años, con DNI ______,

(...)

Firma y Nº de DNI del representante legal del paciente

## ANNEX IV

**CONSORT 2025 Flow Diagram**



## ANNEX V

### Declaration of the Use of Artificial Intelligence (AI) in the Preparation of the Bachelor´s Thesis (TFG)

In the preparation of this thesis, I used artificial intelligence tools to support various stages of the research and writing process. Specifically, I worked with ChatGTP 4.0 to help organize ideas, interpret data, and refine academic writing.

**Tool:** ChatGTP 4.0

**Functions:** Guidance in structuring the Materials and Methods section, support in describing data collection protocols aligned with CONSORT guidelines, assistance in organizing and interpreting descriptive and inferential statistics, and refining the academic tone of the text, making sure that the text was easier to understand.

**Examples:** *“How do I present head and neck posture data in a clear format?”. What is the best way to write up the results of a Wilcoxon Signed Rank Test for spinal alignment?”. Make this explanation less scientific”.*

**Link:** https://chatgpt.com

***All AI-generated suggestions were reviewed carefully and adjusted.**

# IMPACT OF OCCLUSAL INTERVENTIONS USING THE MESSERMAN TEST ON POSTURAL AND MUSCULOSKELETAL STABILITY IN ADULT WEIGHTLIFTERS UNDER STATIC CONDITIONS: EXPERIMENTAL STUDY

**Running title: Impact of Occlusal Interventions on Postural and Musculoskeletal Stability in Weightlifters**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## Abstract

**Introduction:** This study investigates whether occlusal interventions, using the Messerman Test, may improve postural and musculoskeletal stability in adult weightlifters under static conditions compared to natural occlusion. Despite their high level of physical training, athletes often present with postural misalignments. These imbalances may not only affect athletic performance but also predispose athletes to injury. The aim was to determine whether occlusal adjustments could positively impact overall postural alignment, including both upper and lower body regions.

**Materials and methods:** A pre- and post-experimental study was performed to assess static posture before and after the occlusal intervention. Postural evaluation was performed using both the Messerman Test and the APECS system. Variables analyzed included craniovertebral angle (CVA), head and shoulder alignment (CHA), lower body deviations (feet, knees), and spinal alignment.

**Results:** Results showed that prior to the intervention, common postural imbalances were observed. Post-intervention, significant improvements were noted in head-neck alignment and reduced head tilt. However, improvements in body alignment were limited, with slight improvements in feet and knees, but a deterioration in spinal alignment, and balance remained unchanged.

**Conclusion:** The occlusal intervention showed limited effects on overall static postural control in trained weightlifters. While some improvements were observed in craniofacial and lower limb alignment, spinal alignment did not benefit, indicating that occlusal changes alone may not sufficiently address overall postural stability. Further research is needed to explore the interaction between dental occlusion and musculoskeletal alignment in athletes.



***Key words:*** *APECS, Messerman Test, Occlusion, Posture, Weightlifting.*

## Introduction

Dentistry is evolving beyond the oral cavity to adopt a whole-body approach, as growing evidence links dental occlusion with postural control and balance. This highlights the importance of multidisciplinary collaboration, as postural issues, such as imbalances in foot pressure or spinal alignment, often correlate with dental malocclusions (1).

The posture of the body is maintained through coordinated muscle contractions and neuromuscular adjustments, with the cranio-cervical region playing a key role (2,3). The sub-occipital, sternocleidomastoid, and deep cervical flexor muscles stabilize the head posture, while suprahyoid muscles influence jaw and spinal alignment (4). These muscles, connected to the jaw, head, and neck, interact with the nervous system, especially the trigeminal nerve, which provides proprioceptive input from the teeth, masticatory muscles, and temporomandibular joint (TMJ) to the CNS (4,5). This input contributes to the body´s broader postural control mechanisms, which rely on the integration of nerve signals, within the CNS (2,6). The trigeminal nerve forms direct neural connections with cervical and lumbar motor pathways and helps coordinate postural responses by influencing the activity of cervical muscles (7,8,9).

Occlusal imbalances can alter proprioceptive input, leading to neuromuscular changes that affect, head, neck, and spinal alignment (8,10,11). These disruptions may impact postural stability and muscular symmetry, especially during high-demanding activities like weightlifting (12,13,14). To measure these postural changes, the AI Posture Evaluation and Correction system (APECS) is a valuable tool to make a whole-body postural assessment (15).

Although growing evidence suggests a link between occlusion and posture, findings remain inconsistent (1,12,16). The Messerman Test offers a standardized way to explore this connection, however their application in sports like weightlifting has been overlooked (16,17). Due to the neuromuscular demands of weightlifting, more research is needed to determine if occlusal interventions affect static posture and stability. Therefore, the aim of this study is to evaluate the effects of occlusal adjustment using the Messerman Test on postural and musculoskeletal stability in adult weightlifters under static conditions, as compared to their natural occlusion.

## Materials and Methods

*Study Design and Sample Size*

This was a non-randomized, within-subject, pre-post experimental study, conducted with adult weightlifters, evaluated under natural occlusion and after occlusal intervention using the Messerman Test. The study followed the CONSORT 2025 guidelines and adhered to ethical standards outlined by the Declaration of Helsinki and Spanish biomedical research regulations (Law 14/2007), with approval from the Research Ethics Committee of the European University, with a registration code: 2024-520.

Nineteen adult weightlifters (aged 19-38) were selected from a local CrossFit training club in Valencia Spain, after applying inclusion and exclusion criteria (Figure 1). Inclusion required the participants to be over 18 years old, actively training in weightlifting, and systematically health. Exclusion criteria included being over 40 years old, pregnant, using biomechanical aids, or undergoing active dental treatment (orthodontics or implants). Informed consent was obtained from all participants, and there were no dropouts throughout the study.

*Materials*

The primary tool for postural assessment was APECS, which uses AI to analyze the static posture of the weightlifters through digital radiographs. The photographs were taken using an iPhone on a tripod, from frontal and lateral views (right and left), to assess key anatomical landmarks. During the intervention phase, the Messerman Test was applied by placing two cotton rolls in the premolar region to achieve posterior disocclusion.

Data such as age, training history, and health status were recorded in Microsoft Excel, and statistical analysis was performed using IBM SPSS Statistics 29.0.

*Procedure and Data Collection*

The participants underwent two postural evaluations, with the final analysis being the comparison between the two. First the participants were evaluated in basal conditions, without any intervention. For the second evaluation, the Messerman Test was applied by placing two cotton rolls in the premolar region. The third evaluation was the analysis of the two conditions to see the effect of the occlusal intervention. Due to the nature of the intervention, blinding was not performed.

The data collection followed a standardized, structured approach to guarantee accuracy for all participants. The main tool used was the APECS software, which identified the anatomical reference points from the photographs, which then generated a postural analysis report indicating potential imbalances.

The sociodemographic data of the participants, including the inclusion and exclusion criteria were recorded using Microsoft Excel.

Once all data had been collected, statistical analysis was performed for the descriptive analysis and normality tests (Shapiro-Wilk Test), as well as using the Wilcoxon Signed Rank Test to compare pre- and post-intervention results within the same participant.

