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INAÊ DE OLIVEIRA MARCELO

THE USE OF CLINICAL TESTS TO PREDICT BIOMECHANICAL OUTCOMES IN FUTSAL ATHLETES

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Dissertação de Mestrado apresentada ao Programa de Pós-graduação Multicêntrico em Ciências Fisiológicas da Universidade Federal do Pampa (UNIPAMPA, RS), como requisito parcial para obtenção do grau de Mestre em Ciências Fisiológicas.

Orientador: Prof. Dr. Felipe Pivetta Carpes

Coorientadora: Profa. Dra. Karine Josibel Velasques Stoelben

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DEDICATÓRIA

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“Por vezes sentimos que aquilo que fazemos não é senão uma gota de água no mar. Mas o mar seria menor se lhe faltasse uma gota.”

Madre Tereza de Calcutá

ABSTRACT

In sports involving jump and landing, soft tissues injuries are the most prevalent, with the anterior cruciate ligament (ACL) being the most affected in the lower extremity. The identification of risk factors for this injury is of great importance in the sports environment, aiming to develop protocols that help prevent these injuries. However, the gold standard method for identifying potential risk factors for these injuries involves a specialized, high-cost environment that is not always accessible to sports clubs. In the other hand, clinical tests are a quick, cheap, and easy-to-apply option, which has been highly recognized in terms of validity and replicability for detecting risk factors for injuries. However, it remains unclear whether the results found in these clinical tests correspond to biomechanical parameters considered as indicatives of injury risk. Thus, in this dissertation, we determine the ability of clinical tests to predict biomechanical parameters associated with ACL injury during a bilateral and unilateral landing task. The study included 26 male professional futsal athletes, who completed a battery of clinical tests followed by a 3D motion analysis considering kinematics and kinetics outcomes. Associations between clinical tests and biomechanical variables were analyzed. Our main findings support the use of clinical tests as predictors of important biomechanical variables for injury risk. Knee and hip isometric strength proved to be strong predictors of biomechanical outcomes in the motion analysis evaluation. In addition, the strongest prediction models showed combinations of more than one clinical test, especially those involving tests of isometric strength and joint mobility. Similar results of predictions were found for bilateral and unilateral jumps. We conclude that specific combinations of clinical tests can better predict biomechanical variables in motion analysis related to identification of ACL injury risk factors. We strongly suggest using strength tests for muscles producing motion in both knee and hip joints. Our results provide directions for a clinical evaluation with the potential to assist in clinical decision-making. The prediction equations generated requires further validation.

Keywords: lower extremity; anterior cruciate ligament; knee; athletes; injury prevention.

O USO DE TESTES CLÍNICOS PARA PREDIZER RESULTADOS BIOMECÂNICOS EM ATLETAS DE FUTSAL

RESUMO

Em esportes que envolvem saltos e aterrisagens, lesões de tecidos moles são as mais predominantes, sendo o ligamento cruzado anterior (LCA) o mais acometido na extremidade inferior. A identificação de fatores de risco para essa lesão é de suma importância no ambiente esportivo, visando elaborar protocolos que auxiliem a prevenção dessas lesões. Entretanto, o padrão ouro para identificação desses potenciais riscos de lesões envolve um ambiente especializado, de alto custo e nem sempre acessível a clubes esportivos. Os testes clínicos são uma opção rápida, barata e de fácil aplicação, que vem sendo altamente reconhecidos quanto validade e replicabilidade para detecção de lesões. Porém, ainda existe dúvida se os resultados encontrados nestes testes clínicos correspondem a parâmetros biomecânicos considerados como indicativos de lesão. Assim, nessa dissertação, determinamos a capacidade de testes clínicos predizerem parâmetros biomecânicos associados a lesão do LCA durante uma tarefa de aterrissagem bilateral e unilateral. Participaram do estudo 26 atletas de futsal profissional, do sexo masculino, que completaram uma bateria de testes clínicos seguida de uma análise de movimento 3D considerando parâmetros cinemáticos e cinéticos. Associações entre os testes clínicos e as variáveis biomecânicas foram analisadas. Nossos principais achados suportam a utilização de testes clínicos como preditores de variáveis biomecânicas importantes para risco de lesão. A força isométrica de joelho e quadril apresentou-se como forte preditor de variáveis biomecânicas na avaliação de análise de movimento. Além disso, os modelos de predição mais fortes apresentaram combinações de mais de um teste clínico, principalmente àqueles envolvendo testes de força isométrica e mobilidade articular. Resultados similares de predição foram encontrados para saltos bilaterais e unilaterais. Concluímos que combinações específicas de testes clínicos podem predizer melhor as variáveis biomecânicas de análise de movimento relacionadas na identificação de fatores de risco de lesão de LCA. Sugerimos fortemente a utilização de testes de força tanto para músculos da articulação de joelho, como para músculos da articulação do quadril. Nossos resultados fornecem direções para uma avaliação clínica com potencial para auxiliar na tomada de decisão clínica. As equações de previsão encontradas requerem validação adicional.

Palavras-chave: extremidade inferior; ligamento cruzado anterior; joelho; atletas; prevenção de lesão.

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LISTA DE ABREVIATURAS E SIGLAS

Abd/Add: hip abductor to adduction strength ratio
Abd: hip abductors strength
ACL: anterior cruciate ligament
ASIS: anterior superior iliac spine
Ext: knee extensor strength
Flex/Ext strength ratio: knee flexor to extensor strength ratio
Flex: knee flexors strength
GRF: ground reaction force
HS: hop single
HT: hop triple
IC: initial contact
KAM: knee abductor angle
L: lunge
LSD: lateral step down
SA: SEBT Anterior
SEBT: modified star excursion balance test
SPM: SEBT Postero Medial
vGRF: vertical ground reaction force

SUMÁRIO

1 INTRODUCTION

Biomechanical assessment is an essential part of the routine in physical training and rehabilitation. The assessment of kinematics and kinetics characteristics of the human movement along with the technical knowledge regarding factors of influence on performance and injury risk, which include but are not limited to participant characteristics, equipment, training status and environmental factors, provide fundamental information to assist training and clinical decisions. In different sports, the knowledge of biomechanics will play an important role also in the construction of training and assessments routines allowing to establish more effective injury prevention planning.

In sports involving jump landing tasks, biomechanics is a major factor not only for performance but also for injury risk. It helps to justify the reason for different clinical and functional tests being used in the field to evaluate athletes aiming to screen potential technique deviations and movements deficits that might negatively impact on biomechanics characteristics of high-risk movements like jump landing. However, there still pending questions about how the outcomes of these clinical and functional tests performed in the field, often related to scores of performances, observation, and perceptual classifications, relates to the biomechanics characteristics regarding objective measures of kinematics and kinetics of the movement obtained in biomechanical evaluations. In this dissertation, we describe the research developed aiming to understand the associations between performance outcomes in clinical and functional tests and the actual biomechanical outcomes during performance of jump landing tasks eliciting risk factors for lower extremity injury in male professional futsal athletes.

Therefore, this document is organized to report our experiments and the main results found. We initially provide a background of the topic based on a general overview of the relevant literature, followed by the rationale for establishing our research question. Finally, the material and methods are detailed before our results and discussions are presented. We also included copies of relevant documentation regarding the institutional register of our research.

1.1 Background

Sports involving fundamental movements like running and jumping result in higher mechanical demands to the lower extremity, in which biomechanics factors play a determinant role not only for performance but also for injury risks. Among the lower extremity joints, the knee is one experiencing high mechanical demands (FLANDRY; HOMMEL, 2011) and plays a determining role in performance in different sports (HEWETT; BATES, 2017b). In running and jumping landing movements, impact forces can easily overcome 2.5 times the individual body weight (NIGG; J. DENOTH; PH NEUKROMM, 1981), as well as higher magnitudes of energy absorption are observed for joint moments in frontal (NORCROSS et al., 2013a) and transverse planes (DONELON et al., 2020b). Furthermore, the knee joint is highly involved in the control of stability during unipodal actions (LEHMANN; PASCHEN; BAUMEISTER, 2017) and changes of direction (DONELON et al., 2020a). As a result, knee joint structures suffer overloads and mechanical stress that can cause acute or chronic injuries of different types and magnitudes.

The most common knee injuries in athletes affect soft tissues, such as ligaments (MAJEWSKI; SUSANNE; KLAUS, 2006), being a high prevalence observed for the anterior cruciate ligament (ACL). The ACL is the main ligament stabilizing the knee (PAPPAS et al., 2013), and its injury causes loss of postural stability (LEHMANN; PASCHEN; BAUMEISTER, 2017), impaired dynamic balance (CULVENOR et al., 2016), loss of lower extremity range of motion (DE FONTENAY et al., 2014) and persistent quadriceps and hamstring weakness (THOMAS et al., 2013), which leads on difficulty in returning to sports practice (VEREIJKEN et al., 2020). It is estimated that after an ACL rupture, the rehabilitation can take 6 to 9 months, postponing the safe return to the sportive practice for at least two months (GLOGOVAC; SCHUMAIER; GRAWE, 2019). Furthermore, ACL injury has a ~30% prevalence for a second injury (LOSCIALE et al., 2019). ACL injury is also a risk factor for developing other dysfunctions, such as osteoarthritis (CARBONE; RODEO, 2017). As a result, the effects of this type of injury go beyond the sporting context and may affect the individual's independence and quality of life.

Regarding the risk associated with specific sports practice, epidemiological data suggest that the main risk might not be the sport *per se*, but the movements involved in the technique. For example, jump landing tasks, change of direction, and deceleration-acceleration movements all increase ACL tension (DONELON et al., 2020a) and hazards for such injury (HEWETT;

BATES, 2017a). Among these movements, some biomechanics characteristics are shared. They required muscle strength, proper articular range of motion, joint stability and joint alignment (LARWA et al., 2021).

Biomechanics components of the movement are determinants for the occurrence of an injury. Thus, assessing kinematics and kinetics parameters can help identify the modifiable injury risk factors (PEDLEY et al., 2020). Landing from jumps and turning maneuvers are the main tasks in which non-contact ACL injuries occur. In these movements, reduced hip and knee flexion (UEBAYASHI et al., 2019) and increased tibial internal rotation (DELLA VILLA et al., 2020) increase tension in the ACL. An internal hip rotation while the foot is in stable contact with the ground, contributing to knee valgus, is also considered a significant risk factor (DELLA VILLA et al., 2020). Specifically, jump and landing assessments provide information about an individual's ability to attenuate ground reaction forces (GRF), generate lower limb power, and maintain joint alignment (PEDLEY et al., 2020). Hewett et al (HEWETT et al., 2005) showed that higher knee abduction angle and moment, and larger GRF magnitudes at landing from drop jumps are predictors of ACL injury risks. These findings are confirmed by other studies that also found that a stiffer landing (e.g., higher GRF) is associated with an increased risk of ACL injuries in athletes (LEPPÄNEN et al., 2017). Furthermore, during a bilateral drop landing task knee abduction and internal rotation moments increases ACL strain, leading to elevated injury risk (NAVACCHIA et al., 2019).

Leg asymmetries found in kinematics and kinetics parameters may also be related to ACL injury (PAPPAS; CARPES, 2012). Knee valgus moment asymmetry predicts ACL injury in athletes (HEWETT et al., 2005) and leg asymmetries found in GRF have been identified as a risk factor for ACL injury (DAI et al., 2014). Other potential risk factors for ACL injury includes impairment of dynamic postural control and joint mobility. Regarding joint mobility, less ankle, knee and hip motion during landing predisposes a stiffer landing, that increases ACL load (BODEN et al., 2009). Poor postural control increases the stabilizing requirement of the ACL during jump and landing (LARWA et al., 2021). In addition to the kinematics and kinetics features of these movements, neuromuscular performance is also a factor in the analysis of injury risks. The athlete who presents strength asymmetry between quadriceps and hamstrings may also experience greater tension on the ACL in these tasks (WALSH et al., 2012).

Therefore, identifying injury screening tools becomes essential for preventing these injuries, and biomechanical evaluations are the gold standard method for this purpose.

However, including biomechanics assessments in the routine of sports training can be challenging, not only due to the costs of instrumentation but also because some measurements can be time-consuming. As part of the prevention planning, clinical tests are used to track risk factors for injury in sports (GRIBBLE; HERTEL; PLISKY, 2012; HUDSON, 2012) and thus help in decision-making of assessment routines in the physiotherapist clinical practice. These tests involve specific postures and movements that, when performed by the individual, allow a general assessment of the athlete's capacity to perform specific movements (VEREIJKEN et al., 2020). They are carried out with different objectives, from identifying the athlete's aptitude for developing sports activities (REIMAN; MANSKE, 2011), help defining the moment to return to sports after an injury (MANSKE; REIMAN, 2013)(JOREITZ et al., 2020) and, mainly, serving as a screening tool for possible risks of injuries (GRIBBLE; HERTEL; PLISKY, 2012). Finally, indicating a more pertinent alteration serves as a basis for referring an athlete to a biomechanical evaluation, such as in a laboratory or specialized clinic (BUTLER et al., 2010).

The performance in the clinical tests is dependent on biomechanics. For example, assessing lower limb muscle strength is common in the clinical field and is also helpful in identifying injury risk factors (COLLINGS et al., 2022). Muscle strength is required to control frontal plane movements of the hip allowing a proper posture for landing (HOVEY et al., 2021). Hip muscle strength significantly predicts ACL injury (KHAYAMBASHI et al., 2016). For example, hip muscle weakness leads to larger dynamic valgus during landing, which may increase ACL loading (DIX et al., 2019b). Knee muscle strength assessment becomes important to the quadriceps dominance theory, whereas it suggests that excessive relative quadriceps forces or reduced hamstring recruitment place the ACL at a higher risk of injury (PAPPAS et al., 2016). While the technique can be described using kinematics and kinetics, the assessment of muscle strength is easier to perform in the field using a clinical test like the ones employing a handheld dynamometer (STARK et al., 2011). The handheld dynamometer allows to measure isometric strength for movements in different planes of motion and can be performed in a regular basis (STARK et al., 2011). While joint articular mobility is important to help impact absorption (HOVEY et al., 2021), clinical tests like the Lunge test allows the estimation of the ankle dorsiflexion mobility (KONOR et al., 2012). Decreased ankle dorsiflexion range of motion predicts non-contact ACL injury in athletes (AMRAEE et al., 2017) and is associated with higher GRF in a drop jump (MARTINEZ et al., 2022). It also affects the quality of movement during Lateral Step Down (LSD) test, which is usually assessed by a score that quantifies trunk movement, pelvis alignment, knee movement, and unilateral balance (RABIN;

KOZOL, 2010). Altered lower limb movement patterns, specifically in knee alignment, seem to be a possible risk factor for ACL injury (WILCZYŃSKI; ZORENA; ŚLĘZAK, 2020). Furthermore, athletes' functional performance is usually monitored by performance in hop tests. Hop tests are also used to assess patients' lower extremity muscular strength and ability to perform tasks challenging knee stability (FITZGERALD et al., 2001) and serve as reliable tool to measure function after ACL reconstruction (WEST et al., 2023) . Finally, the Star Excursion Balance Test (SEBT) is a functional test that assesses the neuromuscular control of the lower limbs (DOBIJA et al., 2019). Poor performance of one of the limbs in this test indicates a potential risk factor for injury, since a less skilled lower limb can change the way the athlete responds to demanding situations in the sport, being less able to provide a stable base to the athlete (PLISKY et al., 2006).

