STUDY PROTOCOL WITH STATISTICAL ANALYSIS PLAN

Official Study Title:
Determination of the Degree of Dynamic Stability of the Foot in Single-leg Support in Relation to the Foot Posture Index in Judokas

NCT Number: *To be assigned*

Document Date: January 26, 2023

Ethics Committee Approval:
Catholic University of Valencia San Vicente Mártir
Protocol Code: UCV/2022-2023/111

Principal Investigator:
Juan Carlos Parada Souto
Catholic University of Valencia San Vicente Mártir
Faculty of Medicine and Health Sciences
Valencia, Spain

Co-Investigator:
Raúl Gallego Estévez
Catholic University of Valencia San Vicente Mártir
Faculty of Medicine and Health Sciences
Valencia, Spain

ABSTRACT

Background

Judo is the most practiced individual sport in Spain, with approximately 97,000 licenses. One of the fundamental aspects of standing judo consists of knocking down an opponent to make them fall on their back. Maintaining good balance is essential not only for adequate sports performance but also to avoid possible injuries. However, studies describing the dynamic stability of judokas are very scarce, and they do not provide specific or detailed data. Therefore, through this work, we aim to update and increase knowledge about the stability of judokas.

Hypothesis

Judokas who present a neutral foot determined by the Foot Posture Index-6 (FPI-6) will have a greater degree of dynamic stability in single-leg support during the specific techniques of their sport, being able to adapt to different sporting situations during practice, compared to those who present a pronated or supinated foot.

Objectives

Primary Objective: To analyze the degree of dynamic stability through the Y Balance Test (YBT) in judokas according to the type of foot they present, determined by the FPI-6.

Secondary Objectives:

1. To analyze the relationship between the modification of dynamic stability and different sociodemographic variables.
2. To relate injury history with stability in the lower limbs.
3. To determine if there are significant differences in dynamic stability regarding the habitual support foot in the development of specific sports techniques.

Methods

This is a cross-sectional observational study with quantitative methodology conducted on judokas from the Galician provinces of A Coruña and Pontevedra. A sample of 45 participants will be selected. The dynamic stability of participants will be compared through the Y Balance Test in relation to the type of foot determined by the Foot Posture Index.

Expected Outcomes

The study will provide data on dynamic stability in judokas according to foot posture type, contributing to understanding biomechanical factors that may influence sports performance and injury risk in this population.

Keywords: Judo, lower limb, stability, Foot Posture Index, Y Balance Test, dynamic stability, sports biomechanics

1. INTRODUCTION

1.1. Theoretical Framework

1.1.1. History of Judo

Judo, or "the gentle way" in Japanese, is a martial art and Olympic sport that includes standing fighting (tachi-waza) and ground fighting (ne-waza)[1]. It was born at the end of the 18th century by Jigoro Kano in Japan. He began his journey in martial arts practicing ju-jitsu, but due to his thinness and lack of strength, he saw his sports practice limited. This led him to modify the techniques of this sport to take advantage of the opponent's strength more efficiently and better adjust to his physical condition, thus creating judo.

Judo entered the men's Olympic program in 1964 as a demonstration sport and officially in 1972. It was not until 1992 that it began to form part of the women's Olympic agenda [1]. It is the 6th most practiced sport in Spain with 97,000 licenses (2020 data), and almost 9,000 in Galicia alone, making this sport one of the most practiced in the country.

1.1.2. Development of Judo

It is a sport practiced by more than 10 million people worldwide, where two types of competitions are held: individually through combat and in pairs with kata. Individual competition consists of 4-minute combats, where two situations can be found during the dynamics: standing judo and ground judo. The combat begins standing, and due to the evolution of the fight (opponent's takedown or fall of judokas on the mat), it can continue on the ground. Each time the combat is stopped (due to lack of continuity, sanctioning one of the competitors, or reviewing some situation), it will resume with standing judo.

The objective in standing judo is to knock down an opponent of the same weight category, causing loss of balance through grips, displacements, and offensive and/or defensive actions. In ground judo, the judoka must try to control the opponent's body for a certain time or make them give up through segmental control (strangulation or dislocation) [2].

If no score is achieved in the regulatory time, golden score time begins, where the first to score wins the combat.

When speaking of standing judo techniques, four groups are differentiated:

- **Te-waza:** Arm techniques where the objective is to unbalance the opponent by leveraging through the shoulder/arm.
- **Koshi-waza:** Through the hip, the opponent is lifted with the objective of making them lose contact with the ground.
- **Ashi-waza:** Leg techniques, where the takedown is performed through leg movements (divided into sweeps, reaps, and blocks).
- **Sutemi-waza:** So-called sacrifice techniques, where the tori (judoka executing the technique) must throw themselves to the ground for the uke (judoka on whom the technique is performed) to fall on the mat.

The circle of equilibrium is the area in which the judoka's posture can be disturbed and they will always be able to return to their initial position. When performing a judo technique, the first step the tori takes is an unbalancing through arm and body movement on the uke to take them out of this circle of equilibrium. Once this unbalancing has been carried out, it is the moment when the tori performs the technique to throw the uke[2].

Scoring in standing judo depends on the contact of the opponent's back with the mat when a technique is performed. If the contact is with the complete back, an ippon is achieved (10 points) and the combat is automatically won; however, if the contact is not with the entire back but with a part of it, a waza-ari is achieved (1 point). Two waza-aris from the same judoka become an ippon.

Initially, judo competitions did not distinguish by weight, creating a disadvantage for lighter judokas. With the evolution of judo, competitions now differentiate by age, weight, and sex.

1.1.3. Equipment

Practice is carried out with the judogi, attire for judo practice. It consists of a thick cotton jacket (uwagi), pants (shitabaki), and a belt (obi). When competing, to avoid referee confusion, one will wear a white judogi (the traditional color) and another will wear a blue one. The belt indicates the athlete's degree of learning, with the white belt being the first and the highest being the black belt (1st DAN) [1].

1.1.4. Benefits of Judo

One of the main objectives of promoting a healthy lifestyle is increasing the level of physical activity that citizens regularly practice, with the aim that these habits positively influence the physical and psychological condition of the population [5].

The sedentary lifestyle is one of the problems that most concern the childhood stage; children increasingly perform less physical activity and spend more time in front of multimedia screens. To reverse this situation, the WHO (World Health Organization) recommends daily activity to maintain children's psychophysical health [6].

The main benefit of judo is that it is a sport that can be practiced at any age. Its practice at early ages (between 4 and 12 years) has a more recreational function, where the pressure to achieve objectives is much less or nonexistent compared to adult ages, which makes the risk of injury diminished [6].

The practice of martial arts has a large number of benefits. On one hand, there is an improvement in physical condition, common to the vast majority of sports, necessary for good development of sports activity and performance improvement. Various studies affirm that this practice improves the teaching of self-control, self-esteem, increases positive response to physical challenges, and induces greater emotional stability, self-confidence, and assertiveness. It has also been shown to improve concentration in children and self-awareness, as well as cognitive self-regulation [7].

These benefits are related to increased levels of certain hormones, such as oxytocin during sports practice, which increases motivation, empathy, or recognition of emotions, essential for both physical and mental growth of athletes [8,9]. Through the practice of judo or other martial arts, an increase in levels of immunoglobulin A, cortisol, or testosterone is generated, although these are subject to a psychological factor [10].

1.1.5. Biomechanics of Judo

Success in sport depends on athletes' ability to achieve and maintain high levels of perceptual, psychological, cooperative, and conditioning decision-making during competition. Martial arts are cooperative, conditional, and complex, and are based on a variety of skills (i.e., strength, power, aerobic endurance, agility) and aptitudes (i.e., coordination and perceptual decision-making) [2].

During combats, judokas perform great physical efforts that require great muscular strength, optimal range of motion of joints, and maintaining different postures to attack or defend. These skills require postural stability, not only for greater sports performance but to avoid injuries due to lack of balance [13].

The biomechanics of judo will be conditioned by the technique that will be carried out, where both extremities can perform the same movement or one the opposite of the other, although both will always be coordinated.