*Study Variables*

The independent variable was the occlusal condition (with and without the intervention), while the dependent variables were specific, measurable indicators of static postural control. The main postural variables included: Craniovertebral Angle (CVA), Shoulder Alignment, Pelvic Tilt, and Body Alignment. These variables reflect key components of balance, spinal alignment, and weight distribution.

## **Results:**

Nineteen adult weightlifters (58% men, 42% women) participated in the study after applying inclusion and exclusion criteria. The participants' ages ranged from 19-38 years, with 68% being between 19-29 years old. The majority were single (74%) and had a university degree (63%). Most participants were employed (63%) or students (32%), and nearly all (95%) were federated athletes.

*Evaluation of Postural Variables*

Normality testing using the Shapiro-Wilk Test revealed that most postural variables including head tilt, knee and foot angles, and body alignment (frontal and sagittal), did not follow a normal distribution ($p < 0.05$). Only a few variables such as craniovertebral angle (CVA) and cervical horizontal angle (CHA), showed a normal distribution.

Consequently, the Wilcoxon Signed Rank Test was used for statistical comparison (Table 1). Changes Related to the Occlusal Intervention Descriptive statistics were calculated for each postural variable under pre- and post-intervention conditions, as well as for the Δ values (Table 2).

Most variables showed small mean changes between conditions, with a few showing more notable sifts. Among the most relevant findings, the CHA showed a statistically significant increase post-intervention ($p = 0.042$), with a mean change of +1.39° and a median of 2. The LJ-Me angle significantly decreased ($p = 0.012$), with a mean -0.74° and a median of 1.

In terms of Body Alignment, a significant increase was observed in the frontal plane ($p = 0.046$), with a mean difference of +0.21°, and with a median of 0. The sagittal plane also showed a statistically significant increase ($p = 0.024$), with a mean change of +1.37°, although the median remained at 0.

*Comparison of Pre- and Post-Intervention Variables*

The Wilcoxon Signed Rank Test was used to compare pre- and post-intervention measurements, showing notable changes in a few variables, including a significant increase in the Cervical Horizontal Angle (CHA) ($p = 0.042$), a significant decrease in the Lip-Menton Angle (LJ-Me ($p = 0.012$), and a significant increase in Body Alignment, both frontal and sagittal (Frontal: $p = 0.046$; Sagittal: $p = 0.024$). All other variables (CVA, SSP, UHP, LHP, Head Tilt, Shoulder Alignment, Pelvic Tilt, Knees, and Feet) showed no statistically significant differences ($p \geq 0.05$).

These results suggest that while the occlusal intervention did not significantly affect all postural parameters, it did produce notable changes in craniofacial and global alignment, particularly in sagittal and frontal postural planes.

## **Discussion:**

The study aimed to evaluate the impact of occlusal intervention using the Messerman Test on static posture and musculoskeletal stability in adult weightlifters. The findings suggest that occlusal intervention can lead to measurable changes in specific postural variables, highlighting a potential link between dental occlusion and posture. However, the effects were not uniform across participants, with some showing improvements, other minimal changes, and a few experiencing slight worsening. This could be due to individual differences in body alignment and muscle adaptation, particularly in trained athletes who are used to compensating for imbalances.

The study´s sample consisted of adult weightlifters with balanced gender distribution, predominantly federated athletes, and a high level of training experience. This uniformity minimized variability related to training background and physical fitness, providing a focused perspective on the effect of occlusal intervention in a sport-specific context. The inclusion of highly trained individuals improved the study´s relevance for athletic populations.

*Craniovertebral Angle (CVA):* A normal CVA typically ranges from 48-50°, indicating an upright and aligned head posture. Values below this range indicate a FHP, characterized by increased extension of the upper cervical spine and increased flexion of the lower cervical spine and upper thoracic region (16). The results showed that the mean CVA decreased from 57.50° (SD = 3.14) pre-intervention to 56.89° (SD = 2.78) post-intervention, with a mean change of –0.61°. This change indicates slight improvement, bringing the head posture of the participants closer to the ideal value. These findings align with the evidence that cervical posture influences trunk muscles and lumbar spine alignment during weightlifting. A study made on FHP demonstrated that a retracted neck posture, compared to a freestyle or extended posture, reduces lumbar spine flexion and increases activation of stabilizing muscles, including the sternocleidomastoid and lumbar erector spinae. This could indicate that the intervention supports safer lifting mechanics by reducing cervical flexion and improving sternocleidomastoid activation, promoting a more upright head posture (18).

*Shoulder Alignment:* Perfect shoulder alignment is when the shoulders are at the same level, indicating symmetry (16). Pre-intervention, the mean value was 1.37° (SD = 1.50) and post-intervention it increased slightly to 1.53° (SD = 1.43), with a change of +0.16°. This indicates that occlusal modifications did not significantly affect shoulder symmetry, which does not entirely align with evidence suggesting that changes in jaw position can improve shoulder muscular strength, by receiving proprioceptive feedback from the masticatory system (9). However, this minor increase in shoulder tilt angle could be due to individual variability rather than a consistent effect of the intervention.

*Pelvic Tilt:* The goal is to have the right and left anterior superior iliac spine at the same height (17). In this study, the pelvic tilt remained unchanged. Both pre- and post-intervention means were 0.89° (SD = 1.70) and no statistically significant change ($p = 0.972$). The unchanged pelvic tilt observed, despite the occlusal intervention, may indicate stability and strong postural control typically developed in weightlifters. This suggests that the occlusal intervention did not disrupt the established postural control, possibly due to the adaptive strength and neuromuscular coordination characteristics of trained weightlifters (12,18).

*Body Alignment:* The most notable change observed in this study was in the body alignment, where participants demonstrated a statistically significant increase in deviation following the occlusal intervention ($p = 0.046$ for frontal, $p = 0.024$ for sagittal), indicating a movement away from the ideal value. In the frontal plane, the mean deviation increased from 0.37° to 0.58°, and in the sagittal plane, the change was even more pronounced, with a mean deviation increase from 1.89° to 3.26°. This could be explained by the complex relationship between dental occlusion and postural control, since altering mandibular position can influence the body´s vertical alignment through neuromuscular pathways, particularly those involving the trigeminal nerve and the cervical spine (7). This finding suggests that the occlusal intervention might temporarily disrupt the established postural balance, especially in trained weightlifters who typically exhibit strong neuromuscular compensation and stability (7,18).

In addition to the primary postural variables analyzed, several other variables showed slight but consistent improvements. Most notably, a statistically significant reduction was observed in the Lower Jaw-Menton Angle (LJ-Me) ($\Delta = -0.74$, $p = 0.012$). This observed reduction in the LJ-Me angle might indicate that correcting mandibular position through occlusal intervention might help restore more symmetrical muscle activation and improve postural control, potentially reducing strain on the craniofacial and cervical structures (13).

Other variables such as head tilt ($\Delta = -0.42$), lower horizontal plane ($\Delta = -0.42$), knee alignment ($\Delta = -0.42$), and foot alignment ($\Delta = -0.42$), did not show a statistical significance. However, they did show a small and consistent decrease in deviation, indicating movement toward the ideal values following the occlusal intervention. Even though these changes were not statistically significant on their own, the small and consistent improvement may suggest that the body began to adjust its posture in response to the occlusal modifications. This aligns with previous research indicating that individual variability plays a significant role in how postural adjustments are made following occlusal changes, particularly in athletes (10).