1.2 Research problem

Kinetics and kinematics, especially in three-dimensional motion analysis, are the gold standard for assessing movement patterns as reliable, sensitive, and accurate techniques. However, movement analysis is a complex context, since it involves specialized local and personnel, complex equipment, and experimental settings, which turns into challenging to apply in the context of professional sports teams if not considering a multidimensional approach (DE LA FUENTE et al., 2023). While these challenges can be successfully overcome in some sports teams, it remains impossible for most athletes.

More and more researchers dedicate to finding field tests that can satisfactorily help identify risks for injury, not only helping screening athletes at higher risk, but also proposing preventive actions. An alternative option for assessing movement and injury risk factors is the use of clinical tests with adequate validity (BOGDUK, 2022) and reliability (LACHIN, 2004). Validity of a clinical test involves the correct detection that the clinical test is designed to detect, while reliability involves the reproducibility of the measurement when repeated at random in the same participant. Clinical tests have some advantages for physiotherapy, as they can be quick to perform, easy to learn, inexpensive, and practical for application in the field, being alternatives for routine evaluations (THORNQUIST, 1994). However, their association with the biomechanical characteristics of the sports movements is crucial for identifying risk factors for an ACL injury.

The association between performance in clinical tests and biomechanics profiles of movement that elicit risk factors is hypothesized as the basis for using clinical tests selection. As aforementioned, higher knee abduction moment and angles and higher GRF are risk factors for ACL injury (HEWETT et al., 2005). Reduced ankle dorsiflexion and increased hip internal rotation and anteversion range of motion are predictors for ACL injury in male athletes (AMRAEE et al., 2017). Also, deficits in muscle strength, especially in core and hip muscles, are potential primary and secondary ACL injury predictors (STRAUB; POWERS, 2023). Nonetheless, these relationships are not always found. There are studies not reporting significant relationships between hip muscle strength and the knee valgus (DIX et al., 2019a; RABELO; LUCARELI, 2018). Also, Nilstad et al (NILSTAD et al., 2015) showed that quadriceps, hamstring, and hip abductors strength may not be predictors of an ACL injury. We need to better understand the application of strength measures in the assessment of risk factors of ACL injury and its relationship with biomechanical outcomes that are considered potentially predictors of injury. Strength and movement patterns in the performance of clinical tests could allow stratifying individuals, especially when it comes to injury risk during sports activities.

Therefore, several studies suggest that biomechanical measures can predict an ACL injury. Many biomechanics measures can also relate to performance in clinical tests, such as strength, mobility, and stability tests (MANSKE; REIMAN, 2013). However, there is a range of biomechanics variables and a range of clinical tests that can be selected and used in professional practice, but lack of guidance on the best combinations of tests to improve the evaluation outcomes. Finally, there is a challenge in identifying which low-cost clinical tools, such as clinical tests, can better identify biomechanical outcomes related to a knee injury risk. Although all clinical tests involve great muscle strength demand, we hypothesize that specific clinical tests assessing muscle strength may be the best predictors for biomechanical outcomes.

2 RESEARCH GOALS

2.1 General goal

To identify whether clinical tests can predict biomechanical characteristics of jump landing tasks eliciting risk factors for a knee injury in professional futsal male athletes.

2.2 Specific goal

To investigate whether a combination of clinical tests can improve predictions of biomechanical outcomes.

3 MATERIALS AND METHODS

3.1 Experimental design

This research is an observational study. Professional futsal male athletes were recruited from the local community to participate in this study. They were invited to a single visit to the laboratory to perform a battery of clinical tests and jump biomechanical assessments, with 3D kinematics and kinetics data being recorded. The clinical tests included in the battery were the Lunge Test, SEBT, LSD, Hop Tests, and Isometric Muscle Strength. Bilateral and unilateral drop jumps were performed for the biomechanical assessments. Figure 1 illustrates the experimental design of the study.

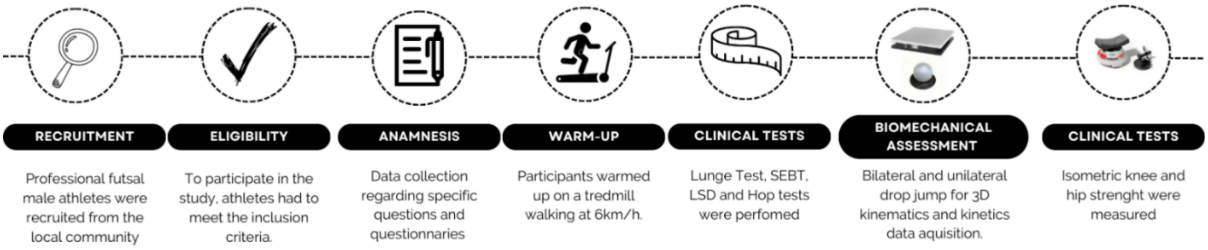

Figure 1. Experimental design of the study.

3.2 Participants

Participants were recruited by disseminating the study in the sports community of the Fronteira Oeste region from Rio Grande do Sul state, Brazil, between September and December of 2022, and February of 2023. Participants signed a consent term accepting the invitation to participate in the study. The local institutional ethics committee approved this study (protocol number: 66752923.7.0000.5323; Annex 1). Physical activities level was assessed by Tegner Scale (BRIGGS et al., 2009). To participate in the study, athletes had to meet the following inclusion criteria: 1) be a professional male athlete, participating in regional competitions for at least the past two years, 2) age between 18 and 35 years, and 3) be free of lower extremity injuries preventing from sports practice for two weeks or more in the past six months. Participants were excluded from the study if they could not complete the tests.

3.3 Procedures

Data collection was organized as follows:

1. *Anamnesis:* data collection regarding name, age, anthropometrical measures, history of previous injuries, and leg preference to kick a ball.
2. *Physical activity level:* Tegner Scale was used to determine physical activity level.
3. *Knee function:* Lysholm Scale was applied to quantify knee function.
4. *Lower extremity function:* Lower Extremity Functional Scale was applied to quantify lower extremity function.
5. *Warm-up:* Participants warmed up on a treadmill walking 5 min at 6 km/h.
6. *Clinical tests:* Athletes performed Lunge Test, SEBT, LSD, and Hop Tests.
7. *Biomechanical assessment:* Athletes performed bilateral and unilateral drop jumps for 3D kinematics and kinetics data acquisition.
8. *Clinical tests:* Isometric knee (extensors and flexors) and hip (abductors and adductors) strength were measured using a hand-held dynamometry.

All procedures were conducted at the Laboratory of Neuromechanics from the Universidade Federal do Pampa, in a room with environment temperature controlled between 20 and 23º C. An interval between tests was allowed according to the participants' request.

3.4 Clinical tests

Clinical tests were performed in the following order: Lunge Test, SEBT, LSD, and Hop Tests. Right after, participants performed jumps for biomechanical assessments and returned to execute a clinical test for isometric strength. Both legs were assessed, and the first leg for all tests was randomized by generating a balanced random list for each group of 10 in random.org. The participants received verbal encouragement and visual demonstrations of all tests were delivered before repeating some trials for familiarization with the tasks.

3.4.1 Lunge Test

Maximal ankle dorsiflexion range of motion was measured in Lunge test weight-bearing position using a metric tape placed on the floor in front of a wall (BENNELL et al., 1998). The participant stood barefoot, facing the tape in a lunge position. The tested foot should have the great toe positioned above the line, 10 cm far from the wall. The non-tested leg was at the back, helping to maintain the balance. Participants were asked to lunge as far as possible, directing the knee until it touched the wall without raising the heel off the floor. The lead foot position was adjusted by 1 cm aiming to find the larger dorsiflexion range of motion. Maximal dorsiflexion range of motion was defined by the maximum distance of the great toe to the wall with the knee leaning against it without removing the heel from the floor.

3.4.2 Modified Star Excursion Balance Test (SEBT)

The maximal distance reached in three valid trials in anterior, postero-medial, and postero-lateral directions was used to quantify the performance of SEBT (PLISKY et al., 2006). The athletes were instructed to stand barefoot with the tested leg in the center of a "Y" made with metric tape, with the great toe positioned at the starting line. The participants were asked to reach the maximal distance with the free stance non-tested leg in the anterior (Figure 2A), postero-medial (Figure 2C), and postero-lateral (Figure 2B) directions. Participants were asked to maintain their hands on the waist during the test. The maximal distance was quantified where the great toe reached the metric tape without weight bearing. The trial was invalid if the participant failed to maintain balance, lifted, or moved the stance leg, weighted bearing with the reach foot, failed to return to starting position or removed hands from the waist. The athletes executed four trials in each direction for each limb for familiarization before the beginning of the test. The results were normalized by the individual's leg length, and directions were randomized in a balanced random list at each group of 10 in random.org.

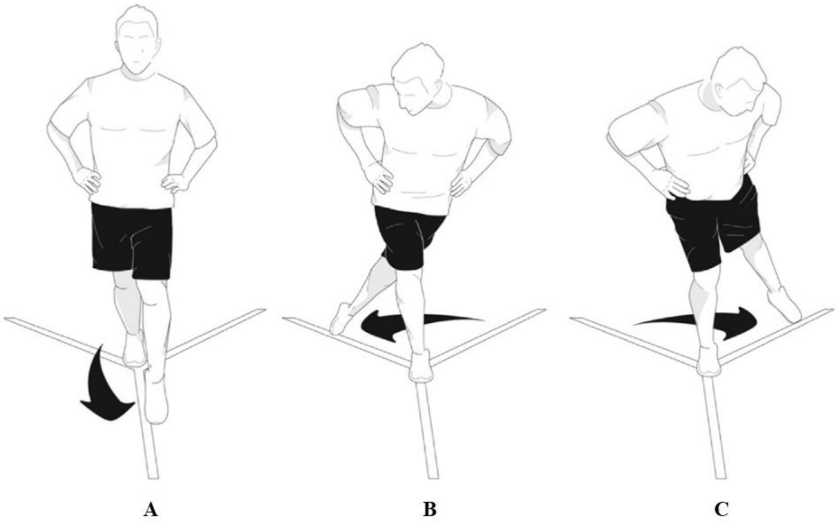

Figure 2. SEBT directions. A: Anterior; B: Postero-Lateral; C: Postero-Medial

Source: by the author, adapted from Madruga-Parera, 2019 (MADRUGA-PARERA et al., 2019).

3.4.3 Lateral Step Down

The quality of movement was analyzed by a total score accessed during LSD (RABIN; KOZOL, 2010). The total score was based on a 6-point criteria scale (see Table 1), and the results were interpreted as good (0-1 point), moderate (2-3 points), or poor quality of moment (4-7 points). Participants stood up barefoot with the tested leg on a box of adjustable height, with the non-tested leg hanging outside the box. The second toe of the tested leg should be aligned with the tape placed in the box. The height ranged between 15 and 25 cm, which was determined based on the participant individual height. Participants shorter than 165 cm used a 15-cm box, those with a height between 165 and 185 cm used a 20-cm box, and participants taller than 186 cm used a 25-cm box. They were instructed to lower their body until the non-tested leg's heel touched the floor, without weight bearing, and return to the starting position, maintaining the hands on the waist. The test was performed on five consecutive repetitions. The athletes were allowed to perform one familiarization with five repetitions for each leg. Skin markers were bilaterally attached to the anatomical landmarks over the anterior superior spine iliac (ASIS) and tibial tuberosities to serve as a visual reference. An experienced physiotherapist was positioned ~3 m apart from the box to perform the assessment.

Table 1. Lateral Step Down score criteria.

Criteria	Interpretation	Score
Arm strategy	Removal of hands from the waist	1
Trunk alignment	Leaning trunk in any direction	1
Pelvic plane	Loss of horizontal plane	1
Knee position	Tibial tuberosity medial to the second toe	1
	Tibial tuberosity medial to medial foot border	2
Steady stance	Weight-bearing in the non-tested leg at reaching the floor	1

Source: by the author, adapted from Rabin & Kozol, 2010 (RABIN; KOZOL, 2010).

3.4.4 Hop tests

The hop tests sequence involved the performance of single-leg hop for distance, triple hop for distance, and crossover hops for distance (ROSS; LANGFORD; WHELAN, 2002). Subjects stood up with the tested leg in the initial position for all tests, with the heel positioned over a mark between two measure tapes set 15 cm apart on the floor. The athletes wore their own athletic footwear to perform the hops. Participants were verbally advised to perform the maximal distance hop as possible. For single-leg hop for distance (Figure 3A), participants were instructed to hop forward as far as possible and land on the same foot. During triple hop for distance (Figure 3B), the athletes hopped forward and landed three consecutive times without pausing between the hops. Finally, for the crossover hop for distance (Figure 3C), participants performed three consecutive hops, laterally cross overing the measure tapes without pausing between the hops. The hops were realized in the same order for all participants (single, triple, and crossover). For all tests, participants were asked to hold the landing position for ~2 seconds and the last hop distance was measured based on where the heel landed. The trial was considered invalid if the participant failed to maintain balance during those 2 seconds, touched the ground with the contralateral leg or hands, or moved the heel after landing. Arm movements were allowed during the hops. The maximal distance reached in three trials in each test was used to quantify performance of the test, and hop distances were normalized to the participant's leg length.

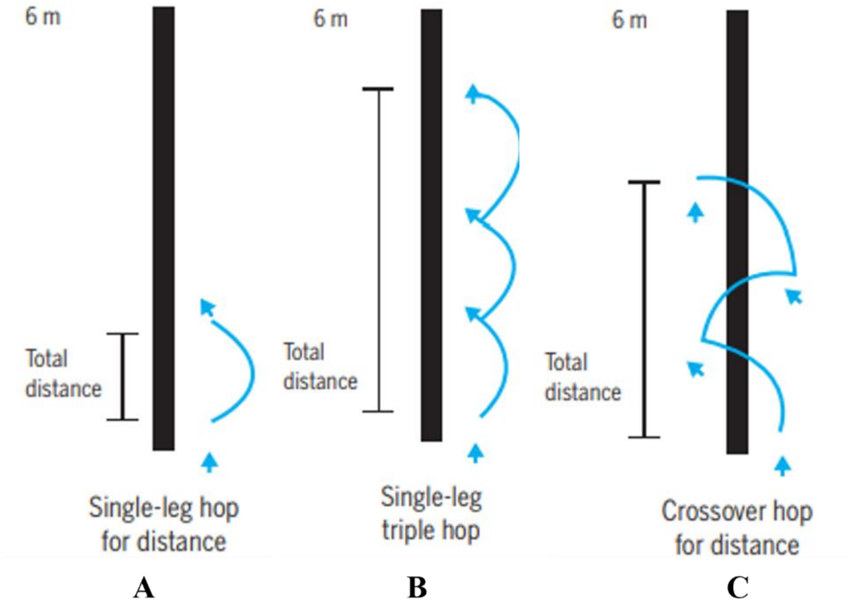

Figure 3. Hop tests performance. A: single leg hop for distance; B: triple hop for distance; C: crossover hop for distance.