A large number of factors can influence an athlete's stability during the execution of a specific task of their sport, among which biomechanical and anthropometric factors, control of the progression of the center of mass in a dynamic or static situation, and the support surface stand out. For this, athletes use different movement strategies to stabilize themselves when initiating a voluntary action, reacting to perturbations caused by unexpected external forces, or anticipating a destabilizing force. All these actions are controlled by the central nervous system, giving greater influence to information from visual, vestibular, and proprioceptive receptors, and executing a musculoskeletal response adapted to the characteristics of the situation [2].

Postural control is essential in combat sports, especially in those where grip is fundamental (such as judo, sambo, or Olympic freestyle wrestling), because success in these sports is based mainly on preserving the center of mass within the base of support that changes continuously, so that from a stable position specific skills can be executed and cause the opponent's loss of balance. Voluntary regulation of the center of gravity in a determined direction is essential both when performing an attack and a defense [2].

The judoka's stability is in continuous change during a combat due to rapid changes in the center of gravity as a consequence of the opponent constantly trying to disturb the judoka's balance to knock them down; in turn, the judoka is also moving their center of mass continuously to try to attack their opponent. This generates modifications in the judoka's base of support, causing them to combine bipodal support with single-leg support to achieve greater balance [13].

In judo, stability will be conditioned by the tractions and thrusts exerted by the upper limb in all directions (antero-posterior, medio-lateral, supero-inferior, rotational, and their variations). These perturbations performed on the upper extremity cause the athlete to change their habitual support strategy, where these alterations must be cushioned by the trunk and lower limbs [2].

Although all body musculature is trained in judo, the core is one of the structures that must be most trained. It is formed by the lumbopelvic complex, the spine, hips and pelvis, proximal lower limbs, and abdominal structures. Its training will improve the ability to control trunk movement over the pelvis and leg to allow optimal production, transfer, and control of force and movement to the terminal segment integrated into specific activities [14].

Core strengthening will not only improve the sports level, through improved balance during attack and defense, but will also reduce the risk of injuries and improve the judoka's body posture both at the sports level and in daily life. Core training is included in injury prevention programs such as anterior cruciate ligament rupture, given that dynamic movement of the trunk and hip joint biomechanically affects the knee joint during physical activities. Neuromuscular control deficits in the trunk and hip joint could increase the risk of anterior cruciate ligament injury [15].

Within all this complexity, it should be indicated that stability in the confrontation depends on the interaction between the judokas, their position during sports activity, and their communication through the grip, reaching situations where the body's center of gravity can be located outside the base of support of one or even both judokas [2].

1.1.6. Epidemiology of Judo

As a result of the literature review, it was not possible to adopt a standardized definition of either injury or its severity. As a MeSH term, injuries are defined as damage inflicted on the body with direct result of an external force, with or without interruption of structural continuity. However, during the Olympic Games, any alteration in which an athlete received medical attention for a recent injury or a new injury after full participation was included as injuries, including injuries in competition or during training [1].

To protect athletes' health, the International Olympic Committee initiated and developed an injury and illness monitoring system during the Beijing 2008 and London 2012 Olympic Games, where the most common and serious injuries would be collected. The objective was to identify the main sports alterations to ensure new knowledge about injury trends over time to thus form the basis for future research on injury mechanisms and finally develop injury prevention programs [1].

The lower extremity is the body region that suffers the most injuries in sport in general terms [16], with the ankle being the joint most likely to suffer damage (around 50% of sports injuries correspond to the tibioperoneal-astragalar mortise), followed by cerebral concussions and anterior cruciate ligament injuries [17].

Around 20% of hospital emergencies correspond to sports injuries, of which judo is the martial art that collects the most, in which 56% of athletes have suffered at least one, where the highest percentage of injuries focuses on the elbow and shoulder, followed by karate and wushu, where the main injuries found are ankle sprains and joint injuries[18].

The prevalence of injuries in judo varies depending on the study. At the Beijing 2008 and London 2012 Olympic Games, there was a prevalence of 11.2-12.3% of injuries in more than 380 participants, although other studies increase this prevalence to 23-29% or 1.18 injuries per year in each athlete. These discrepancies are due to the different levels of judokas who participated in the studies and the definition of injury used in each of them. There is no consensus regarding a higher prevalence of injuries in relation to sex or the moment of injury (training or competition) [1].

The body regions most affected by injuries are the hand/fingers, knee, and shoulder in that order. As previously explained, these values depend on the definition used in the studies and the level of judokas; therefore, some studies identify finger injuries as the most frequent in competition due to gripping in combats, and others do not include them as injuries. In children, injuries focus on the shoulder, ankle, and elbow in that order. There are no differences in the causes of injuries between sexes [1].

85% of injuries occur in standing judo compared to ground judo, mainly because more time is spent in this part of the combat, where the grip struggle constitutes one of the main risk factors (finger injury is described as the most frequent in some studies). The fall is the situation that comprises the most injuries, around 70%, associated with the risk that judokas assume to not fall with their back and thus lose the combat; also, the lack of ability to fall is associated with an increase in both acute and chronic injuries [1].

As previously indicated, there are no significant differences in the cause of injuries in relation to sex or age; however, women have a higher injury prevalence in ground judo. Loss of balance when throwing the opponent also constitutes one of their main causes. These reasons are common to males between 10 and 19 years; from 20 years on, the fall constitutes the main risk factor for them. Seoi Nage techniques (leverage applied with variable arm) are the techniques with the highest risk of shoulder and knee injury, with incorrect technique being the main injury mechanism [1].

Knee injuries, such as anterior cruciate ligament rupture or sprains, are mainly caused by leg techniques such as O Soto Gari, where the violence with which the techniques are performed also influences. Ankle injuries correspond in most cases to sprains of the external ligaments caused by varus torsion [1].

Compared to other Olympic wrestling sports, judo has a shorter injury recovery time than others like taekwondo, although longer than boxing or freestyle wrestling [1].

Several studies have been conducted that highlight that functional taping is the most effective method to prevent injuries in sport along with orthopedic elements [19], a prevention method carried out by a large number of judokas. But this means has several disadvantages: not only does it limit the range of motion of the joint, but it increases the mechanical demand on the rest of the proximal joints, increasing the risk of injuries on them [20].

One of the main areas of greatest risk when applying an ankle taping is the knee; fixation of the tibioperoneal-astragalar (TPA) joint increases tension on the triceps surae (gastrocnemius and soleus), generating greater knee valgus, thus increasing the probability of suffering an injury to it [21].

Both proprioception training and muscular strength training of the lower extremities improve athletic performance and raise the skill level of athletes in maintaining posture in taekwondo. Therefore, the application of these methods in taekwondo training programs has a positive effect on improving competitive performance in these athletes. In particular, the findings confirm that conscious effort to perform the posture with the load applied on the forefoot is related to maintaining balance when performing the posture at the single-leg level [22]. Due to the similarity of both sports, this condition can also be applied to judo.

Due to the presence of all the threats that the judoka's stability must face in a combat, it is not surprising that examination of postural care in judo generates great interest. Previous studies indicate a relationship between the ability to maintain posture and the sports performance achieved in a competition, with performance evaluation based on ranking criteria and levels of activity and competitive effectiveness. When cohorts of judokas were compared with control groups that did not practice physical activity, it was observed that judokas obtained better results by relying more on proprioceptive information. It is this reliance on vestibular and proprioceptive information that makes these athletes obtain greater stability than in other sports such as dance or swimming [23-25].

1.1.7. Foot Posture Index

Variations in foot posture influence lower extremity function and therefore can generate a greater predisposition to suffer overuse injuries [26]. Overuse is defined as excessive force repeatedly applied over a tissue, making it unable to cope with mechanical stress through natural mechanisms of physiological adaptation or tissue repair [27]. This mechanical stress on tissues, of repetitive nature but always below their rupture threshold, leads to the development of a type of injury known as overuse injuries [28].

The Foot Posture Index (FPI-6) is a tool used both clinically and in research. It has been used in studies to determine the biomechanical factors causing neuropathic ulcers in diabetic patients, to determine inclusion and exclusion criteria, or to associate sports injuries with foot types [26].