Improvements observed in the knees and feet, while not statistically significant, changes in occlusal alignment can still influence lower body posture and balance by affecting neuromuscular coordination through the trigeminal-cervical system, suggesting that even minor improvements in alignment may support better postural control during weightlifting tasks (9).

These findings support the idea that occlusal modifications, even as a short-term intervention, can produce effects not only in the mandible, but across multiple regions of the body. The statistically significant improvement in LJ-Me, along with slight improvements in the CVA, head tilt, LHP, knees and feet, supports the hypothesis that dental occlusion plays a role in the regulation of static postural control by influencing neuromuscular balance and alignment across multiple regions of the body.

*Limitations and Future Directions*

Although the within-subject design of the study helped minimize inter-individual variability, and the use of standardized, non-invasive tools such as the APECS software and the Messerman Test ensured consistency in data collection and occlusal intervention, certain limitations remain.

The small sample size (n=19) restricts the generalizability of the findings, and the absence of a control group limits the ability to draw definitive conclusions about the effects of the intervention. Furthermore, the lack of blinding for both participants and evaluators may have introduced potential bias.

Despite these limitations, the study offers valuable insight into the possible influence of occlusal adjustments on craniofacial and postural alignment, particularly in weightlifters. Future research should aim to include larger and more diverse samples, adopt randomized controlled designs, and implement blinding strategies. Additionally, exploring long-term effects and incorporating dynamic postural assessments could further clarify the role of occlusion in athletic performance and postural regulation.

## Conclusion:

The findings indicate that while the occlusal interventions can lead to measurable changes in some postural variables, their overall impact on postural stability is limited. The baseline assessment revealed that even well-trained weightlifters can present postural imbalances under static conditions. The study demonstrated that occlusal interventions using the Messerman Test can positively affect upper body alignment but the effect on spinal alignment is less favorable. Additionally, occlusal intervention showed a limited positive effect on balance, but no improvement in weight distribution, and a negative effect on spinal posture.

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***Table 1:*** *Test of Normality for Pre-, Post-, and Δ Conditions (Shapiro-Wilk)*

| | Statistic | df | Sig. |
|---|---|---|---|
| **CVA Pre** | 0,926 | 19 | 0,144 |
| **CVA Post** | 0,963 | 19 | 0,640 |
| **CVA Δ** | 0,892 | 19 | 0,035 |
| **CHA Pre** | 0,946 | 19 | 0,336 |
| **CHA Post** | 0,943 | 19 | 0,302 |
| **CHA Δ** | 0,842 | 19 | 0,005 |
| **SSP Pre** | 0,902 | 19 | 0,053 |
| **SSP Post** | 0,914 | 19 | 0,088 |
| **SSP Δ** | 0,814 | 19 | 0,002 |
| **UHP Pre** | 0,832 | 19 | 0,004 |
| **UHP Post** | 0,842 | 19 | 0,005 |
| **UHP Δ** | 0,919 | 19 | 0,109 |
| **LHP Pre** | 0,844 | 19 | 0,005 |
| **LHP Post** | 0,850 | 19 | 0,007 |
| **LHP Δ** | 0,959 | 19 | 0,561 |
| **VP Pre** | 0,859 | 19 | 0,009 |
| **VP Post** | 0,877 | 19 | 0,019 |
| **VP Δ** | 0,959 | 19 | 0,558 |
| **LJ-Me Pre** | 0,884 | 19 | 0,025 |
| **LJ-Me Post** | 0,715 | 19 | <0,001 |
| **LJ-Me Δ** | 0,864 | 19 | 0,011 |
| **Head Tilt Pre** | 0,894 | 19 | 0,037 |
| **Head Tilt Post** | 0,844 | 19 | 0,005 |
| **Head Tilt Δ** | 0,793 | 19 | <0,001 |
| **Shoulder Alignment Pre** | 0,818 | 19 | 0,002 |
| **Shoulder Alignment Post** | 0,882 | 19 | 0,023 |
| **Shoulder Alignment Δ** | 0,823 | 19 | 0,003 |
| **Pelvic Tilt Pre** | 0,753 | 19 | <0,001 |
| **Pelvic Tilt Post** | 0,715 | 19 | <0,001 |
| **Pelvic Tilt Δ** | 0,949 | 19 | 0,376 |
| **Knees Pre** | 0,831 | 19 | 0,003 |
| **Knees Post** | 0,713 | 19 | <0,001 |
| **Knees Δ** | 0,883 | 19 | 0,025 |
| **Feet Pre** | 0,836 | 19 | 0,004 |
| **Feet Post** | 0,764 | 19 | <0,001 |
| **Feet Δ** | 0,918 | 19 | 0,106 |

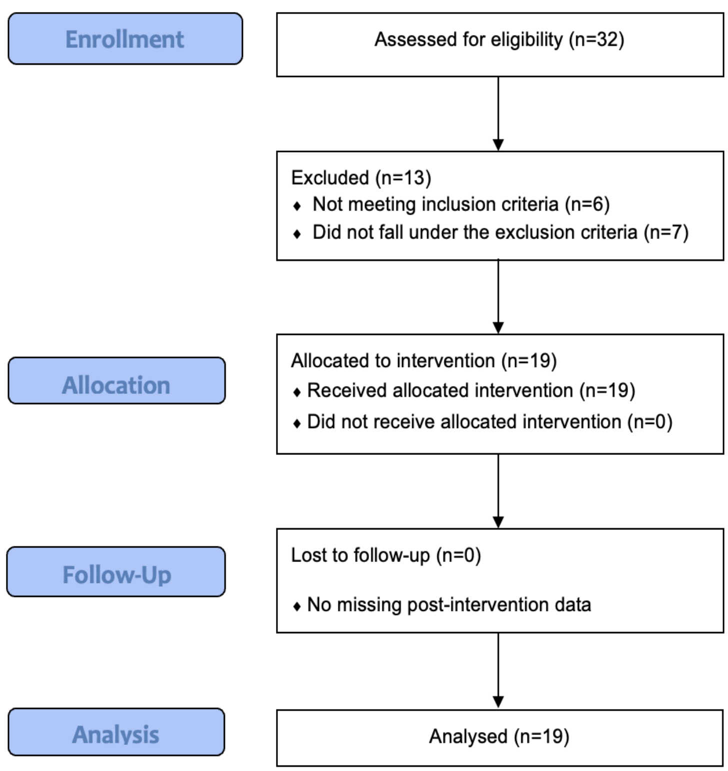
| | | | |
|---|---|---|---|
| **Body Alignment (Frontal) Pre** | 0,616 | 19 | <0,001 |
| **Body Alignment (Frontal) Post** | 0,751 | 19 | <0,001 |
| **Body Alignment (Frontal) Δ** | 0,507 | 19 | <0,001 |
| **Body Alignment (Sagittal) Pre** | 0,612 | 19 | <0,001 |
| **Body Alignment (Sagittal) Post** | 0,716 | 19 | <0,001 |
| **Body Alignment (Sagittal) Δ** | 0,568 | 19 | <0,001 |