Source: by the author, adapted from Noyes et al, 1991 (NOYES; BARBER; MANGINE, 1991).

3.4.5 Isometric strength

Maximal isometric strength was assessed using a hand-held dynamometer (Microfet 2, Hogan Health Industries, West Jordan, UT, USA). Tests were performed for the knee extensors and flexors and the hip abductors and adductors bilaterally, after the biomechanical jump assessments. In all tests, hands should be crossed on the chest to prevent impulse generation and assist in the production of strength. Participants were strongly verbally encouraged to perform their maximal isometric strength against the dynamometer for five seconds during at least three trials for each muscle. A 30-second rest was given between trials. The three trials should not differ by more than 10% in value. When it happened, additional trials were required. The order of the first leg, the muscle group, and the joint tested was randomized by balanced random list generation in blocks of 10 in random.org.

For knee extensor and flexor strength, participants sat on the edge of a stretcher with their lower legs hanging freely at ~90º of knee flexion. A belt was used to stabilize the thighs to the stretcher. It was used a modified belt to stabilize the dynamometer (HANSEN et al., 2015), where, for knee extensor strength, the dynamometer was positioned against the back of the stretcher leg with a belt between the stretcher leg and the participant's leg. For knee flexion strength, the dynamometer was positioned against the stretcher leg with a custom-made stabilization device. The dynamometer was positioned 5 cm proximal to the lateral malleolus (HANSEN et al., 2015).

Participants were in a supine position on the stretcher with the legs in a neutral position for hip abduction and with the contralateral knee and hip flexed for adduction strength (JACKSON et al., 2017). Belts were placed on the ASIS and thigh distal third of the tested leg. The dynamometer was rigidly attached to a custom-made device used in a previous study (GUADAGNIN et al., 2019) and placed 5 cm proximal to the lateral malleolus (for hip abduction) or medial malleolus (for hip adduction) (JACKSON et al., 2017).

The distance, in meters, from the lateral femoral condyle to 5 cm anterior to the lateral malleolus was measured to estimate torque for knee strength. For hip strength, the distance from the ASIS to 5 cm anterior to the lateral malleolus was measured to estimate torque. These values were multiplicated by force measured (N) and normalized to the individual body mass. The peak (highest value) from three trials was analyzed and the outcomes of interest were the flexor and extensor strength, flexor to extensor strength ratio (Flex/Ext strength ratio), abductor and adductor strength, and abductor to adductor strength ratio (Abd/Add strength ratio).

3.5 Biomechanical assessments

For biomechanical assessments, bilateral and unilateral drop jumps were performed. Two force plates (OR6-2000, AMTI Inc., Watertown, MA, USA) placed at floor level sampled the kinetics data at 2 kHz. Kinematics data were recorded with a 3D motion capture system with 15 cameras (Bonita, B10, VICON Motion Systems, Oxford, UK) sampling data at 200 Hz. The same researcher always placed twenty-seven 14 mm spherical reference markers according to the Plug-in Gait Full-Body Functional Model adapted on the anatomical references of the shoulders, clavicle, sternum, 7th cervical vertebra, 10th thoracic vertebra, right back, the anterior and posterior superior iliac spines, lateral thigh, anterior thigh, lateral femoral epicondyle, anterior tibial tuberosity, lateral tibia, calcaneus, lateral malleolus, and 2nd metatarsal head for both sides.

Initial contact (IC) event defined the landing phase. IC was defined by a rise of 20 N in the vertical ground reaction force. Raw ground reaction force signals were used to determine peak values. Three-dimensional joint angles were estimated for the ankle, knee, and hip. Three-dimensional joint moments (ankle, knee, and hip joints) were calculated with inverse dynamics equations of motion by Vicon Plug-In Gait Model (Nexus software, version 2.12). For estimations of joint angles and moments, kinematic and kinetic data were low-pass filtered by a 4th order zero-lag Butterworth filter with a cut-off frequency of 7 Hz.

Both legs were assessed, and the starting leg for unilateral jumps was randomized by generating a balanced random list at each group of 10 in random.org. The participants received verbal and visual demonstrations of all jumps and realized familiarization with the tasks. The athletes wore their athletic footwear to perform the jumps. Three successful trials were required for each jump and each leg. The trial was considered invalid if the participant lost balance or double hopped after landing and if they removed the hands from the waist.

The kinematics and inverse dynamics variables considered the IC instant and knee abductor peak value. Kinematics and kinetics outcomes were determined considering:

- Ankle sagittal plane angle and moment;
- Knee frontal and sagittal plane angles and moments;
- Hip sagittal, frontal, and transverse planes and moments;
- Peak of the vertical component of ground reaction force (VGRF), and;
- The rate of VGRF in the landing phase.

3.5.1 Bilateral Drop Jump

Participants stood up at the top of a 40 cm height box, with the hands on the waist, to perform a bilateral drop jump. They were instructed to drop off the box, land with one foot in each force plate, and as quickly as possible to realize a countermovement jump and land again in the same position. The second landing was analyzed.

3.5.2 Unilateral Drop Jump

For the unilateral drop jump, participants stood up in the top of a 20 cm height box, with their hands on the waist. They were instructed to drop off and land on single-leg support on a force plate and as quickly as possible to realize a countermovement jump and land again with single-leg support. The second landing was analyzed.

3.6 Statistical analyses

The capacity of clinical tests to predict the biomechanical outcomes was assessed with linear regression analyses and a two-steps process considering data from the preferred and non-preferred legs separately. The first step was selecting clinical outcomes for the regression model by Pearson or Spearman correlation tests (according to data normality verified with Shapiro-Wilk test). Clinical outcomes with association with biomechanical outcomes showing a $p \leq 0.20$ (Appendix A and D) were included in the regression model. Clinical outcomes with a strong correlation ($r \geq 0.7$) (Appendix B and E) between them were not included simultaneously; if that was the case, the independent outcome with a stronger association with the biomechanical outcome was selected.

The second step included stepwise multiple linear regression analyses performed for each biomechanical outcome. Assumptions of linear regression analysis were confirmed: independence of observations (Durbin-Watson value between 1 and 3); linear relationship; data homoscedasticity; non-multicollinearity (correlation coefficients < 0.7, tolerance value > 0.02, and variance inflation factor value < 10); and normality of residuals distribution. Influent cases were identified and excluded when the standard residual was higher than 3, Cook's distance higher than 1, or Mahalanobis distance higher than 11.

All tests were performed using a commercial statistical package (SPSS 22.0 IBM Corp., Armonk, USA), considering a significance level of 0.05. The power and global effect size (f^2) of the final model were also computed. Effect size (f^2) interpretation was: small to ≥ 0.02, medium to ≥ 0.15, and large to ≥ 0.35.

The sample calculation was performed using the G*Power software with the Linear Multiple Regression Fixed model test, single regression coefficient with a significance level (alpha) of 5% and power (beta) of 90%. As a primary outcome we used the peak vertical ground reaction force with an effect size (f^2) of 0.264, which was based in a previous study including with 47 recreational athlete participants and with 6 predictors (STOELBEN, 2022). The total estimated sample size was 35 participants. The actual power for this outcome in our study, with a significance level (alpha) of 5% and power (beta) of 90% was 0.95.

4 RESULTS

From the 32 participants recruited, we included 28 participants satisfying all the inclusion criteria for data analyses. Participants characteristics are described in Table 2. Kinetic and kinematics data from two participants considering data from preferred and non-preferred leg were excluded due to signal processing issues.

Table 2. Athletes' characteristics. Data are presented as mean ± SD, median (min-max) or absolute number [percentile].

Characteristics	n = 26
Age (years)	23.5 (18.0 – 34.0)
Body mass (kg)	75.4 ± 8.5
Height (m)	1.74 ± 5.8
Tegner Physical Activity Level (Score)	9.0 ± 0.0
Knee function by the Lysholm Scale (score)	88.5 (49 – 100)
Lower Extremity Functional Scale (score)	79.0 (64.0 – 80.0)
Right limb preference (participants)	17 [60.7]

Results concern only on those models that explained >20% of the variance (Appendix D and F). The results are present in two sections: results regarding the bilateral landing and regarding the unilateral landings. All models can be found in Appendix A-F.

4.1 Biomechanical outcomes during bilateral landing

Biomechanical outcomes predicted by clinical tests during bilateral landing were found for knee and hip joint kinematics. Flex/Ext strength ratio and LSD predicted knee frontal plane angle of the non-preferred leg (large effect size, Figure 4A). A lower Flex/Ext strength ratio and higher LSD scores were associated with higher knee frontal plane angle. Lunge outcomes predicted knee frontal plane moment of the preferred leg (medium effect size, Figure 4B). Higher ankle dorsiflexion was associated with higher knee abductor moment (KAM). Knee abductor peak moment was predicted by hip abductors strength (medium effect size, Figure 4C). Stronger hip abductors were associated with lower KAM. Finally, Flex/Ext strength ratio, LSD and SEBT Anterior predicted knee sagittal plane moment (large effect size, Figure 4D). Higher Flex/Ext strength ratio was associated with higher knee sagittal plane moment. Higher distances in SEBT Anterior and higher LSD score were associated with lower knee sagittal plane moment.

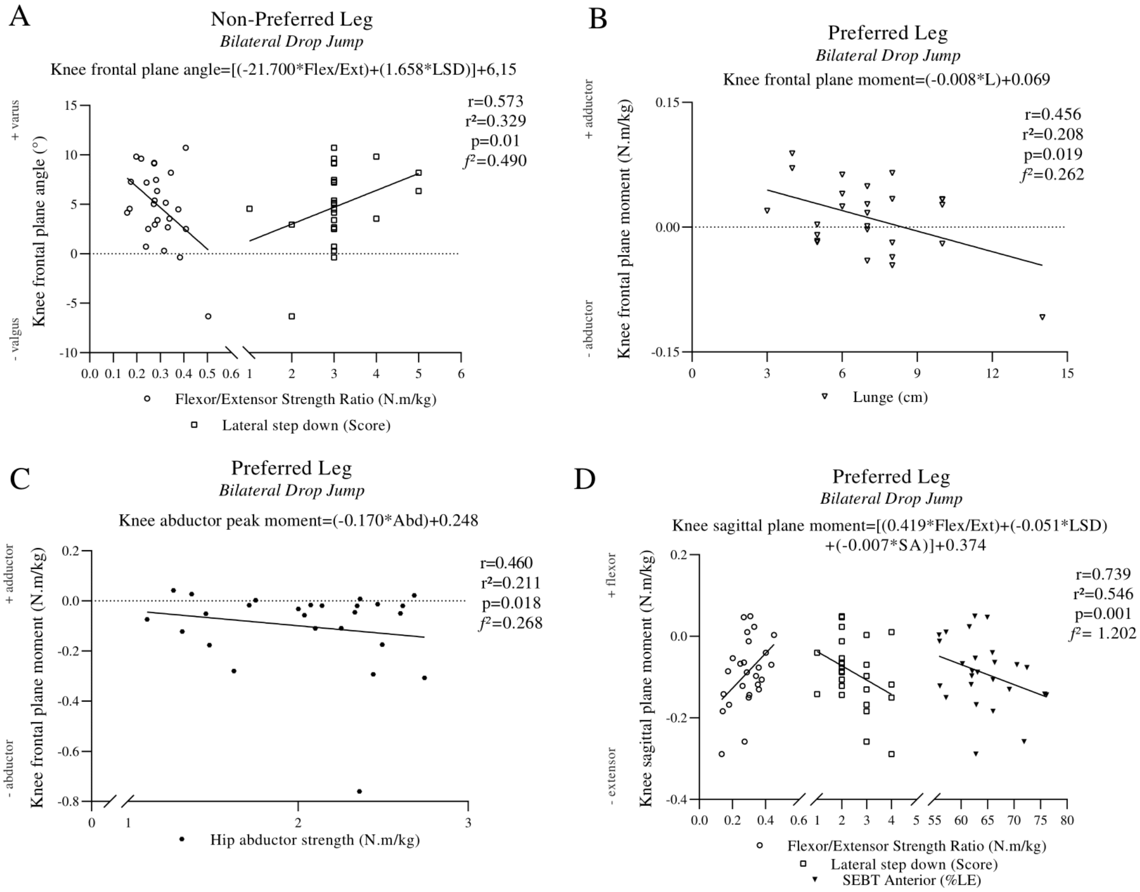

Figure 4. Knee biomechanical outcomes being predicted by clinical tests for bilateral drop jump.

Flex/Ext: flexors/extensors strength ratio; LSD: lateral step down; L: Lunge; Abd: hip abductors strength; SA: SEBT anterior.

Source: by the author

Flex/Ext strength ratio, Lunge and Triple Hop test predicted hip transverse plane angle of the non-preferred leg (large effect size, Figure 5A). Higher Flex/Ext strength ratio and longer distance reached in triple hop test were associated with lower hip external rotation angles. A higher Lunge value was associated with higher hip external rotation angles. For the preferred leg, SEBT Anterior predicted hip sagittal plane angles (large effect size, Figure 5B). Higher distances reached in SEBT Anterior were associated with less hip flexion angle. The knee flexors strength and performance in the single hop test predicted hip sagittal plane moment (large effect size, Figure 5C). Stronger knee flexors were associated with lower hip sagittal plane moment, while a higher distance in single hop test was associated with higher hip sagittal plane moment. As for the angle, Flex/Ext strength ratio, Lunge and SEBT Postero Medial predicted hip transverse plane moment (large effect size, Figure 5D). Higher Flex/Ext strength ratio and higher distance in SEBT Postero Medial were associated with higher hip transverse plane moment, while higher Lunge was associated with lower hip transverse plane moment.