The FPI-6 is a validated test that allows determining the postural index of the foot in a quick, simple, and reliable way through palpation and visual inspection of 6 items: palpation of the talar head, supra and inframaleolar curvature, relaxed calcaneal position in support, navicular prominence, congruence of the medial longitudinal arch (MLA), and the degree of adduction/abduction of the forefoot relative to the rearfoot [29].

Each of these parameters is assessed on a 5-point scale, ranging from -2 to +2, with -2 corresponding to a high supination position, 0 a neutral position, and +2 a maximum pronation position. The FPI-6 value is given by the sum of all the values obtained, providing values between -12 and +12; these measurements must be performed on both feet. Those feet with an FPI-6 from -12 to -5 will be classified as highly supinated, from -4 to -1 as supinated, from 0 to +5 as neutral, from +6 to +9 as pronated, and from +10 to +12 as highly pronated [29,30].

According to Cheung RTH et al. [30], a meta-analysis studying the efficacy of external controls for overpronation, foot pronation involves multiple joint movements in the rearfoot and midfoot, which are necessary for optimal movement and shock absorption during the initial and mid-phase of gait; however, people with excessive foot pronation are vulnerable to injuries both distally (metatarsal pathologies or fasciopathies) or proximally (patellofemoral pain) in the lower extremity.

Although the evidence is not conclusive, MLA characteristics have been discussed as possible factors contributing to overuse injuries of the lower extremity. Feet with a higher MLA have less shock absorption capacity, associating this characteristic with a higher incidence of ankle injuries, bone injuries (mainly in tibia or femur), or on the lateral side of the lower extremity. Conversely, a decreased MLA is more prone to relate to soft tissue injuries and on the medial side of the lower extremity [31].

High positive values on the FPI-6, which classify the foot as a pronated foot, are related to overuse pathologies in the lower extremity and the appearance of osteoarthritis in the knee [32].

Those feet considered supinated through the FPI-6 will have altered stability, where the presence of an elevated arch height and increased ankle inversion force are related to a decrease in postural stability in single-leg support [33].

Koyama K et al. [34] studied how judo affects foot structure. It was found that after specific judo training, the foot arch was lower compared to a healthy population of the same characteristics who did not practice judo, with judokas presenting greater strength in the toe flexor and also superior foot arch dynamics. In this way, it was possible to affirm that specific judo training can affect force generation capacity, morphological structure, and foot arch function.

1.1.8. Dynamic Stability

From the biomechanical point of view, balance arises from the interaction of external forces acting on the body and internally generated movements to prevent falls and maintain body posture [35].

When speaking of stability, we must speak of two different types: postural stability and dynamic stability. The first is defined as the ability to remain close to a desired body position, without falling or taking a step (i.e., maintaining balance), under brief perturbations of external forces and spontaneous changes in intrinsic body states [36].

Dynamic stability is known as the ability to conserve a stable static condition on a base of support after a dynamic transition (i.e., after a movement). Since judo is a sport in which continuous displacements and variations of the center of gravity are performed, this study will focus on performing an analysis of dynamic stability.

Work on postural control and balance is fundamental to avoid falls and decrease the risk of pathologies, affecting both the childhood and adult stages [37].

Postural control requires maintaining an upright posture, requiring correct motor behavior. Maintaining this depends on the integration of sensory inputs from the vestibular, visual, and proprioceptive systems; if one or more of these components are compromised, muscles are activated to reduce oscillations and maintain postural balance [38].

Proprioceptive sensory receptors, located in the skin, muscles, joints, tendons, and ligaments, are responsible for sending the information provided by these structures to the central nervous system. This information is complemented by that provided by the visual system and vestibular system to maintain balance and body position. For this reason, when an injury occurs, the mechanoreceptors of the affected region can be damaged and cause some tissues to lose their function and thus reduce their proprioceptive capacity [39].

The main cause of falls in the population is lack of balance, generated by lack of postural control that increases with advancing age by presenting less postural stability (hunched posture, greater muscular coactivation, and postural sway). An improvement in posture of an ascending character (i.e., improving stability and balance of the lower extremity initially) can decrease excessive muscular coactivation and thus improve balance not only in older adults but in the general population, including athletes [40].

In medical evaluations, postural control analyses are recurrent to assess injury risk, initial injury deficits, and the level of improvement after intervention for an injury. This postural control is necessary to maintain during statics and during movement. Musculoskeletal pathological conditions of the lower extremities are generally associated with deficits in postural and neuromuscular control [41].

Dynamic stability allows expected movement around a base of support, such as jumping or moving to a new location and immediately attempting to maintain posture or perform the movement without compromising the established base of support [41].

One of the tests that has gained notoriety in clinical settings and research is the Star Excursion Balance Test (SEBT), a dynamic stability test tool for rehabilitation in which, through a series of single-extremity squats, the unsupported extremity is used to reach maximum distance at 8 different points designated on the ground. The objective of this test is for the individual to establish a stable base of support on the posture extremity in the middle of the test grid and maintain it through a maximum reach excursion in one of the prescribed directions [41].

This test is used to determine the extent of an injury in the lower extremity, in which the patient is asked to perform the test while in single-leg support on the affected extremity to maintain balance, finding a deficit in reach distances, indicating a limitation in dynamic stability associated with the pathological condition [41].

Patients and athletes suffer injuries both for the first time and of a repetitive nature, so physicians must identify injury risk and determine if patients have recovered a level of dynamic and postural control that minimizes injury risk when they return to sports practice. Dynamic stability tests such as the SEBT or Y Balance Test (YBT) can help determine if the patient possesses optimal or symmetrical values of this. This test can be used as a marker of normalization of neuromuscular control for return to play after an injury [41].

As just mentioned, these tests can be used to identify individuals at higher risk of injury and reduce future sports injuries. By requiring strength, flexibility, neuromuscular control, core stability, wide range of joint mobility, balance, and proprioception for its performance, it is an excellent test for pre-participation physical and clinical examinations, since finding any of these components defective would cause a defective test [41].

A study carried out on soccer players by Yu N et al. [39] concludes that through the combination of proprioceptive training with ankle muscular strength training, dynamic and static stability can be improved and thus decrease the risk of ankle injuries in players. They also indicate that the stability of martial arts athletes decreases in the antero-posterior direction.

1.2. Study Justification

Through the literature search carried out for this study, no research has been found that relates dynamic stability of the lower limb in judokas with the type of foot they present. Although there are multiple studies about injuries in this sport or foot posture and its relationship with injuries, they do not analyze how the type of foot influences the balance of athletes.

Balance and stability are essential for good sports performance and injury prevention, especially in a sport like judo where continuous changes in the center of gravity and the base of support occur. Understanding how foot posture affects dynamic stability could provide valuable information for:

- Improving training programs
- Developing specific injury prevention strategies
- Optimizing sports performance
- Guiding orthopedic interventions when necessary

This study aims to fill this gap in the scientific literature and provide practical information for coaches, podiatrists, and sports medicine professionals working with judokas.

Additionally, the Y Balance Test has proven to be a reliable and valid tool for assessing dynamic stability in various sports populations, but its application and normative values in judokas remain limited. This study will contribute to expanding the knowledge base about dynamic stability assessment in this specific population.

2. HYPOTHESIS

2.1. Conceptual Hypothesis

Judokas who present a neutral foot determined by the FPI-6 will have a greater degree of dynamic stability in single-leg support during the specific techniques of their sport, being able to adapt to different sporting situations during practice, compared to those who present a pronated or supinated foot.

2.2. Statistical Hypotheses

Hypothesis H1 (Primary):

- **Null hypothesis (H0):** There is no relationship between foot posture type (determined by FPI-6) and dynamic stability (measured by YBT).
- **Alternative hypothesis (H1):** There is a relationship between foot posture type and dynamic stability.

Hypothesis H2 (Secondary 1):

- **Null hypothesis (H0):** There is no relationship between dynamic stability and sociodemographic variables (sex, age, weight category).
- **Alternative hypothesis (H1):** There is a relationship between dynamic stability and sociodemographic variables.