## ***Table 2:*** *Descriptive Statistics for Pre-, Post-, and Δ Conditions*

| | Valid N | Mean | SD | Median | Percentile 25 | Percentile 75 | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| **CVA Pre** | 19 | 57,50 | 3,14 | 58,00 | 55,00 | 60,00 | 53,00 | 63,00 |
| **CVA Post** | 19 | 56,89 | 2,78 | 56,50 | 55,50 | 58,50 | 52,00 | 62,00 |
| **CVA Δ** | 19 | -0,61 | 1,90 | -0,50 | -2,00 | 1,00 | -3,50 | 2,00 |
| **CHA Pre** | 19 | 10,11 | 7,20 | 10,00 | 3,00 | 15,00 | 0,00 | 24,00 |
| **CHA Post** | 19 | 11,50 | 6,18 | 11,00 | 6,00 | 15,00 | 2,00 | 22,00 |
| **CHA Δ** | 19 | 1,39 | 4,49 | 2,00 | -0,50 | 4,00 | -13,00 | 7,00 |
| **SSP Pre** | 19 | 9,97 | 6,89 | 9,50 | 5,00 | 13,50 | 1,00 | 25,00 |
| **SSP Post** | 19 | 10,71 | 8,26 | 9,00 | 3,00 | 18,00 | 1,00 | 26,00 |
| **SSP Δ** | 19 | 0,74 | 5,82 | -2,00 | -3,00 | 3,00 | -6,00 | 15,50 |
| **UHP Pre** | 19 | 1,26 | 1,33 | 1,00 | 0,00 | 2,00 | 0,00 | 5,00 |
| **UHP Post** | 19 | 1,42 | 1,39 | 1,00 | 0,00 | 3,00 | 0,00 | 4,00 |
| **UHP Δ** | 19 | 0,16 | 1,17 | 0,00 | -1,00 | 1,00 | -2,00 | 2,00 |
| **LHP Pre** | 19 | 1,42 | 1,57 | 1,00 | 0,00 | 3,00 | 0,00 | 5,00 |
| **LHP Post** | 19 | 1,00 | 0,94 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **LHP Δ** | 19 | -0,42 | 2,12 | 0,00 | -2,00 | 1,00 | -5,00 | 3,00 |
| **VP Pre** | 19 | 2,11 | 2,26 | 1,00 | 0,00 | 4,00 | 0,00 | 7,00 |
| **VP Post** | 19 | 2,74 | 1,97 | 3,00 | 1,00 | 3,00 | 0,00 | 7,00 |
| **VP Δ** | 19 | 0,63 | 2,81 | 0,00 | -1,00 | 3,00 | -4,00 | 6,00 |
| **LJ-Me Pre** | 19 | 1,47 | 1,31 | 1,00 | 0,00 | 2,00 | 0,00 | 4,00 |
| **LJ-Me Post** | 19 | 0,74 | 1,10 | 0,00 | 0,00 | 1,00 | 0,00 | 4,00 |
| **LJ-Me Δ** | 19 | -0,74 | 1,10 | -1,00 | -2,00 | 0,00 | -2,00 | 1,00 |
| **Head Tilt Pre** | 19 | 1,58 | 1,39 | 1,00 | 0,00 | 3,00 | 0,00 | 5,00 |
| **Head Tilt Post** | 19 | 1,16 | 1,12 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Head Tilt Δ** | 19 | -0,42 | 1,43 | 0,00 | -1,00 | 1,00 | -5,00 | 1,00 |
| **Shoulder Alignment Pre** | 19 | 1,37 | 1,50 | 1,00 | 0,00 | 2,00 | 0,00 | 4,00 |
| **Shoulder Alignment Post** | 19 | 1,53 | 1,43 | 1,00 | 0,00 | 2,00 | 0,00 | 5,00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Shoulder Alignment Δ** | 19 | 0,16 | 0,90 | 0,00 | 0,00 | 1,00 | -2,00 | 1,00 |
| **Pelvic Tilt Pre** | 19 | 0,89 | 1,15 | 0,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Pelvic Tilt Post** | 19 | 0,89 | 1,29 | 0,00 | 0,00 | 1,00 | 0,00 | 4,00 |
| **Pelvic Tilt Δ** | 19 | 0,00 | 1,70 | 0,00 | -1,00 | 1,00 | -3,00 | 3,00 |
| **Knees Pre** | 19 | 0,89 | 0,94 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Knees Post** | 19 | 0,47 | 0,61 | 0,00 | 0,00 | 1,00 | 0,00 | 2,00 |
| **Knees Δ** | 19 | -0,42 | 1,02 | 0,00 | -1,00 | 0,00 | -2,00 | 2,00 |
| **Feet Pre** | 19 | 1,11 | 1,10 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Feet Post** | 19 | 0,68 | 0,89 | 0,00 | 0,00 | 1,00 | 0,00 | 3,00 |
| **Feet Δ** | 19 | -0,42 | 1,30 | 0,00 | -1,00 | 0,00 | -3,00 | 3,00 |
| **BA (Frontal) Pre** | 19 | 0,37 | 0,50 | 0,00 | 0,00 | 1,00 | 0,00 | 1,00 |
| **BA (Frontal) Post** | 19 | 0,58 | 0,69 | 0,00 | 0,00 | 1,00 | 0,00 | 2,00 |
| **BA (Frontal) Δ** | 19 | 0,21 | 0,42 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 |
| **BA (Sagittal) Pre** | 19 | 1,89 | 3,33 | 1,00 | 0,00 | 2,00 | 0,00 | 14,00 |
| **BA (Sagittal) Post** | 19 | 3,26 | 4,58 | 2,00 | 0,00 | 4,00 | 0,00 | 17,00 |
| **BA (Sagittal) Δ** | 19 | 1,37 | 3,11 | 0,00 | 0,00 | 2,00 | -1,00 | 13,00 |

***Figure 1:*** *CONSORT 2025 Flow Diagram*



# IMPACTO DE LAS INTERVENCIONES OCLUSALES MEDIANTE EL TEST DE MESSERMAN EN LA ESTABILIDAD POSTURAL Y MUSCULOESQUELÉTICA EN LEVANTADORES DE PESAS ADULTOS EN CONDICIONES ESTÁTICAS: ESTUDIO EXPERIMENTAL

**Título abreviado: Impacto de las intervenciones oclusales en la estabilidad postural y musculoesquelética en levantadores de pesas**

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**Resumen**

**Introducción:** Este estudio investiga si las intervenciones oclusales, utilizando el Test de Messerman, pueden mejorar la estabilidad postural y musculoesquelética en halterófilos adultos en condiciones estáticas en comparación con la oclusión natural. A pesar de su alto nivel de entrenamiento físico, los atletas a menudo presentan desalineaciones posturales. Estos desequilibrios no solo pueden afectar el rendimiento atlético, sino también predisponer a los atletas a lesiones. El objetivo es determinar si los ajustes oclusales podían impactar positivamente en la alineación postural general, incluyendo tanto las regiones superiores como inferiores del cuerpo.