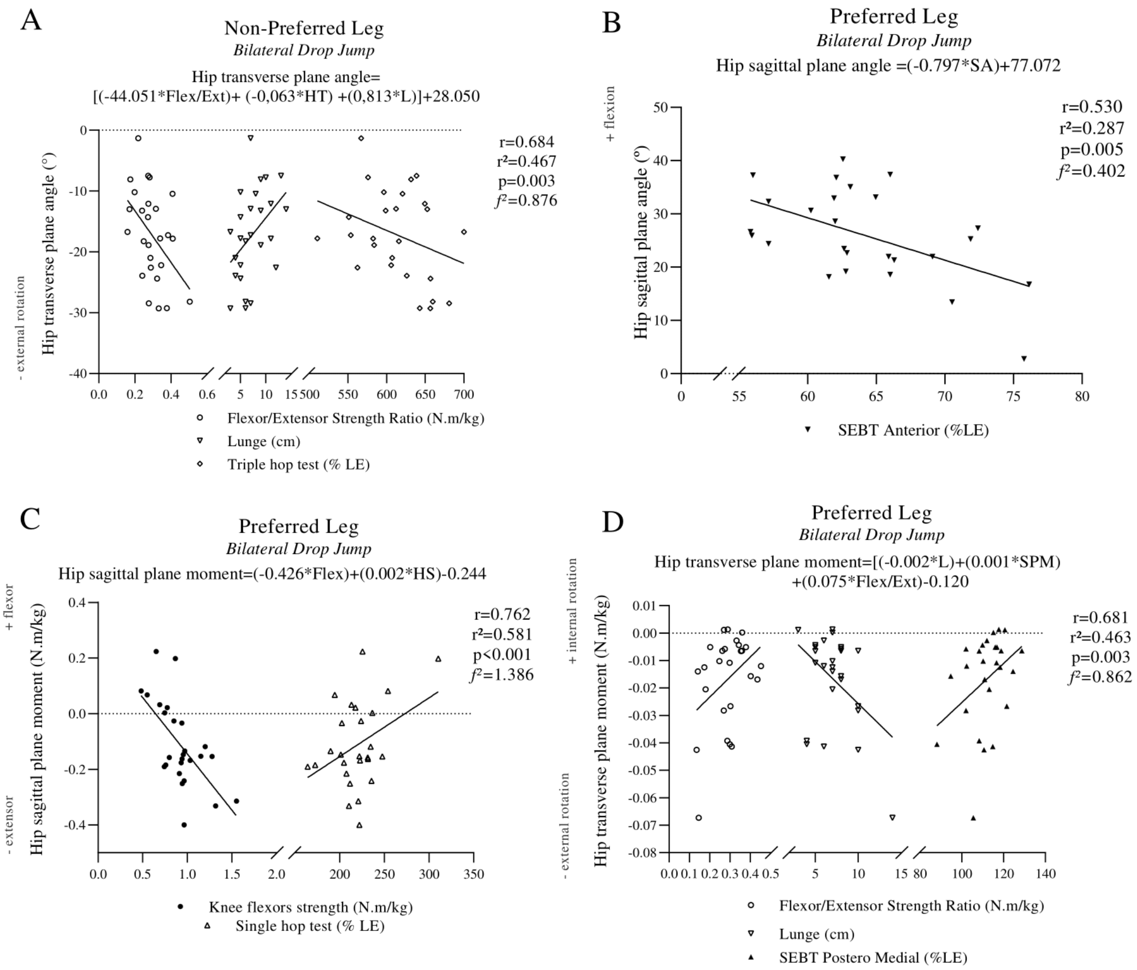

Figure 5. Hip biomechanical outcomes being predicted by clinical tests for bilateral drop jump.

Flex/Ext: flexors/extensors strength ratio; L: Lunge; HT: hop triple; SA: SEBT anterior; Flex: knee flexors strength; HS: hop single; SPM: SEBT posteromedial.

Source: by the author

4.2 Biomechanical outcomes during unilateral landing

Biomechanical outcomes predicted by clinical tests during unilateral landing were found for ankle, knee, and hip kinematics, VGRF, and rate of VGRF. Performance in single hop test predicted ankle sagittal plane moment of the non-preferred leg (large effect size, Figure 6). Higher distances in single hop test were associated with lower ankle sagittal plane moments.

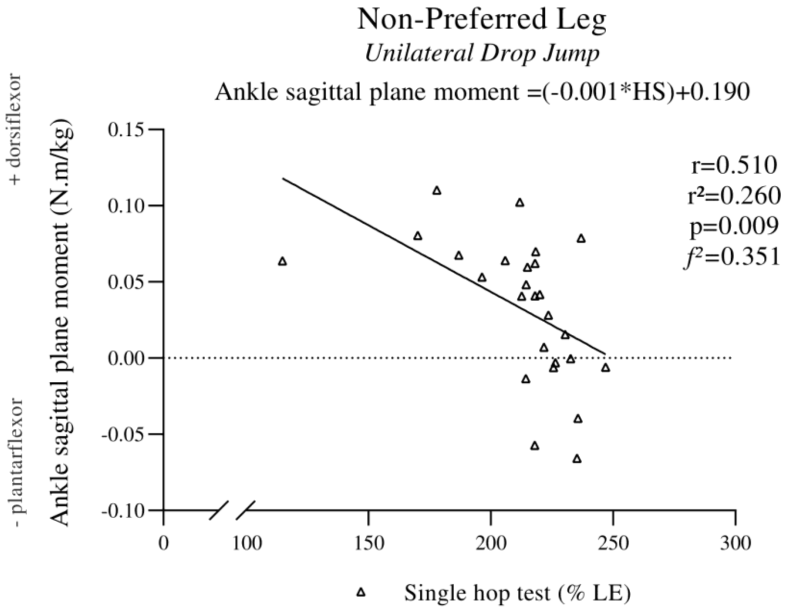

Figure 6. Ankle biomechanical outcomes being predicted by clinical tests for unilateral drop jump.

HS: hop single.

Source: by the author

Lunge, SEBT Postero Medial and Triple Hop Test predicted knee flexion angle of the non-preferred leg (large effect size, Figure 7A). Higher Lunge and distance reached in Triple Hop test were associated with higher knee flexion angle. Lower SEBT Postero Medial distance was associated with higher knee flexion angle. Still regarding the non-preferred leg, knee frontal plane angle was predicted by LSD, in which higher scores were associated with higher knee frontal plane angles (large effect size, Figure 7B). Knee sagittal plane moment for the preferred leg was predicted by Abd/Add strength ratio (medium effect size, Figure 7C). Stronger Abd/Add strength ratio was associated with less knee extensor moment. Also, for the preferred leg, hip abductors strength predicted knee frontal plane moment (large effect size, Figure 7D). Stronger hip abductors were associated with lower KAM.

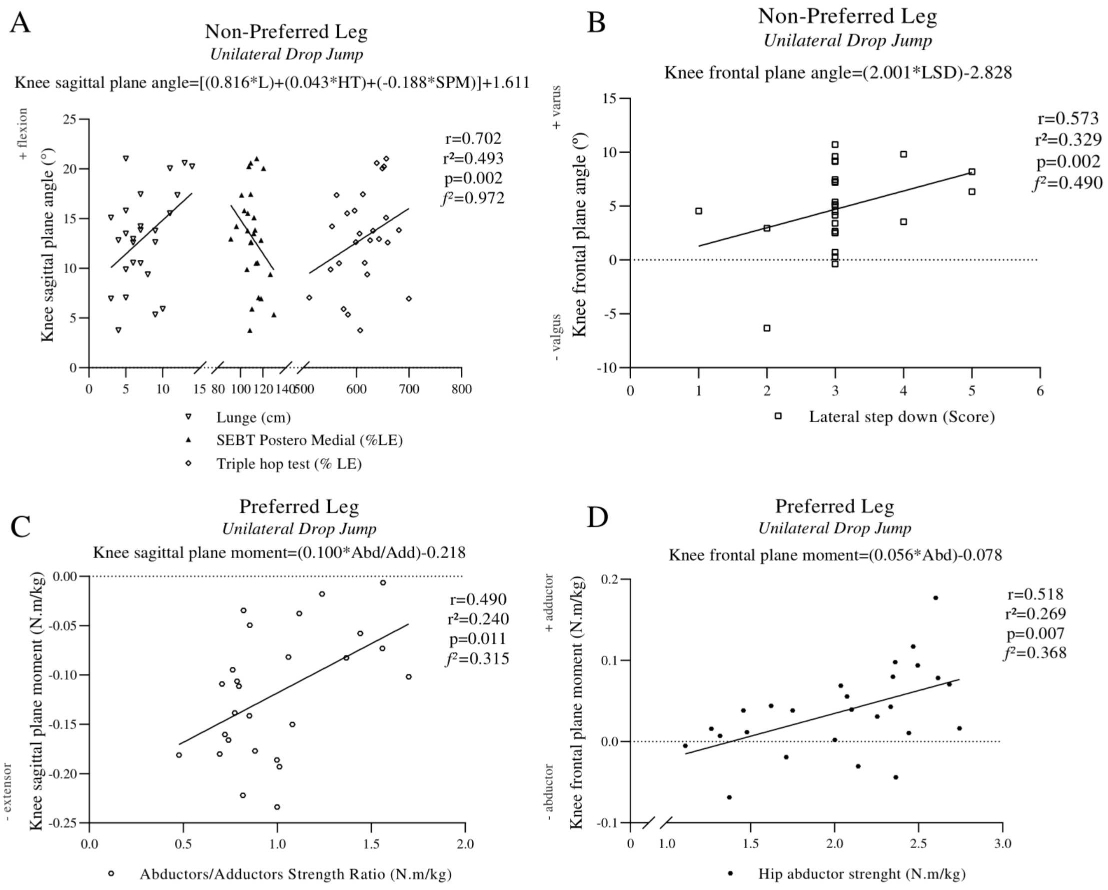

Figure 7. Knee biomechanical outcomes being predicted by clinical tests for unilateral drop jump.

L: Lunge; HT: hop triple; SPM: SEBT posteromedial; LSD: lateral step down; Abd/Add: abductors/adductors ratio; Abd: hip abductors strength.

Source: by the author.

SEBT Postero Medial distance predicted hip flexion of the non-preferred leg (medium effect size, Figure 8A). Higher distances in SEBT Postero Medial were associated with lower hip flexion. The same occurred for the preferred leg, but hip flexion angle was predicted by SEBT Anterior (large effect size, Figure 8B). Knee extensors strength and SEBT Postero Lateral distance predicted hip sagittal plane moment (large effect size, Figure 8C). Stronger knee extensors and larger distance in SEBT Postero Medial were associated with lower hip flexor moment. Higher LSD scores predicted higher hip abductor moment (large effect size, Figure 8D).

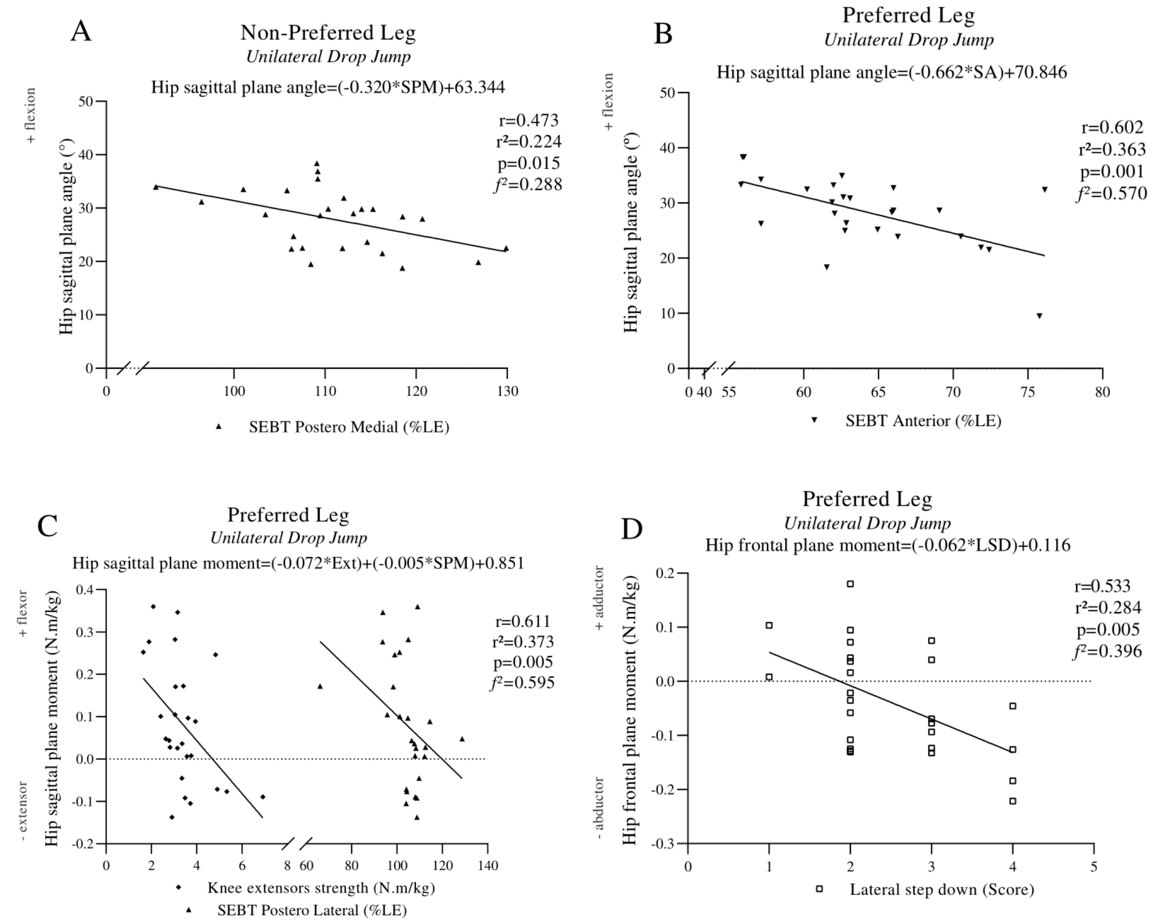

Figure 8. Hip biomechanical outcomes being predicted by clinical tests for unilateral drop jump.

SPM: SEBT posteromedial; SA: SEBT anterior; Ext: knee extensors strength; LSD: lateral step down.

Source: by the author.

Finally, predictions of kinetics outcomes were found for the preferred and non-preferred leg in unilateral landing. For the preferred leg, peak of VGRF was predicted by knee flexor strength (large effect size, Figure 9A). Stronger knee flexors were associated with lower peak of VGRF. For the non-preferred leg, Flex/Ext strength ratio predicted VGRF rate (large effect size, Figure 9B). Higher Flex/Ext strength ratio was associated with lower rate of VGRF.

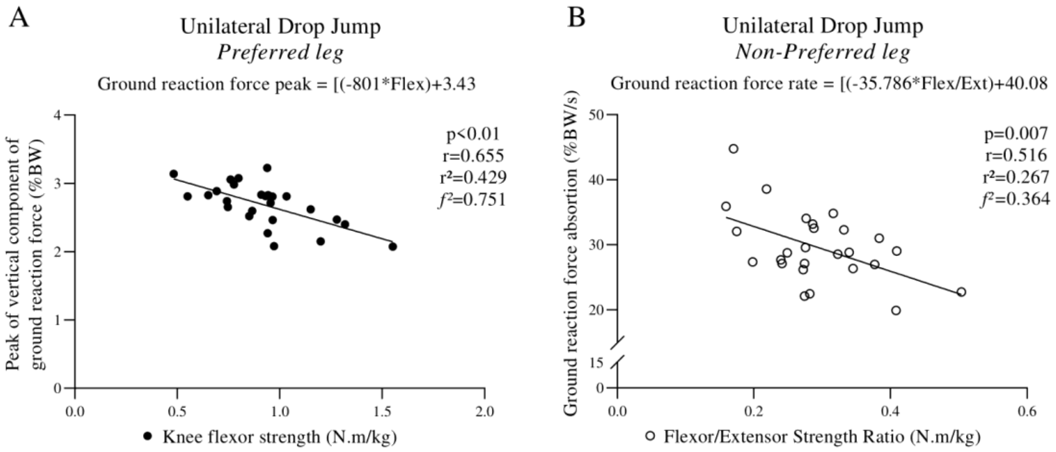

Figure 9. Kinetics biomechanical outcomes being predicted by clinical tests for unilateral drop jump.