Hypothesis H3 (Secondary 2):

- **Null hypothesis (H0):** There is no relationship between injury history and lower limb stability.
- **Alternative hypothesis (H1):** There is a relationship between injury history and lower limb stability.

Hypothesis H4 (Secondary 3):

- **Null hypothesis (H0):** There are no significant differences between the habitual support foot and the non-habitual support foot in the development of specific sports techniques.

- **Alternative hypothesis (H1):** There are significant differences between the habitual support foot and the non-habitual support foot in the development of specific sports techniques.

3. OBJECTIVES

3.1. Primary Objective

To analyze the degree of dynamic stability through the Y Balance Test (YBT) in judokas according to the type of foot they present, determined by the Foot Posture Index-6 (FPI-6).

3.2. Secondary Objectives

1. To analyze the relationship between the modification of dynamic stability and different sociodemographic variables (sex, age, weight category).

2. To relate injury history (neck, back, hip, or rest of the lower extremity) with dynamic stability in the lower limbs.

3. To determine if there are significant differences in dynamic stability regarding the habitual support foot (dominant foot) versus the non-habitual support foot (non-dominant foot) in the development of specific single-leg sports techniques.

4. MATERIALS AND METHODS

4.1. Bibliographic Search Criteria

The bibliographic search was conducted during the first week of work. It aimed to gather all available information on lower limb stability during sports practice in judo. To collect the maximum available information, no temporal limits or publication type limits were applied; regarding language, only articles in Spanish or English were included.

The search strategy included the following databases:

- PubMed/MEDLINE
- Scopus
- Web of Science
- SPORTDiscus
- Google Scholar

Search terms used:

- Judo AND (stability OR balance)
- Judo AND (lower limb OR lower extremity)
- Judo AND injuries
- Foot Posture Index AND (stability OR balance)
- Y Balance Test AND athletes
- Dynamic stability AND martial arts

4.2. Study Design

4.2.1. Type of Design

Cross-sectional observational study with quantitative methodology.

On January 26, 2023, the Research Ethics Committee of the Catholic University of Valencia approved the conduct of the study "Determination of the degree of dynamic stability in single-leg support in relation to the Foot Posture Index in judokas" with project code UCV/2022-2023/111.

4.2.2. Study Setting

The study will be carried out in judo centers in the Galician provinces of A Coruña and Pontevedra, Spain.

4.2.3. Study Population

Federated judokas who train regularly in judo clubs in the provinces of A Coruña and Pontevedra.

4.2.4. Study Period

Recruitment period: February 1, 2023 to February 15, 2023

Data collection period: March 1, 2023 to May 23, 2023

Total duration: Approximately 4 months

4.2.5. Selection Criteria

4.2.5.1. Inclusion Criteria

Participants must meet ALL of the following criteria to be included:

1. Federated judokas (holding a valid judo federation license)
2. Age between 10 and 40 years
3. Training at least 2 hours per week
4. At least 1 year of federated experience in judo
5. Willing to participate and sign informed consent (or parental consent for minors under 18 years, with assent for those 14-17 years old)

4.2.5.2. Exclusion Criteria

Participants will be excluded if they present ANY of the following:

1. Current lower limb injury that prevents normal sports practice
2. Lower limb surgery in the last 12 months
3. Neurological pathologies affecting balance or coordination
4. Vestibular disorders
5. Visual impairments not corrected by lenses that affect balance
6. Inability to understand or follow study instructions
7. Refusal to sign informed consent
8. Pregnancy (for female participants)
9. Use of orthopedic devices (orthoses, braces) during judo practice that cannot be temporarily removed for testing

4.2.6. Sample Size

The sample size was determined using the GPower software (Erdfelder, Faul, Buchner, 1996), using as reference a similar study by Cote KP et al.[45] to identify the true difference in dynamic stability score means in the 3 foot types.

Sample size calculation parameters:

- Statistical test: ANOVA (one-way)
- Effect size (f): 0.40 (medium effect)
- Alpha (α): 0.05 (significance level)
- Power (1-β): 0.95 (95% power)
- Number of groups: 3 (neutral, pronated, supinated foot)

Calculated sample size: 42 participants

Adjusted for expected losses (15%): 45 participants total (15 per group)

Distribution: 15 participants with neutral foot, 15 with pronated foot, 15 with supinated foot.

Although the sample size is estimated over the total population of Galicia that practices judo, only those participants who meet the inclusion criteria will be included in the study.

4.2.7. Establishment of Variables and Measurement Methodology

4.2.7.1. Sociodemographic and Anthropometric Variables

Age:

- Type: Quantitative continuous
- Unit: Years
- Measurement method: Self-reported from identification document

Sex:

- Type: Qualitative dichotomous
- Categories: Male / Female
- Measurement method: Self-reported

Weight:

- Type: Quantitative continuous
- Unit: Kilograms (kg)
- Measurement method: Weight category in which they compete. For non-competing participants, current weight will be recorded.
- Categories according to Sub-21 and absolute category (see Table 1 in Introduction)

Height:

- Type: Quantitative continuous

- Unit: Centimeters (cm)
- Measurement method: Standard stadiometer measurement

Leg length:

- Type: Quantitative continuous
- Unit: Centimeters (cm)
- Measurement method: Distance from anterosuperior iliac spine to the most distal area of the tibial malleolus, measured with tape measure

4.2.7.2. Podiatric Variables and Variables Related to Sports Practice

Training frequency:

- Type: Quantitative continuous
- Unit: Hours per week
- Measurement method: Self-reported

Federated time in sports practice:

- Type: Quantitative continuous
- Unit: Years
- Measurement method: Self-reported, verified with federation records when possible

Foot posture:

- Type: Qualitative ordinal
- Categories: Highly supinated (-12 to -5), Supinated (-4 to -1), Neutral (0 to +5), Pronated (+6 to +9), Highly pronated (+10 to +12)
- Measurement tool: Foot Posture Index-6 (FPI-6)

- Measurement method: Clinical assessment by trained podiatrist using standardized FPI-6 protocol

Dominant foot:

- Type: Qualitative dichotomous
- Categories: Right / Left
- Measurement method: Determined as the habitual support foot in single-leg techniques (uchi-mata, harai-goshi, etc.)

Dynamic stability:

- Type: Quantitative continuous
- Unit: Percentage (%)
- Measurement tool: Y Balance Test (YBT)
- Measurement method: Normalized composite score calculated as: [(Sum of three reach distances) / (3 × leg length)] × 100

Injury history:

- Type: Qualitative dichotomous
- Categories: Yes / No
- Specification: Location (neck, back, hip, lower extremity), type of injury, context (training, physical test, competition)
- Measurement method: Self-reported questionnaire
- Timeframe: Injuries in the last 12 months

4.3. Data Collection

4.3.1. Constitution of the Work Team

The work team consists of two podiatrists:

1. **Juan Carlos Parada Souto**

   - Master's student in Sports Podiatry at the Catholic University of Valencia (UCV)
   - Principal investigator
   - Role: Data collection, FPI-6 assessment, YBT administration
2. **Raúl Gallego Estévez**
   - Teaching and Research Staff (PDI) at UCV with research profile in podiatric pathology
   - Role: Study director, methodological supervision, data analysis

4.3.2. Request to Judo Centers

Judo club directors located in the Galician provinces of A Coruña and Pontevedra will be contacted and the purpose of the study explained. If they accept to participate in the study, they will send a communication to their federated athletes inviting them to participate.

Contact will be made through email using a standardized invitation letter that includes:

- Study objectives and relevance
- Procedures and time commitment required
- Ethical approvals obtained
- Contact information for questions

4.3.3. Recruitment of Participants

Judo centers that accept to participate in the study will provide a list of their federated judokas who accept to participate. These judokas will contact the principal investigator through telephone or email, previously provided.

The club directors will be informed of the possibility of scheduling an appointment to attend the training center with interested athletes.