**Material y método:** Se realizó un estudio experimental pre y post intervención para evaluar la postura estática antes y después de la intervención oclusal. La evaluación postural se llevó a cabo utilizando tanto el Test de Messerman como el sistema APECS. Las variables analizadas incluyeron el ACV, la alineación de la cabeza y los hombros (AHC), las desviaciones en la parte inferior del cuerpo y la alineación espinal.

**Resultados:** Pre-intervención, los resultados evidenciaron desequilibrios posturales comunes, mientras que tras la intervención se observaron mejoras significativas en la alineación cabeza-cuello y una reducción en la inclinación de la cabeza. No obstante, las mejoras en la alineación corporal fueron limitadas, con ligeros avances en la posición de pies y rodillas, pero un empeoramiento en la alineación espinal, y sin cambios en el equilibrio.

**Conclusión:** La intervención oclusal mostró efectos limitados en el control postural estático general en halterófilos entrenados. Aunque se observaron algunas mejoras en la alineación craneofacial y de las extremidades inferiores, la alineación espinal no mostró beneficios significativos, lo que indica que los cambios oclusales por sí solos pueden no ser suficientes para abordar la estabilidad postural general. Se necesitan más investigaciones para explorar la interacción entre la oclusión dental y la alineación musculoesquelética en los atletas.

***Palabras clave:*** *APECS, Test de Messerman, Oclusión, Postura, Halterófilos.*

## **Introducción**

La odontología está evolucionando más allá de la cavidad oral para adoptar un enfoque integral del cuerpo, ya que cada vez hay más evidencia que vincula la oclusión dental con el control postural y el equilibrio. Esto resalta la importancia de la colaboración multidisciplinaria, ya que los problemas posturales, como los desequilibrios en la presión plantar o la alineación de la columna, a menudo se correlacionan con maloclusiones dentales (1).

La postura del cuerpo se mantiene mediante contracciones musculares coordinadas y ajustes neuromusculares, siendo la región cráneo-cervical un componente clave (2,3). Los músculos suboccipitales, esternocleidomastoideos y los flexores cervicales profundos estabilizan la postura de la cabeza, mientras que los músculos suprahioideos influyen en la postura mandibular y la alineación espinal (4). Estos músculos, conectados con la mandíbula, cabeza y cuello, interactúan con el sistema nervioso, especialmente con el nervio trigémino, que proporciona información propioceptiva desde los dientes, los músculos masticatorios y la articulación temporomandibular (ATM) al sistema nervioso central (4,5). Esta información contribuye a los mecanismos generales de control postural del cuerpo, los cuales dependen de la integración de señales nerviosas dentro del sistema nervioso central (2,6). El nervio trigémino forma conexiones neuronales directas con las vías motoras cervicales y lumbares y ayuda a coordinar respuestas posturales al influir en la actividad de los músculos cervicales (7,8,9).

Los desequilibrios oclusales pueden alterar la entrada propioceptiva, provocando cambios neuromusculares que afectan la alineación de la cabeza, el cuello y la columna vertebral (8,10,11). Estas alteraciones pueden impactar en la estabilidad postural y la simetría muscular, especialmente durante actividades de alta exigencia física como la halterofilia (12,13,14). Para medir estos cambios posturales, el sistema de Evaluación y Corrección Postural por Inteligencia Artificial (APECS) es una herramienta valiosa para realizar una evaluación postural de cuerpo completo (15).

Aunque la evidencia sobre la relación entre oclusión y postura va en aumento, los resultados siguen siendo inconsistentes (1,12,16). El Test de Messerman ofrece una forma estandarizada de explorar esta conexión, sin embargo, su aplicación en deportes como la halterofilia ha sido en gran medida ignorada (16,17). Debido a las demandas neuromusculares de la halterofilia, se necesita más investigación para determinar si las intervenciones oclusales afectan la postura estática y la estabilidad. Por lo tanto, el objetivo de este estudio es evaluar los efectos del ajuste oclusal mediante el Test de Messerman sobre la estabilidad postural y musculoesquelética en halterófilos adultos en condiciones estáticas, en comparación con su oclusión natural.

## Material y métodos

*Diseño del estudio y tamaño de la muestra*

Este fue un estudio experimental pre-post, intra-sujeto y no aleatorizado, realizado con halterófilos adultos, evaluados bajo oclusión natural y tras la intervención oclusal utilizando el Test de Messerman. El estudio siguió las directrices CONSORT 2025 y se ajustó a los estándares éticos establecidos por la Declaración de Helsinki y la normativa española en investigación biomédica (Ley 14/2007), con aprobación del Comité de Ética de Investigación de la Universidad Europea, código de registro: 2024-520.

Se seleccionaron diecinueve halterófilos adultos (entre 19 y 38 años) de un club local de CrossFit en Valencia, España, tras aplicar criterios de inclusión y exclusión (Figura 1). Los criterios de inclusión exigían que los participantes fueran mayores de 18 años, practicaran halterofilia activamente y gozaran de salud general. Los criterios de exclusión incluyeron ser mayor de 40 años, embarazo, uso de ayudas biomecánicas o estar bajo tratamiento dental activo (ortodoncia o implantes). Se obtuvo consentimiento informado de todos los participantes y no hubo abandonos durante el estudio.

*Material*

La herramienta principal para la evaluación postural fue APECS, que utiliza inteligencia artificial para analizar la postura estática de los halterófilos mediante fotografías digitales. Las imágenes fueron tomadas con un iPhone sobre un trípode, desde vistas frontal y lateral (derecha e izquierda), evaluando referencias anatómicas clave. Durante la fase de intervención, se aplicó el Test de Messerman colocando dos rollos de algodón en la región premolar para lograr la des-oclusión posterior. Los datos como edad, historia de entrenamiento y estado de salud fueron registrados en Microsoft Excel, y el análisis estadístico se realizó con IBM SPSS Statistics 29.0.

*Procedimiento y selección de datos*

Los participantes realizaron dos evaluaciones posturales, y el análisis final consistió en la comparación entre ambas condiciones. Primero, se evaluaron en condiciones basales, sin intervención. Para la segunda evaluación, se aplicó el Test de Messerman mediante la colocación de rollos de algodón en la región premolar. La tercera evaluación consistió en el análisis comparativo entre ambas condiciones para determinar el efecto de la intervención oclusal. Debido a la naturaleza de la intervención, no se realizó enmascaramiento.

La recolección de datos siguió un enfoque estructurado y estandarizado para garantizar precisión en todos los participantes. La herramienta principal fue el software APECS, que identificó puntos de referencia anatómicos a partir de las fotografías, generando un informe de análisis postural indicando posibles desequilibrios.

Los datos sociodemográficos y los criterios de inclusión y exclusión fueron registrados en Microsoft Excel.

Una vez recopilados todos los datos, se realizaron análisis estadísticos descriptivos, pruebas de normalidad (test de Shapiro-Wilk) y el test de los rangos con signo de Wilcoxon para comparar los resultados pre y post intervención dentro de cada participante.