Flex: knee flexors strength; Flex/Ext: flexors/extensors strength ratio.

Source: by the author.

5 DISCUSSION

In this dissertation, we investigated whether clinical tests commonly used in the physiotherapy practice predict biomechanical outcomes obtained in motion analysis evaluations and associated with ACL injury risk factors during bilateral and unilateral landing in professional futsal athletes. Our main finding is that a combination of clinical tests has a stronger prediction capacity of biomechanical outcomes associated with ACL injury risk, regardless of whether the landing technique is bilateral or unilateral. When clinical tests were applied individually, they provided poor predictions, around ~25%, except for knee flexors strength predicting peak of vGRF in unilateral landing. We also found that prediction models including isometric strength result in the strongest predictions. Furthermore, the predictions were stronger when combining LSD and Lunge test with isometric strength outcomes. In general, predictions involving clinical tests of muscle strength with mobility test or quality of movement test improves the prediction power for kinematic and kinetic outcomes of jump landing.

5.1 Prediction of bilateral landing

The predictive capacity of strength measures was very consistent in our results. We found stronger predictions of biomechanical outcomes in the motion analysis evaluation when isometric muscle strength is part of the prediction model. The importance of muscle strength finds support, for example, on the role that hip muscles plays to provide stability and weight support (BHANOT et al., 2019). Indeed, hip muscle weakness may result in movement dysfunctions, such as knee valgus (DIX et al., 2019a). We also found an important relationship of hip muscles strength with KAM. Our results indicated that stronger hip abductors were associated with lower KAM.

In addition to the predictive role of muscle strength found, we also have results indicating that a proper strength balance between muscles crossing a joint is a matter of importance for prediction of biomechanics outcomes. In this regard, hip strength was not the only predictor of biomechanical parameters of injury risk. Knee Flex/Ext strength ratio was also a strong predictor for KAM and for knee and hip sagittal plane joint moment. The strength ratio between hamstring and quadriceps muscles is considered one of the risk factors for future lower limb injuries (LEE et al., 2018) and has been suggested as one of the criteria for a safe return to sport (ERICKSON; SHERRY, 2017). In addition, poor strength of muscles producing movement in the sagittal plane may limit the flexion-extension movement during landing (SWANK; SHARP, 2016). Such assumptions are consistent with our findings regarding the higher Flex/Ext strength ratio being associated with a higher knee and hip sagittal plane joint moment.

Muscle strength is a powerful predictor of outcomes in the motion analysis, but the multifactorial characteristics of movement control also led to the need of additional inputs to improve the predictive models. When combined with isometric strength, Lunge, LSD and SEBT Anterior were the clinical tests most frequently being identified as significative predictors of knee and hip kinematics. Particularly, the LSD was included in models predicting knee frontal plane angle and sagittal plane joint moment. We argue that its association most likely results from the quality of movement requiring complex and combined neuromuscular control for the trunk, hip, and knee (SILVA et al., 2019). Similar rationale helps to explain the inclusion of Lunge and SEBT in the models. Regarding ankle joint mobility, reduced ankle joint dorsiflexion during a drop jump landing were associated with corresponding lower levels of knee and hip range of motion (TAYLOR et al., 2022). Our findings agree with the previous evidence, since we found a negative association between Lunge and knee frontal plane angle and hip transverse plane angle and joint moment. Furthermore, tests requiring greater dynamic control, such as SEBT and Hop tests, predicted knee and hip sagittal and transverse planes angles and joint moments. This finding can be explained by the need of great neuromuscular and posture control (BHANOT et al., 2019), since they involve great demand of the lower limbs (KOTSIFAKI et al., 2021).

It is difficult to state the movement control in a single plane of motion is enough to ensure a proper technique, as well as it is evident that the control of lower extremity biomechanics in landing requires simultaneous control of the different degrees of freedom in the different joints. Bilateral drop jump landing involves higher frontal plane movement control due to larger joint excursions observed (TAYLOR et al., 2016), but we found the strongest predictions (>50%) being related to the movement in sagittal plane. Nevertheless, reduced hip, knee and ankle flexion may contribute to movement patterns extremely associated with knee injury risk, such as knee valgus (TAYLOR et al., 2022). It also can provide a stiffer landing posture, specially, due to reduced knee flexion (LARWA et al., 2021; LEPPÄNEN et al., 2017). To prevent tibiofemoral shear and compressive forces, it is recommended to increase hip and knee flexion during bilateral drop jump landing (TSAI et al., 2017).

In summary, for clinical tests predicting biomechanical bilateral drop jump landing outcomes of motion analysis evaluations we recommend including not only knee muscle strength assessment, but also hip strength assessment. For stronger predictions, in addition to the strength testing, tests addressing mobility and quality of movement should also be performed. Regarding dynamic control tests, multiplanar movements need to be considered for better predictions.

5.2 Prediction of unilateral landing

Unilateral landing is more challenging for athletes, and also requires additional analysis when aiming to generate predictive models based in motion analysis evaluations. Different from what we found in bilateral landing, in unilateral landing, the predictions were similarly divided into the preferred and non-preferred leg. The preferred leg is generally more recruited for actions requiring force and mobility, while the non-preferred leg is more recruited for stabilization tasks (CARPES; MOTA; FARIA, 2010). Asymmetries are known to be task-dependent, and therefore the individual demand for each leg in different tasks can lead to different strategies during performance of clinical tests, which limits prediction models. It is difficult to identify which leg can be injured, therefore, the assessment and prevention for both legs still is the better choice. In this regard, it is tempting to say that non preferred leg, which in daily life is usually the one less required for challenging tasks, could contribute more to stabilization. However, such argument can be limited in terms of the way leg preference is assessed. In our study, in unilateral landing performed on the non-preferred leg there were more clinical tests related to stabilization and control predicting ankle, knee, hip and vGRF outcomes. It also in unilateral landing performed on the non-preferred leg that we found predictive potential (event though medium effect size) for clinical tests working alone.

It would be somewhat expected that clinical tests involving unilateral performance would be potential to predict unilateral landing. It was the case here, in which we found the ankle dorsiflexor moment predicted by the single hop test in the non-preferred leg. We did not detail the predictions being associated with a concentric or eccentric phase of the movement, but in the landing the ankle dorsiflexion is associated with an eccentric action of the triceps sural. Although this result requires a further investigation, it is possible that the importance of the triceps sural to the performance of the hop test reflect in some manner an association of this test with the dorsiflexion movement control. Similar rationale is possible to explain other associations found. Regarding the non-preferred leg, the quality of movement assessed by the LSD is extremely influenced by knee frontal plane displacement (SILVA et al., 2019). Higher scores, which classifies the participant as having poor quality of movement, are usually related to knee valgus. In our study we found greater knee frontal plane angle being associated with a higher LSD score. We also found higher distances reached in SEBT Postero Medial associated with hip sagittal plane motion. Indeed, hip movement in the sagittal plane strongly influence SEBT performance (GRIBBLE; HERTEL; PLISKY, 2012). Additionally, when Lunge, SEBT Postero Medial and Triple Hop Test were combined, they predicted knee sagittal plane, which agrees with the contribution of the knee in mobility (BAUMBACH et al., 2014) and stability tests (GRIBBLE; HERTEL; PLISKY, 2012).

Leg preference is associated with confidence, and when allowed to choose, participants will most likely prefer the same leg with some consistence. However, real life sports context might not always allow the athlete to choose in which leg to land, which configures a limitation when searching for predictions in the unilateral landing. That said, considering the preferred leg being more recruited in tasks requiring strength and precision, ours results showed large effect sizes for strength tests predicting knee, hip and vGRF outcomes from the motion analysis evaluations for the preferred leg. Hip abductors strength strongly correlated with knee frontal plane joint moment; thus, stronger abductors result in lower KAM (CEBALLOS-LAITA et al., 2022). However, hip strength does not only contribute to knee frontal plane motion control. We found hip Abd/Add strength ratio associated with knee sagittal plane moment. Such association may rely on the fact that hip muscles acting to control frontal plane movements are also helping to maintain knee alignment and to reduce knee joint loads (CEBALLOS-LAITA et al., 2022). We were unable to discuss the different contributions of the hip and knee muscles in terms of monoarticular and biarticular muscles and respective movements. However, we hypothesize that this could be an important venue for further research regarding strength predictions for motion analysis outcomes.

The knee is the most responsible joint for attenuating the kinetics loads of a landing (NORCROSS et al., 2013b). Specifically, the hamstrings musculature can be activated before and after the initial contact in a unilateral jump landing (WALSH et al., 2012), which seems to increase knee flexion and help attenuate vGRF loads on the knee joint (PODRAZA; WHITE, 2010). We found an inverse association between knee flexors strength and peak of vGRF and consider that a higher knee Flex/Ext strength ratio may have helped to attenuate vGRF.

Literature suggests that greater knee extensor and flexors strength may predict greater knee energy absorption during drop jumping (SCHMITZ; SHULTZ, 2010).

5.3 Limitations

Our study has inherent limitations. We considered the professional futsal athletes' from our community therefore the type of sample limits the generalization of our findings for different sports populations. We may not extrapolate our conclusions to women because sex differences for many of the biomechanics outcomes must be considered and better understood. We selected only a few types of clinical tests, and despite the wide application of these tests in physiotherapy context, there are other tests not considered that may also have predictive power. We selected a specific landing moment (IC) for the analysis included in this dissertation. The IC is critical for ACL injury, but there are other phases of the landing movement are also important to be analyzed in the future. We are aware that our results concern isometric strength while landing cycle involves a significant amount of eccentric muscle actions. However, we included measures of isometric strength due to its easy implementation. Finally, unexpected changes of direction or with the need to choose one of the legs for landing need to be better explored.

6 CONCLUSIONS

For male professional futsal athletes, clinical tests can predict biomechanical outcomes of motion analysis evaluations eliciting increased risk for an ACL injury during bilateral and unilateral drop landings. However, the predictions found require attention to the following conditions:

- Stronger predictions are achieved when including muscle strength testing associated with a mobility or quality of movement test.
- Regarding bilateral landing, only knee frontal plane angle and joint moment and sagittal plane angle and hip sagittal and transverse planes angles and joint moments outcomes are predicted by clinical tests.
- For unilateral landing, predictors were found for ankle sagittal plane joint moment, knee angles at the sagittal and frontal planes and joint moments; hip sagittal plane angle and joint moment and frontal plane joint moment; and peak and rate of absorption of vGRF.

In general, at least two clinical tests combined are required for a good prediction (>45%) of biomechanical outcomes of motion analysis evaluations. The strongest predictions (>50%) were found for hip and knee joint moments in the sagittal plane during bilateral landing, both with three clinical tests acting as predictors.

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APPENDIX A – Correlation matrix between clinical and biomechanical outcomes – Bilateral landing

Correlation matrix of clinical and biomechanical outcomes for the preferred leg

Biomechanical outcome				Clinical outcomes													
Joint	**Instant**	**Outcome**	**Correlatation information**	**Lunge**	**SEBT A***	**SEBT PM**	**SEBT PL***	**LSD***	**Hop Single***	**Hop Triple**	**Hop Cross**	**Knee Ext strength**	**Knee Flex strength**	**Hip Abd strength**	**Hip Add strength**	**Flex/Ext ratio**	**Abd/Add ratio***
Ankle	IC	Sagital plane angle *	r	-.005	.039	.277	.143	-.216	.082	-.257	-.122	-.154	0.119	.201	.203	.216	-.002
			p	.982	.849	.170	.485	.290	.692	.206	.552	.453	.560	.324	.321	.289	.991
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Sagital plane angle*	r	.037	-.090	.284	-.065	-.186	-.031	-.218	-.234	-.162	.080	-.102	.100	.015	-.134
			p	.856	.661	.159	.754	.363	.880	.284	.250	.430	.699	.622	.626	.943	.513
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Frontal plane angle	r	-0.26	-.096	.220	.240	.340	-.052	-.208	.004	-.096	.176	.022	-.106	.190	.052
			p	.199	.640	.279	.237	.090	.800	.307	.983	.642	.390	.915	.605	.354	.800
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Sagital plane angle	r	-,399*	-,535**	.150	-.234	.108	.024	.056	-.013	-.043	0.0478	-.068	-.192	-.063	.048
			p	.044	.005	.464	.251	.598	.909	.787	.949	.835	.816	.742	.348	.762	.815
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Frontal plane angle	r	-.104	.210	-.095	-.063	-.290	.090	-.194	-.145	-.282	-.346	.033	.202	.019	-.163
			p	.612	.304	.643	.759	.151	.662	.341	.479	.163	.084	.874	.323	.927	.426
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Transverse plane angle*	r	-.113	-.173	-.301	.105	.203	-.085	.099	.229	.244	.000	.043	-.182	-.111	.234
			p	.581	.399	.136	.610	.320	.679	.631	.261	.230	.999	.836	.373	.589	.250
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Ankle	IC	Sagital plane moment	r	-.090	0.00921648	-.186	-.104	-.191	-.256	-.146	.121	-.326	-.002	0.135373816	-.156	.333	0.182
			p	.661	.964	.362	.615	.349	.207	.478	.557	.104	.993	.510	.448	.096	.373
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Sagital plane moment	r	-.294	-.339	-.184	.260	-.376	-.231	-.217	-.059	-.161	,396*	.363	-.081	,443*	,426*
			p	.145	.091	.368	.199	.058	.257	.288	.775	.431	.045	.068	.694	.023	.030
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Frontal plane moment	r	-,456*	-.355	-.315	-.174	-.084	.061	-.015	-.181	-.184	.022	0.135707105	-.300	.120	,432*
			p	.019	.075	.117	.395	.683	.766	.943	.375	.368	.915	.509	.136	.559	.027
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Sagital plane moment	r	0.20931081	.248	.062	-.387	.247	.288	.193	-.030	.114	-,628**	-,443*	.017	-,548**	-,434*
			p	.305	.221	.762	.051	.223	.153	.344	.885	.579	.001	.023	.934	.004	.027
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Frontal plane moment	r	.016	-.104	-.264	-.198	-.240	-.080	-.196	-,392*	.203	.093	.142	-.316	-.191	.286
			p	.938	.613	.192	.332	.238	.696	.338	.048	.319	.652	.488	.116	.349	.156
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Transverse plane moment*	r	-.288	-.136	.373	,435*	.220	.255	.045	.030	-.195	.236	-.283	-.041	.261	-.227
			p	.153	.506	.061	.027	.280	.209	.825	.885	.341	.247	.162	.844	.198	.264
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	Peak valgus	Frontal plane angle	r	-.106	-.031	0.14143209	-.021	.071	-.001	.168	.092	-.083	0.237	.375	.023	.223	.312
			p	.608	.881	.491	.919	.730	.995	.412	.656	.687	.244	.059	.912	.273	.121
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	Peak abductor	Frontal plane moment*	r	-.215	.000	-.187	-.081	.168	.053	.049	.124	-.215	-,421*	-,587**	.004	-.027	-,429*
			p	.291	.999	.361	.694	.413	.796	.814	.547	.291	.032	.002	.984	.897	.029
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
N/A	Peak	Ground reaction force	r	.010	.012	-.291	-.188	.105	-.285	-.251	-.275	-.338	-.354	-.281	.045	.149	-.268
			p	.963	.952	.149	.359	.610	.159	.215	.174	.091	.076	.164	.827	.468	.186
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
N/A	Rate	Ground reaction force	r	-.321	-.019	.024	.189	-.067	-.138	-.089	-.056	-.212	-.041	-.003	-.064	.189	.026
			p	.110	.928	.909	.355	.746	.502	.665	.787	.298	.844	.986	.757	.356	.901
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26

*Spearmann correlation; Cells highlighted in light orange are p values ≤ 0.20; Cells highlighted in dark orange are the clinical outcomes inserted in each model.