Once at the club, the project will be explained to them, resolving any doubts that may arise. Interested parties will be provided with:

1. **Information sheet** about the research, explaining:
   - Study purpose and procedures
   - Risks and benefits
   - Data confidentiality measures
   - Right to withdraw at any time
2. **Informed consent forms** to be signed before participation:
   - Adult consent form (≥18 years)
   - Parental consent form (<18 years)
   - Assent form (14-17 years)
3. **Confidentiality commitment document**

These documents must be signed and delivered before the scheduled appointment with their club, at which analysis and data collection will proceed.

4.3.4. Data Collection and Coding

General Data Collection

General data will be collected through a standardized form that includes:

Section 1: Personal Information

- Participant code
- Age
- Sex
- Weight / Weight category
- Height

Section 2: Sports Practice Information

- Dominant foot (habitual support foot in single-leg techniques)
- Shoe size
- Years federated
- Hours dedicated to weekly training
- Competition level (regional, national, international, or non-competing)

Section 3: Injury History

- Previous injuries (yes/no)
- If yes: Location, type, context (training/competition), time since injury

Foot Posture Assessment (FPI-6)

The FPI-6 will be administered by a trained podiatrist following the standardized protocol:

Six components assessed (each scored -2 to +2):

1. Talar head palpation
2. Curves above and below the lateral malleoli
3. Calcaneal frontal plane position
4. Prominence in the region of the talonavicular joint
5. Congruence of the medial longitudinal arch
6. Abduction/adduction of the forefoot on the rearfoot

Assessment conditions:

- Participant standing in relaxed stance
- Feet hip-width apart
- Weight evenly distributed

- After brief walk to assume natural position
- Both feet assessed

Scoring:

- Total score: Sum of 6 component scores
- Range: -12 to +12
- Classification:
    - Highly supinated: -12 to -5
    - Supinated: -4 to -1
    - Neutral: 0 to +5
    - Pronated: +6 to +9
    - Highly pronated: +10 to +12

Y Balance Test (YBT)

Test description:

The Y Balance Test is a dynamic stability test that requires strength, stability, and proprioception. It is based on the Star Excursion Balance Test (SEBT) with modifications[36,48].

Setup:

- Three lines marked on the mat (tatami)
- Anterior direction
- Posteromedial direction (120° from anterior)
- Posterolateral direction (120° from anterior)

Test procedure:

1. **Preparation phase:**

- Participant completes their usual warm-up routine with judogi
- Changes to short athletic pants (or provided shorts) to visualize lower extremity
- Leg length measured bilaterally (ASIS to tibial malleolus)
- Four familiarization trials performed with each leg

2. **Testing phase:**
   - Participant stands barefoot on center of Y
   - Hands placed on hips (to prevent compensations)
   - With opposite foot, reaches as far as possible in each direction:
     - Anterior reach
     - Posteromedial reach
     - Posterolateral reach
   - Toe touch must be light (avoiding balance recovery)
   - Returns to center between each reach
   - Three valid trials in each direction
   - Procedure repeated for both legs

Trial invalidation criteria (must be repeated):

- Judoka does not maintain single-leg stance (touches down with opposite foot)
- Does not maintain hand position on hips
- Does not return foot to center between reaches
- Uses reaching foot for support/balance recovery
- Lifts stance foot from center

Measurement:

- Reach distances measured from center to furthest point touched
- Recorded in centimeters for each of three directions
- Mean of three trials calculated for each direction

YBT composite score calculation:

$$\text{YBT score } (\%) = \frac{(\text{Anterior} + \text{Posteromedial} + \text{Posterolateral})}{3 \times \text{Leg length}} \times 100 \qquad (1)$$

Where:

- Anterior, Posteromedial, Posterolateral = mean reach distances (cm)
- Leg length = measured from ASIS to tibial malleolus (cm)

Order of testing:

- Dominant foot first (habitual support foot in single-leg techniques)
- Non-dominant foot second

Rest periods:

- 30 seconds rest between each of the three directions
- 2 minutes rest between dominant and non-dominant foot testing

Data Coding and Storage

Data necessary to carry out this study will be collected and stored in coded form. Each participant's data collection sheet will be assigned a code to which only members of the research team will have access; without this code, it will not be possible to identify which participant the collected data corresponds to.

Coding system:

- Format: JC-XXX (where XXX is sequential number 001-045)
- Master code list stored separately from data files
- Only principal investigator and study director have access to code key

Data storage:

- Physical forms: Locked cabinet at research office
- Digital data: Password-protected computer files
- Master code list: Separate secure location
- Retention period: 5 years after study completion (per regulatory requirements)

4.3.5. Intervention

Participants who agreed to participate in the study were scheduled at their training center. The steps to follow for the intervention were as follows:

Step 1: General data collection (10 minutes)

- Complete participant information form
- Record sociodemographic data
- Document training history
- Record injury history

Step 2: Foot Posture Index-6 assessment (10 minutes per participant)

- Participant stands in relaxed stance on tatami
- Both feet assessed following FPI-6 protocol
- Scores recorded for each of six components
- Total FPI-6 score calculated for each foot
- Foot classification determined (supinated/neutral/pronated)

Step 3: Y Balance Test preparation (5 minutes)

- Leg length measurement (bilateral)
- Participant changes to athletic shorts if needed

- Y-pattern marked on tatami with tape
- Belt segments positioned on each of three lines for distance marking
- Instructions explained and demonstrated

Step 4: Y Balance Test familiarization (10 minutes)

- Four practice trials with each leg
- Feedback provided on technique
- Questions answered

Step 5: Y Balance Test measurement (15 minutes)

- Three valid trials in each direction (anterior, posteromedial, posterolateral)
- Dominant foot tested first
- 30-second rest between directions
- 2-minute rest before non-dominant foot testing
- Same procedure repeated for non-dominant foot
- Distances recorded for each trial

Total time per participant: Approximately 50-60 minutes

Testing conditions:

- Conducted on tatami (judo mat surface)
- Barefoot for YBT
- After participant's normal warm-up
- Same time of day when possible (to control for fatigue effects)

4.4. Statistical Analysis Plan

4.4.1. Descriptive Analysis

A descriptive analysis will be performed for all variables recorded in the study.

Quantitative variables will be described as:

- Central tendency parameters: Mean and median
- Dispersion parameters: Standard deviation, minimum, maximum, and range
- Normality will be assessed visually (histograms, Q-Q plots) and with statistical tests

Qualitative variables will be described as:

- Absolute value (n)
- Percentage (%)
- Frequency tables and cross-tabulations as appropriate

4.4.2. Normality Testing

Shapiro-Wilk test will be used to determine if quantitative variables are normally distributed:

- Applied to samples or subgroups with $n < 50$
- Significance level: $p < 0.05$ indicates non-normal distribution

Kolmogorov-Smirnov test (with Lilliefors correction) will be used:

- Applied when comparing two independent samples
- Significance level: $p < 0.05$ indicates non-normal distribution

4.4.3. Primary Objective Analysis

Research question: Does foot posture type (FPI-6) affect dynamic stability (YBT)?

Groups:

- Group 1: Neutral foot (FPI-6: 0 to +5) - n=15
- Group 2: Pronated foot (FPI-6: +6 to +12) - n=15

- Group 3: Supinated foot (FPI-6: -12 to -1) - n=15

Dependent variable: YBT composite score of dominant foot (%)

Statistical procedure:

1. **Normality test:** Shapiro-Wilk test for each group
2. **Homogeneity of variances:** Levene's test
   - H0: Variances are equal across groups
   - If $p < 0.05$: Variances are not equal (heteroscedasticity)
3. **Comparison of means:** One-way ANOVA
   - H0: No differences in mean YBT scores among the three groups
   - Alternative: At least one group differs
   - Significance level: $p < 0.05$
4. **Post-hoc tests:** If ANOVA is significant:
   - **If variances are equal (Levene $p \geq 0.05$):** Tukey's HSD test
   - **If variances are unequal (Levene $p < 0.05$):** Dunnett's T3 test
   - Purpose: Identify which specific groups differ from each other
   - Pairwise comparisons: Neutral vs Pronated, Neutral vs Supinated, Pronated vs Supinated

Interpretation:

- Significant ANOVA + post-hoc results will determine which foot types differ in dynamic stability
- Effect sizes will be reported using Cohen's d for pairwise comparisons
- Clinical significance will be interpreted alongside statistical significance

4.4.4. Secondary Objective 1: Sociodemographic Variables

Research question: Is there a relationship between dynamic stability and sex?