*Variables del estudio*

La variable independiente fue la condición oclusal (con y sin intervención), mientras que las variables dependientes fueron indicadores específicos y medibles del control postural estático. Las principales variables posturales incluyeron: ángulo cráneo-vertebral (ACV), alineación de hombros, inclinación pélvica y alineación corporal. Estas variables reflejan componentes clave del equilibrio, la alineación espinal y la distribución del peso.

## Resultados:

Diecinueve halterófilos adultos (58% hombres, 42% mujeres) participaron en el estudio tras aplicar los criterios de inclusión y exclusión. Las edades de los participantes oscilaron entre 19 y 38 años, con un 68% entre 19 y 29 años. La mayoría eran solteros (74%) y tenían un título universitario (63%). La mayoría de los participantes estaban empleados (63%) o eran estudiantes (32%), y casi todos (95%) eran atletas federados.

*Evaluación de las variables posturales*

Las pruebas de normalidad utilizando el Test de Shapiro-Wilk revelaron que la mayoría de las variables posturales, incluyendo inclinación de la cabeza, ángulos de rodillas y pies, y alineación corporal (frontal y sagital), no seguían una distribución normal ($p < 0,05$). Solo unas pocas variables, como el ángulo cráneo-vertebral (ACV) y el ángulo horizontal cervical (AHC), mostraron una distribución normal.

En consecuencia, se utilizó la Prueba de los Rangos con Signo de Wilcoxon para la comparación estadística (Tabla 1).

*Cambios relacionados con la intervención oclusal*

Se calcularon estadísticas descriptivas para cada variable postural bajo condiciones pre y post intervención, así como para los valores Δ (Tabla 2).

La mayoría de las variables mostraron pequeños cambios promedio entre condiciones, con algunas mostrando cambios más notorios. Entre los hallazgos más relevantes, el AHC mostró un aumento estadísticamente significativo post intervención ($p = 0,042$), con un cambio promedio de +1,39° y una mediana de 2. El ángulo LJ-Me disminuyó significativamente ($p = 0,012$), con una media de -0,74° y una mediana de 1.

En términos de Alineación Corporal, se observó un aumento significativo en el plano frontal ($p = 0,046$), con una diferencia media de +0,21°, y con una mediana de 0. El plano sagital también mostró un aumento estadísticamente significativo ($p = 0,024$), con un cambio promedio de +1,37°, aunque la mediana se mantuvo en 0.

*Comparación de las variables pre y post intervención*

Se utilizó la Prueba de Rangos con Signo de Wilcoxon para comparar las mediciones pre y post intervención, mostrando cambios notables en algunas variables, incluyendo un aumento significativo en el Ángulo Horizontal Cervical (ACV) ($p = 0,042$), una disminución significativa en el Ángulo Labio-Mentoniano (LJ-Me) ($p = 0,012$), y un aumento significativo en la Alineación Corporal, tanto en el plano frontal como en el sagital (Frontal: $p = 0,046$; Sagital: $p = 0,024$).

Todas las demás variables (ACV, SSP, PHS, PHI, Inclinación de Cabeza, Alineación de Hombros, Inclinación Pélvica, Rodillas, y Pies) no mostraron diferencias estadísticamente significativas ($p \geq 0,05$).

Estos resultados sugieren que, si bien la intervención oclusal no afectó significativamente a todos los párametros posturales, sí produjo cambios notables en la alineación craneofacial y global, particularmente en los planos posturales sagital y frontal.

**Discusión:**

El estudio tuvo como objetivo evaluar el impacto de la intervención oclusal utilizando el Test de Messerman sobre la postura estática y la estabilidad musculoesquelética en halterófilos adultos. Los hallazgos sugieren que la intervención oclusal puede conducir a cambios medibles en variables posturales específicas, lo que destaca un vínculo potencial entre la oclusión dental y la postura. Sin embargo, los efectos no fueron uniformes entre los participantes, con algunos mostrando mejoras, otros cambios mínimos y unos pocos experimentando un leve empeoramiento. Esto podría deberse a diferencias individuales en la alineación corporal y la adaptación muscular, particularmente en atletas entrenados que están acostumbrados a compensar desequilibrios.

La muestra del estudio consistió en halterófilos adultos con una distribución de género equilibrada, predominantemente atletas federados y con un alto nivel de experiencia en el entrenamiento. Esta uniformidad minimizó la variabilidad relacionada con el historial de entrenamiento y la condición física, proporcionando una perspectiva centrada sobre el efecto de la intervención oclusal en un contexto deportivo específico.

La inclusión de individuos altamente entrenados mejoró la relevancia del estudio para poblaciones atléticas.

*Ángulo cráneo-vertebral (ACV):* Un ACV normal típicamente varía entre 48-50°, lo que indica una postura de cabeza erguida y alineada. Valores por debajo de este rango indican una postura de cabeza adelantada (FHP), caracterizada por mayor extensión de la columna cervical superior y mayor flexión de la columna cervical inferior y la región torácica superior (16). Los resultados mostraron que el ACV promedio disminuyó de 57,50° (DE = 3,14) en la preintervención a 56,89° (DE = 2,78) en la postintervención, con un cambio medio de –0,61°. Este cambio indica una leve mejora, acercando la postura de la cabeza de los participantes al valor ideal. Estos hallazgos se alinean con la evidencia de que la postura cervical influye en los músculos del tronco y la alineación de la columna lumbar durante la halterofilia. Un estudio sobre la FHP demostró que una postura cervical retraída, en comparación con una postura libre o extendida, reduce la flexión de la columna lumbar y aumenta la activación de los músculos estabilizadores, incluido el esternocleidomastoideo y el erector espinal lumbar. Esto podría indicar que la intervención apoya una mecánica de levantamiento más segura al reducir la flexión cervical y mejorar la activación del esternocleidomastoideo, promoviendo una postura de cabeza más erguida (18).

*Alineación de hombros:* La alineación perfecta de los hombros se da cuando ambos están al mismo nivel, indicando simetría (16). En la preintervención, el valor promedio fue de 1,37° (DE = 1,50) y en la postintervención aumentó ligeramente a 1,53° (DE = 1,43), con un cambio de +0,16°. Esto indica que las modificaciones oclusales no afectaron significativamente la simetría de los hombros, lo que no concuerda del todo con la evidencia que sugiere que los cambios en la posición mandibular pueden mejorar la fuerza muscular del hombro, al recibir retroalimentación propioceptiva del sistema masticatorio (9). Sin embargo, este pequeño aumento en el ángulo de inclinación del hombro podría deberse a la variabilidad individual más que a un efecto consistente de la intervención.

*Inclinación pélvica:* El objetivo es que las espinas ilíacas anterosuperiores derecha e izquierda estén a la misma altura (17). En este estudio, la inclinación pélvica se mantuvo sin cambios. Tanto en la pre como en la postintervención los promedios fueron de 0,89° (DE = 1,70) y no hubo cambios estadísticamente significativos (p = 0,972). La inclinación pélvica sin cambios observada, a pesar de la intervención oclusal, puede indicar estabilidad y fuerte control postural típicamente desarrollado en halterófilos. Esto sugiere que la intervención oclusal no perturbó el control postural ya establecido, posiblemente debido a la fuerza adaptativa y la coordinación neuromuscular característica de los halterófilos entrenados (12,18).