Correlation matrix of clinical and biomechanical outcomes for the preferred leg

Biomechanical outcome				**Clinical outcomes**													
Joint	**Instant**	**Outcome**	**Correlatation information**	**Lunge**	**SEBT A***	**SEBT PM**	**SEBT PL***	**LSD***	**Hop Single***	**Hop Triple**	**Hop Cross**	**Knee Ext strength**	**Knee Flex strength**	**Hip Abd strength**	**Hip Add strength**	**Flex/Ext ratio***	**Abd/Add ratio***
Ankle	IC	Sagital plane angle *	r	-.024	.002	-.005	-.007	.140	.212	.002	.141	.119	.017	.061	-.095	-.006	.150
			p	.907	.991	.980	.974	.496	.298	.993	.494	.564	.933	.769	.645	.978	.464
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Sagital plane angle*	r	.195	.194	-.168	.281	-.151	,403*	.126	.179	-.050	.104	.096	-.093	.243	.067
			p	.340	.343	.412	.164	.462	.041	.539	.380	.810	.615	.641	.653	.231	.746
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Frontal plane angle	r	.125	.142	.292	.092	.328	-.108	-.054	.226	.344	-.065	.281	-.003	-,448*	.164
			p	.544	.488	.147	.654	.102	.598	.791	.268	.086	.751	.164	.988	.022	.422
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Sagital plane angle	r	-.145	-.344	-.246	-.091	.262	-.061	.031	-.092	-.028	-.011	.067	.062	.023	-.169
			p	.479	.085	.225	.657	.197	.769	.882	.656	.893	.956	.746	.763	.910	.410
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Frontal plane angle	r	-.034	-.045	-.069	-.037	-,414*	.166	.113	-.021	-.192	.070	-.140	-.139	.247	-.085
			p	.868	.827	.738	.856	.035	.416	.582	.917	.347	.734	.496	.499	.223	.680
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Transverse plane angle	r	.378	.044	.134	-.138	.170	-.172	-.329	-.236	.387	-.050	.300	.076	-,459*	.011
			p	.057	.829	.513	.502	.406	.401	.101	.246	.051	.807	.137	.713	.018	.957
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Ankle	IC	Sagital plane moment *	r	-.193	-.242	-.240	-.150	-.003	-,402*	-.100	.115	.124	.059	.172	.078	-.201	.023
			p	.346	.233	.238	.466	.990	.042	.626	.575	.547	.774	.401	.703	.324	.909
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Sagital plane moment	r	-.012	.086	.054	.061	-.125	.178	-.094	.099	-.257	-.015	.020	-.230	.362	.206
			p	.956	.675	.794	.768	.542	.384	.648	.632	.206	.941	.922	.259	.069	.312
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Frontal plane moment	r	.126	-.189	-,443*	-.116	.034	-.160	-.181	-.089	.111	.116	.369	-.045	.115	.112
			p	.540	.355	.023	.574	.869	.434	.375	.665	.591	.573	.064	.829	.577	.585
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Sagital plane moment	r	-.057	-.169	-.103	.118	-.028	-.132	.172	-.187	-.018	-.123	-.143	.021	-.174	-.077
			p	.782	.409	.616	.566	.893	.519	.400	.361	.929	.550	.487	.921	.396	.708
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Frontal plane moment	r	-.129	-.343	-.326	-,414*	.363	-.277	-.257	-.186	-.052	.014	.218	-.003	-.028	.075
			p	.530	.086	.104	.035	.069	.170	.205	.362	.801	.946	.284	.987	.891	.714
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Transverse plane moment	r	-.024	.110	-.030	.113	-.147	.320	.035	-.229	-.328	-.183	-.185	-.172	.314	.146
			p	.908	.591	.885	.582	.474	.111	.867	.260	.102	.371	.366	.401	.119	.478
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	Peak valgus	Frontal plane angle	r	-.152	-.304	.143	-.222	.336	-.135	-.211	-.068	.292	.056	.387	.012	-,398*	.168
			p	.460	.131	.487	.275	.093	.511	.302	.742	.148	.784	.051	.955	.044	.412
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	Peak abductor	Frontal plane moment*	r	-.105	.177	-.113	.081	.036	-.085	.274	.203	-.195	-.368	-.284	-.164	-.215	.050
			p	.609	.388	.583	.694	.860	.679	.175	.320	.341	.064	.159	.424	.291	.807
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
N/A	Peak	Ground reaction force	r	-.005	.174	-.020	-.030	-.198	-.163	.090	.045	.068	-.276	-.298	-.046	-.304	.025
			p	.980	.395	.922	.883	.333	.426	.661	.825	.743	.172	.140	.822	.131	.902
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
N/A	Rate	Ground reaction force	r	.051	.111	-.049	.038	-.200	.022	.170	.153	.175	-.140	-.103	.064	-,408*	-.016
			p	.805	.588	.812	.855	.327	.914	.405	.456	.393	.496	.617	.757	.038	.938
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26

*Spearmann correlation; Cells highlighted in light orange are p values ≤ 0.20; Cells highlighted in dark orange are the clinical outcomes inserted in each model.

APPENDIX B – Correlation matrix between clinical outcomes – Bilateral landings

Correlation matrix between clinical outcomes for preferred leg

Clinical outcome	Correlation information	Lunge	SEBT A	SEBT PM	SEBT PL*	LSD*	Hop Single*	Hop Triple	Hop Cross	Knee Ext Strength	Knee Flex Strength	Hip Abd Strength	Hip Add Strength	Flex/Ext Ratio	Abd/Add Ratio*
Lunge	r	1	,506**	.020	-.079	-.182	-.033	.019	-.085	,442*	.005	.036	.291	-.273	-.163
	p		.008	.925	.700	.372	.873	.926	.680	.024	.981	.860	.149	.178	.427
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT A	r	,506**	1	.207	.144	-.251	.363	.246	.126	.074	.008	-.064	.035	-.043	-.123
	p	.008		.311	.483	.215	.068	.227	.539	.720	.968	.755	.865	.836	.549
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT PM	r	.020	.207	1	,554**	.064	.330	.210	.291	.088	-.038	-.125	.004	-.214	-.233
	p	.925	.311		.003	.757	.099	.302	.149	.667	.855	.543	.984	.294	.253
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT PL*	r	-.003	.134	.296	1.000	-.028	.213	-.139	.035	.003	,462*	.239	.039	.334	.045
	p	.989	.515	.142		.891	.296	.498	.864	.987	.017	.240	.849	.095	.828
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
LSD*	r	-.243	-.321	.155	-.028	1.000	.274	.176	.074	-.078	.008	-,426*	-.332	.021	-.081
	p	.231	.109	.449	.891		.175	.389	.719	.703	.969	.030	.097	.918	.692
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Single*	r	-.008	,392*	.201	.213	.274	1.000	,594**	.317	.259	.077	-.240	-.207	-.300	-.094
	p	.970	.047	.326	.296	.175		.001	.114	.202	.707	.238	.311	.136	.648
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Triple	r	.019	.246	.210	.030	.143	,636**	1	,724**	.241	.034	-.029	-.160	-.260	.166
	p	.926	.227	.302	.883	.487	.000		.000	.235	.870	.887	.435	.199	.416
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Cross	r	-.085	.126	.291	.279	.038	,472*	,724**	1	.293	.067	.185	.172	-.270	.033
	p	.680	.539	.149	.167	.855	.015	.000		.146	.743	.364	.402	.183	.872
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee Ext Strength	r	,442*	.074	.088	.066	-.054	.290	.241	.293	1	.268	.286	.105	-,711**	.187
	p	.024	.720	.667	.749	.792	.150	.235	.146		.185	.157	.609	.000	.360
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee Flex Strength	r	.005	.008	-.038	,422*	-.061	.073	.034	.067	.268	1	,452*	-.156	,422*	,414*
	p	.981	.968	.855	.032	.768	.724	.870	.743	.185		.021	.448	.032	.035
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip Abd Strength	r	.036	-.064	-.125	.061	-,430*	-.192	-.029	.185	.286	,452*	1	.173	.085	,737**
	p	.860	.755	.543	.766	.028	.346	.887	.364	.157	.021		.397	.680	.000
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip Add Srength	r	.291	.035	.004	-.022	-.352	-.024	-.160	.172	.105	-.156	.173	1	-.106	-,465*
	p	.149	.865	.984	.917	.078	.906	.435	.402	.609	.448	.397		.606	.017
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Flex/Ext ratio	r	-.273	-.043	-.214	.242	.046	-.221	-.260	-.270	-,711**	,422*	.085	-.106	1	.108
	p	.178	.836	.294	.234	.824	.278	.199	.183	.000	.032	.680	.606		.601
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Abd/Add ratio*	r	-.208	-.052	-.093	.045	-.081	-.094	.127	.079	.121	,478*	,737**	-,549**	.179	1.000
	p	.308	.801	.651	.828	.692	.648	.538	.702	.556	.014	.000	.004	.382	
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26

*Spearmann correlation; Cells highlighted in green are correlation coefficients ≤ 0.7;

Correlation matrix between clinical outcomes for non-preferred leg

Clinical outcome	Correlation information	Lunge	SEBT A*	SEBT PM	SEBT PL*	LSD*	Hop Single*	Hop Triple	Hop Cross	Knee Ext Strength	Knee Flex Strength*	Hip Abd Strength*	Hip Add Strength	Flex/Ext Ratio	Abd/Add Ratio
Lunge	r	1	.333	-.059	.293	-,435*	.138	-.027	.078	,450*	.375	.131	.342	-.082	-.251
	p		.097	.776	.146	.026	.500	.897	.704	.021	.059	.522	.087	.690	.217
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT A*	r	.333	1.000	.152	,433*	-.181	.294	.238	.182	-.147	-.058	-.034	.112	.071	-.051
	p	.097		.458	.027	.376	.145	.242	.375	.474	.778	.868	.585	.730	.803
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT PM	r	-.059	.152	1	.212	-.055	,443*	.156	.189	-.142	-.197	-.221	-.330	-.118	.228
	p	.776	.458		.298	.789	.023	.446	.355	.488	.334	.279	.099	.567	.262
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT PL*	r	.293	,433*	.212	1.000	-.112	.302	.229	.211	-.289	.143	.062	-.131	.294	.208
	p	.146	.027	.298		.585	.133	.261	.301	.151	.485	.764	.524	.145	.308
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
LSD*	r	-,435*	-.181	-.055	-.112	1.000	-,525**	-,538**	-,418*	-.105	-.118	.024	-.292	.041	.182
	p	.026	.376	.789	.585		.006	.005	.034	.609	.566	.908	.148	.844	.374
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Single*	r	.138	.294	,443*	.302	-,525**	1.000	,632**	,439*	.081	.074	.088	.064	-.022	.110
	p	.500	.145	.023	.133	.006		.001	.025	.694	.721	.670	.756	.917	.594
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Triple	r	-.027	.238	.156	.229	-,538**	,632**	1	,761**	.131	-.015	-.145	.239	-.118	-.225
	p	.897	.242	.446	.261	.005	.001		.000	.522	.943	.481	.240	.564	.269
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Cross	r	.078	.182	.189	.211	-,418*	,439*	,761**	1	.366	.182	-.040	.362	-.095	-.377
	p	.704	.375	.355	.301	.034	.025	.000		.066	.375	.846	.069	.646	.058
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee Ext Strength	r	,450*	-.147	-.142	-.289	-.105	.081	.131	.366	1	,427*	,469*	,422*	-,601**	-.178
	p	.021	.474	.488	.151	.609	.694	.522	.066		.030	.016	.032	.001	.385
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee Flex Strength*	r	.375	-.058	-.197	.143	-.118	.074	-.015	.182	,427*	1.000	,445*	,441*	,459*	-.239
	p	.059	.778	.334	.485	.566	.721	.943	.375	.030		.023	.024	.018	.240
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip Abd Strength	r	.131	-.034	-.221	.062	.024	.088	-.145	-.040	,469*	,445*	1.000	.201	-.137	.352
	p	.522	.868	.279	.764	.908	.670	.481	.846	.016	.023		.324	.504	.077
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip Add Srength	r	.342	.112	-.330	-.131	-.292	.064	.239	.362	,422*	,441*	.201	1	-.114	-,714**
	p	.087	.585	.099	.524	.148	.756	.240	.069	.032	.024	.324		.578	.000
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Flex/Ext ratio	r	-.082	.071	-.118	.294	.041	-.022	-.118	-.095	-,601**	,459*	-.137	-.114	1	-.037
	p	.690	.730	.567	.145	.844	.917	.564	.646	.001	.018	.504	.578		.856
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Abd/Add ratio	r	-.251	-.051	.228	.208	.182	.110	-.225	-.377	-.178	-.239	.352	-,714**	-.037	1
	p	.217	.803	.262	.308	.374	.594	.269	.058	.385	.240	.077	.000	.856	
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26

*Spearmann correlation; Cells highlighted in green are correlation coefficients ≤ 0.7;

APPENDIX C – Linear regression models – Bilateral landings

Linear regression analyses for bilateral jump landing with the preferred and non-preferred legs

Dependent varible	Independent variable	r	r²	p	*f*²
Preferred leg					
Knee					
Flexor/extensor moment	Flexor/extensor ratio, Lateral step down and SEBT Anterior	0.739	0.546	0.001	1.202
Adductor/Abductor moment	Lunge	0.456	0.208	0.0019	0.262
Abductor peak moment	Hip abductor strength	0.46	0.211	0.018	0.268
Hip					
Flexion angle	SEBT Anterior	0.53	0.287	0.005	0.402
Flexor/extensor moment	Knee flexors strength and Single Hop Test	0.762	0.581	<0.001	1.386
Internal/external rotation moment	Flexor/extensor ratio, Lunge and SEBT Postero Medial	0.681	0.463	0.003	0.862
Non-preferred leg					
Knee					
Varus/valgus angle	Flexor/extensor ratio and Lateral Step Down	0.573	0.329	0.01	0.49
Hip					
External rotation angle	Flexor/extensor ratio, Lunge and Triple Hop Test	0.684	0.467	0.003	0.876