Groups:

- Group 1: Male (n ≈ 37, expected based on judo demographics)
- Group 2: Female (n ≈ 8, expected)

Dependent variable: YBT composite score of dominant foot (%)

Statistical procedure:

1. **Normality test:** Kolmogorov-Smirnov test for YBT scores in each sex
2. **Comparison of means:** Independent samples t-test
    - H0: No difference in mean YBT scores between sexes
    - Alternative: Mean YBT scores differ between sexes
    - Significance level: $p < 0.05$
    - Two-tailed test
3. **Effect size:** Cohen's d will be calculated

Note: Other sociodemographic variables (age, weight category, training hours, years federated) may be explored using:

- Pearson or Spearman correlation (depending on normality)
- Linear regression if associations are found

4.4.5. Secondary Objective 2: Injury History

Research question: Is there a relationship between injury history and dynamic stability?

Groups:

- Group 1: Injury history present (injuries in neck, back, hip, or lower extremity in past 12 months)

- Group 2: No injury history

Dependent variable: YBT composite score of dominant foot (%)

Statistical procedure:

1. **Normality test:** Kolmogorov-Smirnov test for YBT scores in each group
2. **Comparison of means:** Independent samples t-test
   - H0: No difference in mean YBT scores between injury and no-injury groups
   - Alternative: Mean YBT scores differ between groups
   - Significance level: $p < 0.05$
   - Two-tailed test
3. **Effect size:** Cohen's d will be calculated

4.4.6. Secondary Objective 3: Dominant vs Non-Dominant Foot

Research question: Are there differences in dynamic stability between dominant and non-dominant foot?

Groups:

- Dominant foot YBT scores (habitual support foot) - n=45
- Non-dominant foot YBT scores (non-habitual support foot) - n=45

Design: Paired samples (same participants tested on both feet)

Statistical procedure:

1. **Normality test:** Kolmogorov-Smirnov test for YBT scores of each foot
2. **Comparison of means:** Paired samples t-test
   - H0: No difference in mean YBT scores between dominant and non-dominant foot

    - Alternative: Mean YBT scores differ between feet
    - Significance level: $p < 0.05$
    - Two-tailed test
3. **Effect size:** Cohen's d for paired samples will be calculated
4. **Interpretation:** Consider potential order effects (dominant foot always tested first)

4.4.7. General Statistical Considerations

Significance level: $\alpha = 0.05$ for all tests (two-tailed unless otherwise specified)

Missing data:

- Cases with missing primary outcome data (YBT or FPI-6) will be excluded from analyses
- Missing data for secondary variables will be reported
- No imputation planned due to small sample size

Outliers:

- Will be identified using box plots and z-scores ($|z| > 3.0$)
- Outliers will be checked for data entry errors
- Sensitivity analyses may be conducted with and without outliers if present

Multiple comparisons:

- Post-hoc tests will use appropriate adjustments (Tukey, Dunnett)
- For multiple secondary analyses, results will be interpreted with caution
- Bonferroni correction will NOT be applied to maintain statistical power in this exploratory study, but results will be interpreted conservatively

Effect sizes:

- Cohen's d: Small (0.2), Medium (0.5), Large (0.8)

- Will be reported for all comparisons to assess clinical significance

Software: All statistical analyses will be performed using IBM SPSS Statistics version 22.0 or higher.

Reporting: Results will follow STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

4.5. Ethical Aspects

4.5.1. Ethical Approval

This research complies with the good research practice standards of the Declaration of Helsinki. Given that this study collects health data and the tests performed are non-invasive, a favorable ethical report was requested from the Research and Teaching Ethics Committee of the Catholic University of Valencia.

Ethics approval obtained:

- Institution: Catholic University of Valencia San Vicente Mártir
- Committee: Research Ethics Committee
- Approval date: January 26, 2023
- Protocol code: UCV/2022-2023/111

4.5.2. Data Protection and Confidentiality

Appropriate measures have been adopted to guarantee complete confidentiality of personal data, in accordance with the provisions of:

- **Spanish legislation:**
    - Organic Law 3/2018, of December 5, on Protection of Personal Data and guarantee of digital rights
- **European legislation:**

    - Regulation (EU) 2016/679 of the European Parliament and of the Council, of April 27, 2016, on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation - GDPR)

Data protection measures:

1. **Pseudonymization:** All data will be collected and stored in coded form using unique participant codes (JC-001 to JC-045)

2. **Limited access:** Only research team members will have access to the code key linking codes to participant identities

3. **Secure storage:**

    - Physical documents: Locked filing cabinet
    - Electronic data: Password-protected, encrypted files
    - Code key: Stored separately from research data

4. **Data retention:** 5 years after study completion, then securely destroyed

5. **Data sharing:** Only de-identified data may be shared for scientific purposes with appropriate safeguards

4.5.3. Informed Consent Process

All participants will be informed about the characteristics of the research and the confidentiality commitment before enrollment.

Informed consent requirements:

For adults (≥18 years):

- Must sign adult informed consent form
- Must receive copy of signed consent
- Must receive information sheet about study

For minors (<18 years):

- **Ages 14-17 years:**
  - Parental consent required (signed by legal guardian)
  - Minor assent required (signed by participant)
  - Verbal assent confirmed at time of intervention
- **Ages 10-13 years:**
  - Parental consent required (signed by legal guardian)
  - Verbal assent from minor confirmed at time of intervention

Information provided in consent documents:

- Study purpose and procedures
- Voluntary nature of participation
- Right to withdraw at any time without consequences
- Confidentiality measures
- Potential risks (minimal: temporary fatigue, mild muscle soreness)
- Potential benefits (knowledge about their stability, contribution to science)
- Contact information for questions
- Ethics committee approval information

4.5.4. Participant Rights

All participants have the right to:

1. **Access:** Request access to their personal data collected in the study
2. **Rectification:** Correct any inaccurate personal data
3. **Erasure:** Request deletion of their data (right to be forgotten)
4. **Restriction:** Request limitation of data processing

5. **Portability:** Receive their data in structured, commonly used format
6. **Objection:** Object to data processing for specific purposes
7. **Withdrawal:** Withdraw from study at any time without explanation or negative consequences

Exercise of rights: Participants may exercise these rights by contacting the principal investigator using the contact information provided in the consent form.

4.5.5. Risk-Benefit Assessment

Risks:

- **Minimal risk study**
- Temporary muscle fatigue from YBT testing
- Minimal risk of fall during balance testing (mitigated by supervision)
- Potential mild muscle soreness (less than typical training)

Benefits:

- Individual: Knowledge about their dynamic stability and foot posture
- Scientific: Contributing to knowledge about judo biomechanics and injury prevention
- Future: May inform training and injury prevention programs for judokas

Risk mitigation:

- Testing supervised by qualified podiatrist
- Participants complete usual warm-up before testing
- Testing surface is tatami (cushioned, familiar to participants)
- Participants can stop testing at any time

4.5.6. Conflict of Interest

The research team declares no conflicts of interest. This study is conducted as part of an academic Master's thesis and receives no commercial funding.

4.5.7. Dissemination of Results

Results will be disseminated through:

- Master's thesis publication
- Scientific journal publications
- Presentations at scientific conferences
- Summary report to participating clubs and participants (if requested)

All dissemination will maintain participant confidentiality and report only aggregate data.

5. REFERENCES

[1] Pococco E, Ruedl G, Stankovic N, Sterkowicz S, Del Vecchio FB, Gutiérrez-García C, Rousseau R, Wolf M, Kopp M, Miarka B, Menz V, Krüsmann P, Calmet M, Malliaropoulos N, Burtscher M. Injuries in judo: a systematic literature review including suggestions for prevention. Br J Sports Med. 2013 Dec;47(18):1139-43. doi: 10.1136/bjsports-2013-092886. PMID: 24255909.