*Alineación corporal:* El cambio más notable observado en este estudio fue en la alineación corporal, donde los participantes demostraron un aumento estadísticamente significativo en la desviación tras la intervención oclusal (p = 0,046 para el plano frontal, p = 0,024 para el plano sagital), indicando un alejamiento del valor ideal. En el plano frontal, la desviación media aumentó de 0,37° a 0,58°, y en el plano sagital, el cambio fue aún más pronunciado, con un aumento medio de 1,89° a 3,26°. Esto podría explicarse por la compleja relación entre la oclusión dental y el control postural, ya que alterar la posición mandibular puede influir en la alineación vertical del cuerpo a través de vías neuromusculares, particularmente aquellas que involucran el nervio trigémino y la columna cervical (7). Este hallazgo sugiere que la intervención oclusal podría perturbar temporalmente el equilibrio postural establecido, especialmente en halterófilos entrenados que típicamente exhiben fuertes mecanismos de compensación y estabilidad neuromuscular (7,18).

Otras variables como la inclinación de la cabeza (Δ = -0,42), el plano horizontal inferior (Δ = -0,42), la alineación de las rodillas (Δ = -0,42) y la alineación de los pies (Δ = -0,42) no mostraron significancia estadística. Sin embargo, presentaron una disminución pequeña y constante en la desviación, lo que indica un movimiento hacia los valores ideales tras la intervención oclusal. Aunque estos cambios no fueron estadísticamente significativos por sí solos, la mejora leve y constante podría sugerir que el cuerpo comenzó a ajustar su postura en respuesta a las modificaciones oclusales. Esto concuerda con investigaciones previas que señalan que la variabilidad individual juega un papel importante en cómo se realizan los ajustes posturales tras los cambios oclusales, especialmente en atletas (10).

Las mejoras observadas en rodillas y pies, aunque no significativas estadísticamente, indican que los cambios en la alineación oclusal pueden influir en la postura del tren inferior y el equilibrio al afectar la coordinación neuromuscular a través del sistema trigémino-cervical, lo que sugiere que incluso mejoras menores en la alineación podrían favorecer un mejor control postural durante tareas de levantamiento de pesas (9).

Estos hallazgos respaldan la idea de que las modificaciones oclusales, incluso como intervención a corto plazo, pueden producir efectos no solo en la mandíbula, sino en múltiples regiones del cuerpo. La mejora estadísticamente significativa en el ángulo LJ-Me, junto con mejoras leves en el CVA, la inclinación de la cabeza, el LHP, las rodillas y los pies, apoya la hipótesis de que la oclusión dental influye en la regulación del control postural estático al afectar el equilibrio y la alineación neuromuscular en diversas zonas del cuerpo.

*Limitaciones y líneas futuras*

Aunque el diseño intra-sujeto del estudio ayudó a minimizar la variabilidad interindividual, y el uso de herramientas estandarizadas y no invasivas como el software APECS y el Test de Messerman garantizó la consistencia en la recolección de datos y en la intervención oclusal, persisten ciertas limitaciones.

El tamaño reducido de la muestra (n=19) limita la generalización de los resultados, y la ausencia de un grupo control dificulta la obtención de conclusiones definitivas sobre los efectos de la intervención. Además, la falta de enmascaramiento (blinding) tanto para los participantes como para los evaluadores podría haber introducido sesgos.

A pesar de estas limitaciones, el estudio aporta información valiosa sobre la posible influencia de los ajustes oclusales en la alineación craneofacial y postural, especialmente en halterófilos. Las investigaciones futuras deberían incluir muestras más amplias y diversas, adoptar diseños controlados aleatorizados, e implementar estrategias de enmascaramiento. Asimismo, explorar los efectos a largo plazo e incorporar evaluaciones posturales dinámicas podría ayudar a esclarecer aún más el papel de la oclusión en el rendimiento deportivo y la regulación postural.

**Conclusión:**

Los hallazgos indican que, si bien las intervenciones oclusales pueden llevar a cambios medibles en algunas variables posturales, su impacto general en la estabilidad postural es limitado. La evaluación basal reveló que incluso los halterófilos bien entrenados pueden presentar desequilibrios posturales bajo condiciones estáticas. El estudio demostró que las intervenciones oclusales utilizando el Test de Messerman pueden afectar positivamente la alineación del tronco superior, pero el efecto en la alineación espinal es menos favorable. Además, la intervención oclusal mostró un efecto positivo limitado en el equilibrio, pero no produjo mejoría en la distribución del peso, y tuvo un efecto negativo en la postura espinal.

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***Tabla 1:*** *Prueba de Normalidad para las Condiciones Pre, Post, y Δ (Shapiro-Wilk)*

| | Estatístico | df | Sig. |
|---|---|---|---|
| **ACV Pre** | 0,926 | 19 | 0,144 |
| **ACV Post** | 0,963 | 19 | 0,640 |
| **ACV Δ** | 0,892 | 19 | 0,035 |
| **AHC Pre** | 0,946 | 19 | 0,336 |
| **AHC Post** | 0,943 | 19 | 0,302 |
| **AHC Δ** | 0,842 | 19 | 0,005 |
| **SSP Pre** | 0,902 | 19 | 0,053 |
| **SSP Post** | 0,914 | 19 | 0,088 |
| **SSP Δ** | 0,814 | 19 | 0,002 |
| **PHS Pre** | 0,832 | 19 | 0,004 |
| **PHS Post** | 0,842 | 19 | 0,005 |
| **PHS Δ** | 0,919 | 19 | 0,109 |
| **PHI Pre** | 0,844 | 19 | 0,005 |
| **PHI Post** | 0,850 | 19 | 0,007 |
| **PHI Δ** | 0,959 | 19 | 0,561 |
| **PV Pre** | 0,859 | 19 | 0,009 |
| **PV Post** | 0,877 | 19 | 0,019 |
| **PV Δ** | 0,959 | 19 | 0,558 |
| **LJ-Me Pre** | 0,884 | 19 | 0,025 |
| **LJ-Me Post** | 0,715 | 19 | <0,001 |
| **LJ-Me Δ** | 0,864 | 19 | 0,011 |
| **Inclinación de la Cabeza Pre** | 0,894 | 19 | 0,037 |
| **Inclinación de la Cabeza Post** | 0,844 | 19 | 0,005 |
| **Inclinación de la Cabeza Δ** | 0,793 | 19 | <0,001 |
| **Inclinación de la Hombros Pre** | 0,818 | 19 | 0,002 |
| **Inclinación de la Hombros Post** | 0,882 | 19 | 0,023 |
| **Inclinación de la Hombros Δ** | 0,823 | 19 | 0,003 |
| **Inclinación Pélvica Pre** | 0,753 | 19 | <0,001 |
| **Inclinación Pélvica Post** | 0,715 | 19 | <0,001 |
| **Inclinación Pélvica Δ** | 0,949 | 19 | 0,376 |
| **Rodillas Pre** | 0,831 | 19 | 0,003 |
| **Rodillas Post** | 0,713 | 19 | <0,001 |
| **Rodillas Δ** | 0,883 | 19 | 0,025 |
| **Pies Pre** | 0,836 | 19 | 0,004 |
| **Pies Post** | 0,764 | 19 | <0,001 |
| **Pies Δ** | 0,918 | 19 | 0,106 |

| | | | |
|---|---|---|---|
| **Alineación Corporal (Frontal) Pre** | 0,616 | 19 | <0,001 |
| **Alineación Corporal(Frontal) Post** | 0,751 | 19 | <0,001 |
| **Alineación Corporal (Frontal) Δ** | 0,507 | 19 | <0,001 |
| **Alineación Corporal (Sagittal) Pre** | 0,612 | 19 | <0,001 |
| **Alineación Corporal (Sagittal) Post** | 0,716 | 19 | <0,001 |
| **Alineación Corporal (Sagittal) Δ** | 0,568 | 19 | <0,001 |