APPENDIX D – Correlation matrix between clinical and biomechanical outcomes – Unilateral landings

Correlation matrix of clinical and biomechanical outcomes for the preferred leg

Biomechanical outcome				Clinical outcomes													
Joint	**Instant**	**Outcome**	**Correlatation information**	**Lunge**	**SEBT A**	**SEBT PM**	**SEBT PL***	**LSD***	**Hop Single***	**Hop Triple**	**Hop Cross**	**Knee Ext strength**	**Knee Flex strength**	**Hip Abd strength**	**Hip Add strength**	**Flex/Ext ratio**	**Abd/Add ratio***
Ankle	IC	Sagital plane angle *	r	.208	.194	,515**	.292	-.321	.080	-.249	-.089	.050	.340	.334	.270	.149	.066
			p	.309	.343	.007	.148	.109	.699	.220	.667	.807	.089	.095	.181	.468	.749
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Sagital plane angle*	r	-.079	.127	.111	.130	-.220	.082	-.080	-.187	-,475*	.072	-.174	.059	.318	-.246
			p	.700	.538	.588	.526	.281	.689	.696	.360	.014	.726	.395	.774	.113	.225
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Frontal plane angle*	r	.091	.164	-.013	.150	.175	-.011	.032	.107	.192	.181	.099	-.074	-.042	.171
			p	.658	.424	.950	.464	.391	.956	.877	.603	.346	.377	.631	.721	.838	.405
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Sagital plane angle	r	-,429*	-,602**	-.020	-.150	.096	-.157	-.122	-.008	-.313	-.047	-.149	-.115	.167	-.103
			p	.029	.001	.921	.464	.640	.444	.552	.971	.120	.819	.467	.574	.415	.617
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Frontal plane angle	r	-.139	-.192	-.198	-.297	-.261	-.010	-.071	-.056	-.069	-.094	.075	.108	.060	-.024
			p	.498	.349	.332	.141	.198	.962	.729	.787	.737	.647	.717	.599	.771	.906
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Transverse plane angle*	r	-.117	-.243	-.271	.076	.127	-.019	.208	.212	.354	.105	-.020	-.199	-.251	.175
			p	.570	.232	.180	.714	.538	.925	.307	.298	.076	.610	.922	.329	.217	.393
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Ankle	IC	Sagital plane moment	r	.084	-.140	-.342	-.091	-.097	-.159	-.207	.097	.038	-.036	.264	-.029	.051	.169
			p	.682	.496	.087	.660	.636	.438	.311	.638	.852	.860	.192	.889	.805	.409
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Sagital plane moment	r	-.118	-.233	-.129	.161	-.370	-.210	.072	.123	.278	.278	.365	-.246	-.096	,471*
			p	.567	.252	.530	.432	.063	.304	.727	.550	.169	.169	.067	.225	.642	.015
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Frontal plane moment	r	-.183	-.265	-.129	-.009	-.281	-.091	.102	.251	.228	.379	,518**	-.075	.031	,519**
			p	.372	.191	.531	.967	.165	.657	.621	.216	.263	.056	.007	.715	.881	.007
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Sagital plane moment	r	-.050	.129	-.270	-,451*	.280	.092	-.091	-.197	-,482*	-,419*	-.303	.156	.206	-.277
			p	.807	.531	.182	.021	.167	.655	.659	.334	.013	.033	.132	.447	.313	.170
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Frontal plane moment	r	.115	-.021	-.165	-.195	-,495*	-.153	-.189	-.068	.242	.103	.303	.196	-.064	.076
			p	.576	.919	.422	.341	.010	.456	.355	.742	.233	.616	.133	.336	.758	.714
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Transverse plane moment	r	.017	-.102	-.097	.091	.295	-.083	-.048	-.188	-.242	-.046	-.332	.145	.247	-.300
			p	.935	.619	.637	.657	.143	.687	.816	.358	.233	.824	.097	.481	.224	.137
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	Peak valgus	Frontal plane angle	r	-.234	-.115	-.048	.016	.328	-.153	-.205	.012	-.019	.127	.148	-.205	.114	.138
			p	.249	.575	.816	.938	.102	.455	.316	.955	.928	.536	.470	.314	.578	.500
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	Peak abductor	Frontal plane moment*	r	.208	.315	.289	-.111	-.013	.185	-.356	-.261	.083	-.101	-.100	.199	-.244	-.283
			p	.308	.117	.152	.589	.948	.365	.075	.199	.685	.623	.627	.330	.229	.161
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
N/A	Peak	Ground reaction force	r	-.112	-.033	-.139	-.251	-.128	-.140	-.080	.054	-.245	-,655**	-.183	.145	-.188	-.240
			p	.586	.874	.499	.216	.532	.496	.697	.794	.228	.000	.371	.481	.358	.237
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
N/A	Rate	Ground reaction force	r	-.159	-.041	-.008	.032	-.114	-.024	.141	.263	-.069	-.196	.110	.166	-.064	.087
			p	.439	.844	.968	.877	.580	.909	.492	.195	.739	.336	.593	.417	.757	.672
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26

*Spearmann correlation; Cells highlighted in light orange are p values ≤ 0.20; Cells highlighted in dark orange are the clinical outcomes inserted in each model.

Correlation matrix of clinical and biomechanical outcomes for the non-preferred leg

Biomechanical outcome				Clinical outcomes													
Joint	**Instant**	**Outcome**	**Correlatation information**	**Lunge**	**SEBT A***	**SEBT PM**	**SEBT PL***	**LSD***	**Hop Single***	**Hop Triple**	**Hop Cross**	**Knee Ext strength**	**Knee Flex strength**	**Hip Abd strength**	**Hip Add strength**	**Flex/Ext ratio***	**Abd/Add ratio***
Ankle	IC	Sagital plane angle *	r	.036	.188	-.030	-.006	-.052	.180	.208	.204	.061	-.160	-.110	-.035	-.138	.013
			p	.862	.357	.885	.978	.801	.378	.307	.317	.769	.434	.591	.867	.502	.951
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Sagital plane angle	r	,520**	,522**	-.292	.189	-.348	.320	.333	.199	.181	.165	.070	.214	-.002	-.111
			p	.006	.006	.148	.356	.081	.111	.097	.331	.376	.420	.734	.293	.994	.590
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Frontal plane angle*	r	-.151	-.210	.257	.033	,611**	-.294	-.277	-.128	.084	-.136	.182	-.293	-.218	.281
			p	.460	.304	.205	.873	.001	.144	.170	.535	.684	.506	.373	.146	.284	.165
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Sagital plane angle	r	.091	-.176	-,473*	-.231	-.273	.074	.065	-.032	-.104	.087	.035	.112	.190	-.190
			p	.658	.388	.015	.256	.177	.719	.753	.875	.613	.672	.867	.585	.352	.352
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Frontal plane angle	r	.335	.180	-.092	.113	-.241	.253	.331	.212	.139	-.028	-.074	-.128	-.164	-.006
			p	.094	.379	.654	.582	.235	.213	.098	.297	.498	.893	.719	.533	.423	.977
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Transverse plane angle	r	.298	.018	.124	-.151	.155	-.112	-.288	-.287	.192	-.170	.089	-.059	-.378	.136
			p	.140	.929	.547	.462	.450	.584	.153	.155	.348	.407	.667	.776	.057	.507
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Ankle	IC	Sagital plane moment *	r	-.159	-.183	-.195	-.242	-.131	.093	.140	.226	.200	.194	-.071	.006	.059	-.240
			p	.438	.370	.340	.234	.523	.653	.496	.268	.327	.342	.731	.975	.773	.237
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Sagital plane moment	r	.208	.247	.136	.024	-.046	.245	.065	.175	.255	.288	.057	-.010	.039	.077
			p	.308	.225	.507	.908	.823	.227	.753	.393	.210	.154	.782	.961	.851	.709
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	IC	Frontal plane moment	r	.280	-.199	-.383	-.273	.042	-.277	-.307	.023	.345	.238	.284	-.035	.005	-.022
			p	.166	.331	.053	.177	.839	.170	.127	.912	.084	.242	.160	.867	.982	.917
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Sagital plane moment	r	-.295	-.258	-.171	-.119	-.085	-.080	.228	.134	-.207	-.258	-.177	.154	-.065	-.287
			p	.143	.203	.405	.562	.681	.699	.262	.513	.310	.203	.386	.451	.753	.155
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Frontal plane moment	r	.003	-.076	-.341	-.377	.067	-.225	-.264	.015	.188	.132	.157	-.073	-.104	.075
			p	.988	.714	.089	.058	.747	.270	.193	.943	.358	.522	.444	.722	.614	.714
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip	IC	Transverse plane moment	r	-.121	.195	-.016	.323	-.260	,605**	.362	-.062	-.294	.032	.124	.044	.288	.194
			p	.557	.339	.940	.108	.200	.001	.069	.764	.145	.875	.546	.831	.153	.343
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	Peak valgus	Frontal plane angle*	r	-.193	-,485*	.159	-.150	.222	-.167	-.219	-.100	.277	.093	.290	.032	-.280	.064
			p	.344	.012	.437	.464	.275	.416	.283	.627	.170	.653	.151	.877	.166	.756
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee	Peak abductor	Frontal plane moment	r	-.105	-.345	-.196	-.341	.086	-,413*	-.148	.091	.181	.169	.206	-.063	-.053	.001
			p	.608	.084	.337	.088	.677	.036	.469	.658	.377	.408	.314	.761	.796	.995
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
N/A	Peak	Ground reaction force	r	-.188	.208	-.178	-.078	-.124	-.079	.175	.240	.169	-.138	-.217	.292	-.303	-.343
			p	.357	.307	.386	.704	.546	.701	.393	.237	.409	.500	.287	.148	.133	.086
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
N/A	Rate	Ground reaction force	r	.077	.129	-.171	-.147	-.134	.064	.114	.111	,473*	-.019	.050	.249	-,516**	-.229
			p	.707	.529	.405	.473	.514	.756	.580	.589	.015	.927	.810	.220	.007	.261
			n	26	26	26	26	26	26	26	26	26	26	26	26	26	26

*Spearmann correlation; Cells highlighted in light orange are p values ≤ 0.20; Cells highlighted in dark orange are the clinical outcomes inserted in each model.

APPENDIX E – Correlation matrix between clinical outcomes – Unilateral landings

Correlation matrix between clinical outcomes for preferred leg

Clinical outcome	Correlation information	Lunge	SEBT A	SEBT PM	SEBT PL*	LSD*	Hop Single*	Hop Triple	Hop Cross	Knee Ext Strength	Knee Flex Strength	Hip Abd Strength	Hip Add Strength	Flex/Ext Ratio	Abd/Add Ratio*
Lunge	r	1	,506**	.020	-.079	-.182	-.033	.019	-.085	,442*	.005	.036	.291	-.273	-.163
	p		.008	.925	.700	.372	.873	.926	.680	.024	.981	.860	.149	.178	.427
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT A	r	,506**	1	.207	.144	-.251	.363	.246	.126	.074	.008	-.064	.035	-.043	-.123
	p	.008		.311	.483	.215	.068	.227	.539	.720	.968	.755	.865	.836	.549
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT PM	r	.020	.207	1	,554**	.064	.330	.210	.291	.088	-.038	-.125	.004	-.214	-.233
	p	.925	.311		.003	.757	.099	.302	.149	.667	.855	.543	.984	.294	.253
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT PL*	r	-.003	.134	.296	1.000	-.028	.213	-.139	.035	.003	,462*	.239	.039	.334	.045
	p	.989	.515	.142		.891	.296	.498	.864	.987	.017	.240	.849	.095	.828
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
LSD*	r	-.243	-.321	.155	-.028	1.000	.274	.176	.074	-.078	.008	-,426*	-.332	.021	-.081
	p	.231	.109	.449	.891		.175	.389	.719	.703	.969	.030	.097	.918	.692
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Single*	r	-.008	,392*	.201	.213	.274	1.000	,594**	.317	.259	.077	-.240	-.207	-.300	-.094
	p	.970	.047	.326	.296	.175		.001	.114	.202	.707	.238	.311	.136	.648
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Triple	r	.019	.246	.210	.030	.143	,636**	1	,724**	.241	.034	-.029	-.160	-.260	.166
	p	.926	.227	.302	.883	.487	.000		.000	.235	.870	.887	.435	.199	.416
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Cross	r	-.085	.126	.291	.279	.038	,472*	,724**	1	.293	.067	.185	.172	-.270	.033
	p	.680	.539	.149	.167	.855	.015	.000		.146	.743	.364	.402	.183	.872
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee Ext Strength	r	,442*	.074	.088	.066	-.054	.290	.241	.293	1	.268	.286	.105	-,711**	.187
	p	.024	.720	.667	.749	.792	.150	.235	.146		.185	.157	.609	.000	.360
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee Flex Strength	r	.005	.008	-.038	,422*	-.061	.073	.034	.067	.268	1	,452*	-.156	,422*	,414*
	p	.981	.968	.855	.032	.768	.724	.870	.743	.185		.021	.448	.032	.035
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip Abd Strength	r	.036	-.064	-.125	.061	-,430*	-.192	-.029	.185	.286	,452*	1	.173	.085	,737**
	p	.860	.755	.543	.766	.028	.346	.887	.364	.157	.021		.397	.680	.000
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip Add Srength	r	.291	.035	.004	-.022	-.352	-.024	-.160	.172	.105	-.156	.173	1	-.106	-,465*
	p	.149	.865	.984	.917	.078	.906	.435	.402	.609	.448	.397		.606	.017
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Flex/Ext ratio	r	-.273	-.043	-.214	.242	.046	-.221	-.260	-.270	-,711**	,422*	.085	-.106	1	.108
	p	.178	.836	.294	.234	.824	.278	.199	.183	.000	.032	.680	.606		.601
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Abd/Add ratio*	r	-.208	-.052	-.093	.045	-.081	-.094	.127	.079	.121	,478*	,737**	-,549**	.179	1.000
	p	.308	.801	.651	.828	.692	.648	.538	.702	.556	.014	.000	.004	.382	
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26

*Spearmann correlation; Cells highlighted in green are correlation coefficients ≤ 0.7;