[2] Franchini E, Brito CJ, Artioli GG. Weight loss in combat sports: physiological, psychological and performance effects. J Int Soc Sports Nutr. 2012 Dec 13;9(1):52. doi: 10.1186/1550-2783-9-52. PMID: 23237303; PMCID: PMC3607973.

[3] Sbriccoli P, Camomilla V, Di Mario A, Quinzi F, Figura F, Felici F. Neuromuscular control adaptations in elite athletes: the case of top level karateka. Eur J Appl Physiol. 2010 Apr;108(6):1269-80. doi: 10.1007/s00421-009-1338-5. Epub 2009 Dec 29. PMID: 20039054.

[4] International Judo Federation. IJF Sport and Organisation Rules [Internet]. Lausanne: IJF; 2022 [cited 2023 Apr 15]. Available from: https://www.ijf.org

[5] World Health Organization. WHO guidelines on physical activity and sedentary behaviour. Geneva: World Health Organization; 2020.

[6] Gutierrez-Garcia C., Astrain I., Izquierdo I., Gomez-Alonso M.T., Yague J.M. Effects of judo participation in children: A systematic review. Ido Mov. Cult. J. Martial Arts Anthropol. 2018; 18:63–73.

[7] Lakes KD, Hoyt WT. Promoting self-regulation through school-based martial arts training. J Appl Dev Psychol. 2004;25(3):283-302. doi: 10.1016/j.appdev.2004.04.002

[8] Woodward TW. A review of the effects of martial arts practice on health. WMJ. 2009 Feb;108(1):40-3. PMID: 19326635.

[9] Drid P, Casals C, Mekic A, Radjo I, Stojanovic M, Ostojic SM. Fitness and Anthropometric Profiles of International vs. National Judo Medalists in Half-Heavyweight Category. J Strength Cond Res. 2015 Aug;29(8):2115-21. doi: 10.1519/JSC.0000000000000861. PMID: 25647645.

[10] Salvador A, Suay F, González-Bono E, Serrano MA. Anticipatory cortisol, testosterone and psychological responses to judo competition in young men. Psychoneuroendocrinology. 2003 Apr;28(3):364-75. doi: 10.1016/s0306-4530(02)00028-8. PMID: 12573302.

[11] Alesi M, Bianco A, Padulo J, Vella FP, Petrucci M, Paoli A, Palma A, Pepi A. Motor and cognitive development: the role of karate. Muscles Ligaments Tendons J. 2014 Jul 14;4(2):114-20. PMID: 25332920; PMCID: PMC4187589.

[12] Fong SS, Ng SS, Chung LM. Health through martial arts training: physical fitness and reaction time in adolescent Taekwondo practitioners. Health. 2013;5(6):1-5.

[13] Paillard T, Montoya R, Dupui P. Postural adaptations specific to preferred throwing techniques practiced by competition-level judoists. J Electromyogr Kinesiol. 2007 Apr;17(2):241-4. doi: 10.1016/j.jelekin.2006.01.006. Epub 2006 Mar 23. PMID: 16563801.

[14] Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports Med. 2006;36(3):189-98. doi: 10.2165/00007256-200636030-00001. PMID: 16526831.

[15] Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. Am J Sports Med. 2007 Jul;35(7):1123-30. doi: 10.1177/0363546507301585. Epub 2007 Apr 27. PMID: 17468378.

[16] Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. J Athl Train. 2007 Apr-Jun;42(2):311-9. PMID: 17710181; PMCID: PMC1941297.

[17] Fong DT, Hong Y, Chan LK, Yung PS, Chan KM. A systematic review on ankle injury and ankle sprain in sports. Sports Med. 2007;37(1):73-94. doi: 10.2165/00007256-200737010-00006. PMID: 17190537.

[18] McPherson M, Pickett W. Characteristics of martial art injuries in a defined Canadian population: a descriptive epidemiological study. BMC Public Health. 2010 Dec 30;10:795. doi: 10.1186/1471-2458-10-795. PMID: 21192801; PMCID: PMC3022864.

[19] Verhagen E, van der Beek A, Twisk J, Bouter L, Bahr R, van Mechelen W. The effect of a proprioceptive balance board training program for the prevention of ankle sprains: a prospective controlled trial. Am J Sports Med. 2004 Sep;32(6):1385-93. doi: 10.1177/0363546503262177. Epub 2004 Jul 20. PMID: 15310562.

[20] Cordova ML, Ingersoll CD, LeBlanc MJ. Influence of ankle support on joint range of motion before and after exercise: a meta-analysis. J Orthop Sports Phys Ther. 2000 Apr;30(4):170-7; discussion 178-82. doi: 10.2519/jospt.2000.30.4.170. PMID: 10778794.

[21] Riemann BL, Schmitz RJ, Gale M, McCaw ST. Effect of ankle taping and bracing on vertical ground reaction forces during drop landings before and after treadmill jogging. J Orthop Sports Phys Ther. 2002 Dec;32(12):628-35. doi: 10.2519/jospt.2002.32.12.628. PMID: 12492272.

[22] Paillard T, Noé F, Rivière T, Marion V, Montoya R, Dupui P. Postural performance and strategy in the unipedal stance of soccer players at different levels of competition. J Athl Train. 2006 Apr-Jun;41(2):172-6. PMID: 16791302; PMCID: PMC1472651.

[23] Perrin P, Deviterne D, Hugel F, Perrot C. Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. Gait Posture. 2002 Apr;15(2):187-94. doi: 10.1016/s0966-6362(01)00149-7. PMID: 11869913.

[24] Paillard T. Plasticity of the postural function to sport and/or motor experience. Neurosci Biobehav Rev. 2017 Jan;72:129-152. doi: 10.1016/j.neubiorev.2016.11.015. Epub 2016 Nov 26. PMID: 27894829.

[25] Paillard T, Margnes E, Portet M, Breucq A. Postural ability reflects the athletic skill level of surfers. Eur J Appl Physiol. 2011 Aug;111(8):1619-23. doi: 10.1007/s00421-010-1782-2. Epub 2010 Dec 31. PMID: 21193925.

[26] Redmond AC, Crosbie J, Ouvrier RA. Development and validation of a novel rating system for scoring standing foot posture: the Foot Posture Index. Clin Biomech (Bristol). 2006 Jan;21(1):89-98. doi: 10.1016/j.clinbiomech.2005.08.002. Epub 2005 Sep 21. PMID: 16182419.

[27] Hreljac A. Impact and overuse injuries in runners. Med Sci Sports Exerc. 2004 May;36(5):845-9. doi: 10.1249/01.mss.0000126803.66636.dd. PMID: 15126720.
[28] Rolf C. Overuse injuries of the lower extremity in runners. Scand J Med Sci Sports. 1995 Aug;5(4):181-90. doi: 10.1111/j.1600-0838.1995.tb00034.x. PMID: 7552763.
[29] Redmond AC, Crane YZ, Menz HB. Normative values for the Foot Posture Index. J Foot Ankle Res. 2008 Jul 31;1(1):6. doi: 10.1186/1757-1146-1-6. PMID: 18822155; PMCID: PMC2553778.
[30] Cheung RT, Chung RC, Ng GY. Efficacies of different external controls for excessive foot pronation: a meta-analysis. Br J Sports Med. 2011 Jul;45(9):743-51. doi: 10.1136/bjsm.2010.079780. Epub 2011 Apr 18. Erratum in: Br J Sports Med. 2012 Apr;46(5):373. PMID: 21504966.
[31] Williams DS 3rd, McClay IS, Hamill J. Arch structure and injury patterns in runners. Clin Biomech (Bristol). 2001 May;16(4):341-7. doi: 10.1016/s0268-0033(01)00005-5. PMID: 11358622.
[32] Neal BS, Griffiths IB, Dowling GJ, Murley GS, Munteanu SE, Franettovich Smith MM, Collins NJ, Barton CJ. Foot posture as a risk factor for lower limb overuse injury: a systematic review and meta-analysis. J Foot Ankle Res. 2014 Dec 19;7(1):55. doi: 10.1186/s13047-014-0055-4. PMID: 25558288; PMCID: PMC4282737.
[33] Hertel J, Gay MR, Denegar CR. Differences in Postural Control During Single-Leg Stance Among Healthy Individuals With Different Foot Types. J Athl Train. 2002 Jun;37(2):129-132. PMID: 12937424; PMCID: PMC164334.
[34] Boyer ER, Ward ED, Derrick TR. Medial longitudinal arch mechanics before and after a 45-minute run. J Am Podiatr Med Assoc. 2014 Jul;104(4):349-56. doi: 10.7547/0003-0538-104.4.349. PMID: 25076077.
[35] Winter DA. Human balance and posture control during standing and walking. Gait Posture. 1995;3(4):193-214. doi: 10.1016/0966-6362(96)82849-9.