***Tabla 2:*** *Estadísticos descriptivos para las condiciones Pre, Post y Δ*

| | N Válido | Media | DE | Mediana | Percentil 25 | Percentil 75 | Mínimo | Máximo |
|---|---|---|---|---|---|---|---|---|
| **ACV Pre** | 19 | 57,50 | 3,14 | 58,00 | 55,00 | 60,00 | 53,00 | 63,00 |
| **ACV Post** | 19 | 56,89 | 2,78 | 56,50 | 55,50 | 58,50 | 52,00 | 62,00 |
| **ACV Δ** | 19 | -0,61 | 1,90 | -0,50 | -2,00 | 1,00 | -3,50 | 2,00 |
| **AHC Pre** | 19 | 10,11 | 7,20 | 10,00 | 3,00 | 15,00 | 0,00 | 24,00 |
| **AHC Post** | 19 | 11,50 | 6,18 | 11,00 | 6,00 | 15,00 | 2,00 | 22,00 |
| **AHC Δ** | 19 | 1,39 | 4,49 | 2,00 | -0,50 | 4,00 | -13,00 | 7,00 |
| **SSP Pre** | 19 | 9,97 | 6,89 | 9,50 | 5,00 | 13,50 | 1,00 | 25,00 |
| **SSP Post** | 19 | 10,71 | 8,26 | 9,00 | 3,00 | 18,00 | 1,00 | 26,00 |
| **SSP Δ** | 19 | 0,74 | 5,82 | -2,00 | -3,00 | 3,00 | -6,00 | 15,50 |
| **PHS Pre** | 19 | 1,26 | 1,33 | 1,00 | 0,00 | 2,00 | 0,00 | 5,00 |
| **PHS Post** | 19 | 1,42 | 1,39 | 1,00 | 0,00 | 3,00 | 0,00 | 4,00 |
| **PHS Δ** | 19 | 0,16 | 1,17 | 0,00 | -1,00 | 1,00 | -2,00 | 2,00 |
| **PHI Pre** | 19 | 1,42 | 1,57 | 1,00 | 0,00 | 3,00 | 0,00 | 5,00 |
| **PHI Post** | 19 | 1,00 | 0,94 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **PHI Δ** | 19 | -0,42 | 2,12 | 0,00 | -2,00 | 1,00 | -5,00 | 3,00 |
| **PV Pre** | 19 | 2,11 | 2,26 | 1,00 | 0,00 | 4,00 | 0,00 | 7,00 |
| **PV Post** | 19 | 2,74 | 1,97 | 3,00 | 1,00 | 3,00 | 0,00 | 7,00 |
| **PV Δ** | 19 | 0,63 | 2,81 | 0,00 | -1,00 | 3,00 | -4,00 | 6,00 |
| **LJ-Me Pre** | 19 | 1,47 | 1,31 | 1,00 | 0,00 | 2,00 | 0,00 | 4,00 |
| **LJ-Me Post** | 19 | 0,74 | 1,10 | 0,00 | 0,00 | 1,00 | 0,00 | 4,00 |
| **LJ-Me Δ** | 19 | -0,74 | 1,10 | -1,00 | -2,00 | 0,00 | -2,00 | 1,00 |
| **Inclinación de la Cabeza Pre** | 19 | 1,58 | 1,39 | 1,00 | 0,00 | 3,00 | 0,00 | 5,00 |
| **Inclinación de la Cabeza Post** | 19 | 1,16 | 1,12 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Inclinación de la Cabeza Δ** | 19 | -0,42 | 1,43 | 0,00 | -1,00 | 1,00 | -5,00 | 1,00 |
| **Inclinación de la Hombros Pre** | 19 | 1,37 | 1,50 | 1,00 | 0,00 | 2,00 | 0,00 | 4,00 |
| **Inclinación de la Hombros Post** | 19 | 1,53 | 1,43 | 1,00 | 0,00 | 2,00 | 0,00 | 5,00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Inclinación de la Hombros Δ** | 19 | 0,16 | 0,90 | 0,00 | 0,00 | 1,00 | -2,00 | 1,00 |
| **Inclinación Pélvica Pre** | 19 | 0,89 | 1,15 | 0,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Inclinación Pélvica Post** | 19 | 0,89 | 1,29 | 0,00 | 0,00 | 1,00 | 0,00 | 4,00 |
| **Inclinación Pélvica Δ** | 19 | 0,00 | 1,70 | 0,00 | -1,00 | 1,00 | -3,00 | 3,00 |
| **Rodillas Pre** | 19 | 0,89 | 0,94 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Rodillas Post** | 19 | 0,47 | 0,61 | 0,00 | 0,00 | 1,00 | 0,00 | 2,00 |
| **Rodillas Δ** | 19 | -0,42 | 1,02 | 0,00 | -1,00 | 0,00 | -2,00 | 2,00 |
| **Pies Pre** | 19 | 1,11 | 1,10 | 1,00 | 0,00 | 2,00 | 0,00 | 3,00 |
| **Pies Post** | 19 | 0,68 | 0,89 | 0,00 | 0,00 | 1,00 | 0,00 | 3,00 |
| **Pies Δ** | 19 | -0,42 | 1,30 | 0,00 | -1,00 | 0,00 | -3,00 | 3,00 |
| **Alineación Corporal (Frontal) Pre** | 19 | 0,37 | 0,50 | 0,00 | 0,00 | 1,00 | 0,00 | 1,00 |
| **Alineación Corporal(Frontal) Post** | 19 | 0,58 | 0,69 | 0,00 | 0,00 | 1,00 | 0,00 | 2,00 |
| **Alineación Corporal (Frontal) Δ** | 19 | 0,21 | 0,42 | 0,00 | 0,00 | 0,00 | 0,00 | 1,00 |
| **Alineación Corporal (Sagittal) Pre** | 19 | 1,89 | 3,33 | 1,00 | 0,00 | 2,00 | 0,00 | 14,00 |
| **Alineación Corporal (Sagittal) Post** | 19 | 3,26 | 4,58 | 2,00 | 0,00 | 4,00 | 0,00 | 17,00 |
| **Alineación Corporal (Sagittal) Δ** | 19 | 1,37 | 3,11 | 0,00 | 0,00 | 2,00 | -1,00 | 13,00 |

***Figura 1:*** *Diagrama de flujo CONSORT 2025*