[36] Horak FB. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? Age Ageing. 2006 Sep;35 Suppl 2:ii7-ii11. doi: 10.1093/ageing/afl077. PMID: 16926210.

[37] Granacher U, Muehlbauer T, Gollhofer A, Kressig RW, Zahner L. An intergenerational approach in the promotion of balance and strength for fall prevention - a mini-review. Gerontology. 2011;57(4):304-15. doi: 10.1159/000320250. Epub 2010 Aug 19. PMID: 20720401.

[38] Horak FB, Nashner LM, Diener HC. Postural strategies associated with somatosensory and vestibular loss. Exp Brain Res. 1990;82(1):167-77. doi: 10.1007/BF00230848. PMID: 2257901.

[39] Yu B, Gabriel D, Noble L, An KN. Estimate of the optimum cutoff frequency for the Butterworth low-pass digital filter. Journal of Applied Biomechanics. 1999 Aug;15(3):318-329. doi: 10.1123/jab.15.3.318

[40] Kang MH, Kim GM, Kwon OY, Weon JH, Oh JS, An DH. Relationship Between the Kinematics of the Trunk and Lower Extremity and Performance on the Y-Balance Test. PM R. 2015 Nov;7(11):1152-1158. doi: 10.1016/j.pmrj.2015.05.004. Epub 2015 May 12. PMID: 25978949.

[41] Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. J Athl Train. 2012 May-Jun;47(3):339-57. doi: 10.4085/1062-6050-47.3.08. PMID: 22892416; PMCID: PMC3392165.

[42] Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. J Orthop Sports Phys Ther. 2006 Dec;36(12):911-9. doi: 10.2519/jospt.2006.2244. PMID: 17193868.

[43] Shaffer SW, Teyhen DS, Lorenson CL, Warren RL, Koreerat CM, Straseske CA, Childs JD. Y-balance test: a reliability study involving multiple raters. Mil Med. 2013 Nov;178(11):1264-70. doi: 10.7205/MILMED-D-13-00222. PMID: 24183777.

[44] Munro AG, Herrington LC. Between-session reliability of the star excursion balance test. Phys Ther Sport. 2010 Nov;11(4):128-32. doi: 10.1016/j.ptsp.2010.07.002. Epub 2010 Aug 17. PMID: 21055706.

[45] Cote KP, Brunet ME, Gansneder BM, Shultz SJ. Effects of Pronated and Supinated Foot Postures on Static and Dynamic Postural Stability. J Athl Train. 2005 Mar;40(1):41-46. PMID: 15902323; PMCID: PMC1088344.

[46] Hoch MC, Staton GS, McKeon PO. Dorsiflexion range of motion significantly influences dynamic balance. J Sci Med Sport. 2011 Jan;14(1):90-2. doi: 10.1016/j.jsams.2010.08.001. Epub 2010 Sep 16. PMID: 20843744.

[47] Terada M, Harkey MS, Wells AM, Pietrosimone BG, Gribble PA. The influence of ankle dorsiflexion and self-reported patient outcomes on dynamic postural control in participants with chronic ankle instability. Gait Posture. 2014;40(1):193-7. doi: 10.1016/j.gaitpost.2014.03.186. Epub 2014 Apr 3. PMID: 24768526.

[48] Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumented device for measuring components of the star excursion balance test. N Am J Sports Phys Ther. 2009 May;4(2):92-9. PMID: 21509114; PMCID: PMC2953327.

[49] Robinson RH, Gribble PA. Support for a reduction in the number of trials needed for the star excursion balance test. Arch Phys Med Rehabil. 2008 Feb;89(2):364-70. doi: 10.1016/j.apmr.2007.08.139. PMID: 18226664.

APPENDICES

Appendices

This protocol includes a series of appendices that document the ethical approval, participant-facing documents, and study instruments used to conduct the research.

Appendix A. Ethics Committee Approval

Favorable opinion issued by the Research Ethics Committee of the Catholic University of Valencia San Vicente Mártir for the study "Determination of the degree of dynamic stability of the foot in single-leg support in relation to the Foot Posture Index in judokas" (Protocol code UCV/2022-2023/111). This appendix confirms that the study was reviewed and approved in accordance with applicable ethical and regulatory standards.

Appendix B. Information Sheet for Participants and Confidentiality Commitment

Full "Participant Information Sheet and Confidentiality Commitment" describing the purpose of the study, eligibility criteria, study procedures, potential risks and benefits, data protection measures, and contact details for the research team. This document is provided to all potential participants prior to obtaining informed consent.

Appendix C. Informed Consent Form – Adults

Template of the informed consent form for adult participants (≥18 years), including specific items on voluntary participation, right to withdraw, use of data for research, teaching and dissemination, access to results, and options regarding data retention and destruction. This form is signed by the participant and the investigator before any study procedure is initiated.

Appendix D. Informed Consent Form – Minors (Parental Consent)

Template of the informed consent form for legal guardians of minors participating in the study, which mirrors the adult consent structure but is addressed to the parent or legal representative. It covers study information, risks and benefits, data protection, and explicit authorization for the minor's participation, as well as conditions for withdrawal and revocation of consent.

Appendix E. Assent Form – Minors (14–17 years)

Age-appropriate assent form for adolescents, summarizing the study in clear and simple language and documenting that the minor has received and understood the information, knows that participation is voluntary, and agrees to take part in the study alongside the consent given by their legal guardian.

Appendix F. Letter to Judo Clubs

Standardized invitation letter sent to judo clubs describing the objectives of the study, eligibility criteria, study procedures (Y-Balance Test and questionnaire), and organizational aspects for recruitment. The letter requests collaboration in disseminating the study information among eligible judokas and provides contact details for the research team.

Appendix G. Participant Information Form (Athlete Data Form)

Data collection form used to record general participant information, including age, sex, weight category, years of federation, weekly training hours, shoe size, dominant foot, and detailed injury history (type of injury, side, context—training or competition—and recovery time).

Appendix H. Foot Posture Index-6 (FPI-6) Assessment Form

Standard FPI-6 scoring sheet used to assess foot posture in both feet. It includes the six items (talar head palpation, supra- and infra-malleolar curvature, calcaneal position, talonavicular prominence, medial longitudinal arch congruence, and forefoot abduction/adduction), each scored from −2 to +2, and provides space to record the total score for each foot.

Appendix I. Y-Balance Test Recording Form

Form for recording reach distances in the different directions of the Y-Balance Test and calculating composite scores for each lower limb. It is used to standardize data collection across all testing sessions.

Appendix J. Coding Sheet (Participant Code Assignment Log)

Master coding sheet listing the unique identification codes assigned to participants and the corresponding fields for recording their personal identifiers. This document is stored separately from the research data, in a secure location, and is accessible only to the principal investigator and authorized supervisors, in order to maintain confidentiality and enable pseudonymization of the dataset.

Appendix K. Bibliographic Search Strategy

Description of the electronic search strategy used for the literature review, including databases searched and key terms/MeSH headings related to martial arts, judo, lower extremity, foot posture, stability, and balance. This appendix documents the reproducibility of the background literature search that supported the rationale and design of the study.

Appendix L. Dissemination Plan

Summary of the planned dissemination activities for the study results, including target professional audiences (podiatrists, sports scientists, physiotherapists, and judo professionals), candidate national and international journals for manuscript submission, and scientific conferences where the findings are intended to be presented.