Correlation matrix between clinical outcomes for non-preferred leg

Clinical outcome	Correlation information	Lunge	SEBT A*	SEBT PM	SEBT PL*	LSD*	Hop Single*	Hop Triple	Hop Cross	Knee Ext Strength	Knee Flex Strength*	Hip Abd Strength*	Hip Add Strength	Flex/Ext Ratio	Abd/Add Ratio
Lunge	r	1	.333	-.059	.293	-,435*	.138	-.027	.078	,450*	.375	.131	.342	-.082	-.251
	p		.097	.776	.146	.026	.500	.897	.704	.021	.059	.522	.087	.690	.217
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT A*	r	.333	1.000	.152	,433*	-.181	.294	.238	.182	-.147	-.058	-.034	.112	.071	-.051
	p	.097		.458	.027	.376	.145	.242	.375	.474	.778	.868	.585	.730	.803
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT PM	r	-.059	.152	1	.212	-.055	,443*	.156	.189	-.142	-.197	-.221	-.330	-.118	.228
	p	.776	.458		.298	.789	.023	.446	.355	.488	.334	.279	.099	.567	.262
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
SEBT PL*	r	.293	,433*	.212	1.000	-.112	.302	.229	.211	-.289	.143	.062	-.131	.294	.208
	p	.146	.027	.298		.585	.133	.261	.301	.151	.485	.764	.524	.145	.308
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
LSD*	r	-,435*	-.181	-.055	-.112	1.000	-,525**	-,538**	-,418*	-.105	-.118	.024	-.292	.041	.182
	p	.026	.376	.789	.585		.006	.005	.034	.609	.566	.908	.148	.844	.374
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Single*	r	.138	.294	,443*	.302	-,525**	1.000	,632**	,439*	.081	.074	.088	.064	-.022	.110
	p	.500	.145	.023	.133	.006		.001	.025	.694	.721	.670	.756	.917	.594
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Triple	r	-.027	.238	.156	.229	-,538**	,632**	1	,761**	.131	-.015	-.145	.239	-.118	-.225
	p	.897	.242	.446	.261	.005	.001		.000	.522	.943	.481	.240	.564	.269
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hop Cross	r	.078	.182	.189	.211	-,418*	,439*	,761**	1	.366	.182	-.040	.362	-.095	-.377
	p	.704	.375	.355	.301	.034	.025	.000		.066	.375	.846	.069	.646	.058
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee Ext Strength	r	,450*	-.147	-.142	-.289	-.105	.081	.131	.366	1	,427*	,469*	,422*	-,601**	-.178
	p	.021	.474	.488	.151	.609	.694	.522	.066		.030	.016	.032	.001	.385
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Knee Flex Strength*	r	.375	-.058	-.197	.143	-.118	.074	-.015	.182	,427*	1.000	,445*	,441*	,459*	-.239
	p	.059	.778	.334	.485	.566	.721	.943	.375	.030		.023	.024	.018	.240
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip Abd Strength	r	.131	-.034	-.221	.062	.024	.088	-.145	-.040	,469*	,445*	1.000	.201	-.137	.352
	p	.522	.868	.279	.764	.908	.670	.481	.846	.016	.023		.324	.504	.077
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Hip Add Srength	r	.342	.112	-.330	-.131	-.292	.064	.239	.362	,422*	,441*	.201	1	-.114	-,714**
	p	.087	.585	.099	.524	.148	.756	.240	.069	.032	.024	.324		.578	.000
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Flex/Ext ratio	r	-.082	.071	-.118	.294	.041	-.022	-.118	-.095	-,601**	,459*	-.137	-.114	1	-.037
	p	.690	.730	.567	.145	.844	.917	.564	.646	.001	.018	.504	.578		.856
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Abd/Add ratio	r	-.251	-.051	.228	.208	.182	.110	-.225	-.377	-.178	-.239	.352	-,714**	-.037	1
	p	.217	.803	.262	.308	.374	.594	.269	.058	.385	.240	.077	.000	.856	
	n	26	26	26	26	26	26	26	26	26	26	26	26	26	26

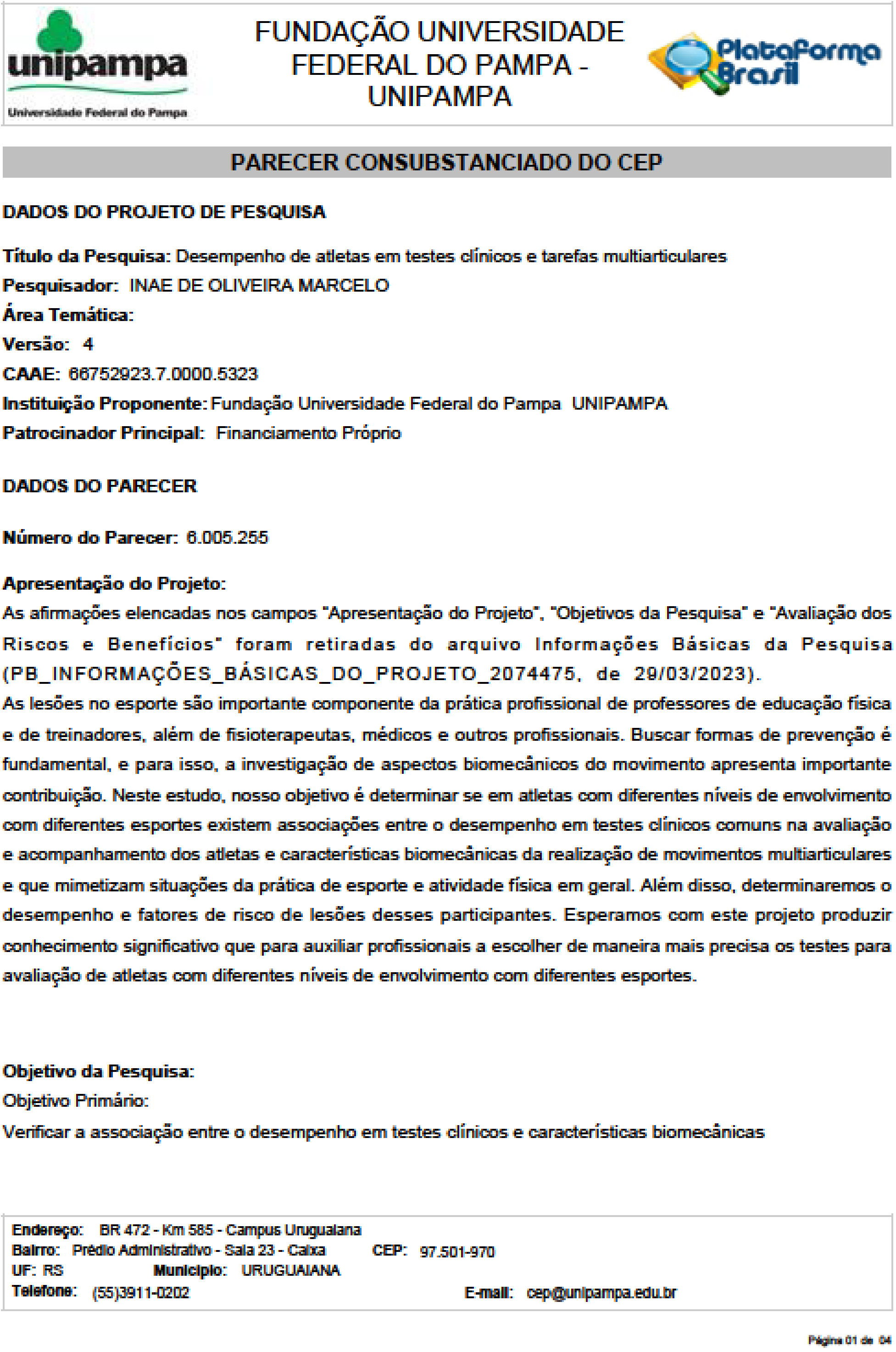
*Spearmann correlation; Cells highlighted in green are correlation coefficients ≤ 0.7;

APPENDIX F – Linear regression models – Unilateral landings

Linear regression analyses for unilateral jump landing with the preferred and non-preferred legs

Dependent varible	Independent variable	r	r^2	p	f^2
Preferred leg					
Knee					
Extensor moment	Abductors/Adductors Ratio	0.49	0.24	0.011	0.315
Adductor/Abductor moment	Hip abductor strength	0.518	0.269	0.007	0.368
Hip					
Flexion angle	SEBT Anterior	0.602	0.363	0.001	0.57
Flexor/extensor moment	Knee flexors strength and SEBT Postero Lateral	0.611	0.373	0.005	0.595
Adductor/Abductor moment	Lateral Step Down	0.533	0.284	0.005	0.396
vGRF component					
vGRF peak	Knee flexors strength	0.655	0.429	<0.001	0.751
Non-preferred leg					
Ankle					
Dorsiflexor/plantarflexor moment	Single Hop Test	0.51	0.26	0.009	0.351
Knee					
Flexion angle	Lunge, SEBT Postero Medial and Triple Hop Test	0.702	0.493	0.002	0.972
Varus/valgus angle	Lateral Step Down	0.573	0.329	0.002	0.49
Hip					
External rotation angle	Flexor/extensor ratio, Lunge and Triple Hop Test	0.684	0.467	0.003	0.876
vGRF component					
vGRF rate	Flexor/extensor ratio	0.516	0.267	0.007	0.364

ANNEX 1 - Ethics committee approval



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Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Desempenho de atletas em testes clínicos e tarefas multiarticulares
Pesquisador: INAE DE OLIVEIRA MARCELO
Área Temática:
Versão: 4
CAAE: 66752923.7.0000.5323
Instituição Proponente: Fundação Universidade Federal do Pampa UNIPAMPA
Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 6.005.255

Apresentação do Projeto:
As afirmações elencadas nos campos "Apresentação do Projeto", "Objetivos da Pesquisa" e "Avaliação dos Riscos e Benefícios" foram retiradas do arquivo Informações Básicas da Pesquisa (PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_2074475, de 29/03/2023).
As lesões no esporte são importante componente da prática profissional de professores de educação física e de treinadores, além de fisioterapeutas, médicos e outros profissionais. Buscar formas de prevenção é fundamental, e para isso, a investigação de aspectos biomecânicos do movimento apresenta importante contribuição. Neste estudo, nosso objetivo é determinar se em atletas com diferentes níveis de envolvimento com diferentes esportes existem associações entre o desempenho em testes clínicos comuns na avaliação e acompanhamento dos atletas e características biomecânicas da realização de movimentos multiarticulares e que mimetizam situações da prática de esporte e atividade física em geral. Além disso, determinaremos o desempenho e fatores de risco de lesões desses participantes. Esperamos com este projeto produzir conhecimento significativo que para auxiliar profissionais a escolher de maneira mais precisa os testes para avaliação de atletas com diferentes níveis de envolvimento com diferentes esportes.

Objetivo da Pesquisa:
Objetivo Primário:
Verificar a associação entre o desempenho em testes clínicos e características biomecânicas

associadas com desempenho e risco de lesão.

Objetivo Secundário:

Avaliar os fatores de risco de lesão de membros inferiores de atletas de diferentes modalidades esportivas. Avaliar o desempenho de atletas de diferentes modalidades esportivas em testes clínicos.

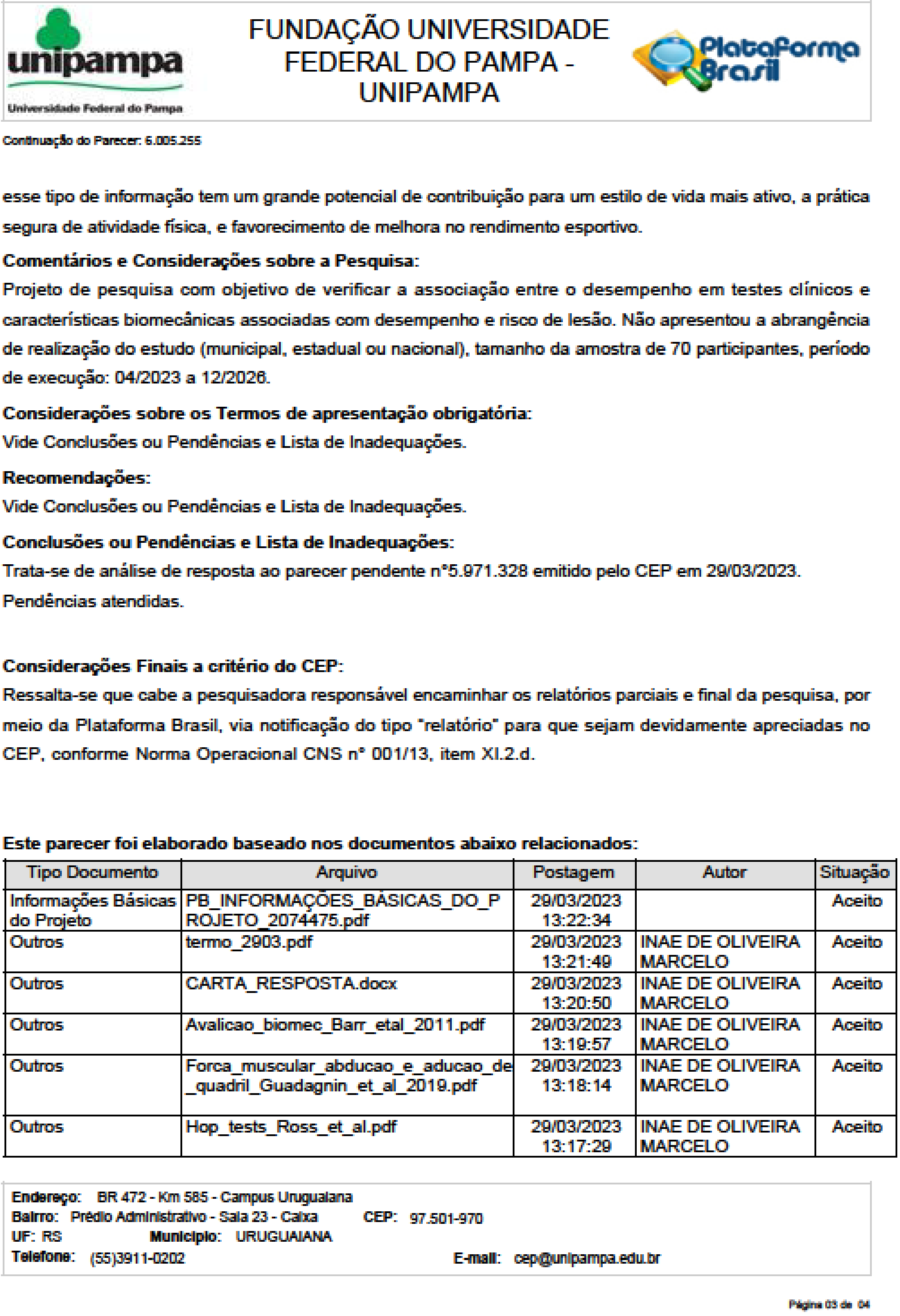
Avaliação dos Riscos e Benefícios:

Riscos:

O participante poderá experenciar sensações de desconforto, vergonha, estresse, aborrecimento, constrangimento ao responder perguntas realizadas na anamnese e nos questionários de anamnese. Para minimizar esses riscos, a equipe de pesquisa irá garantir a privacidade no momento de responder as perguntas, a garantia das explicações necessárias para responder às questões, a liberdade de se recusar a responder, uma abordagem cautelosa ao participante e o sigilo em relação às respostas. Em relação às avaliações físicas, o participante poderá experenciar algum constrangimento ao realizar exames antropométricos e ao se expor, apresentar alterações na pressão arterial, sensação de fadiga e cansaço, aumento da frequência respiratória, tonturas, entre outros. Após a realização dos testes, o participante poderá experenciar dor e desconforto muscular, que não devem diferir muito do que acontece ao realizar uma sessão de exercícios físicos. Como forma de minimização dos riscos, os testes serão realizados por profissionais capacitados e treinados que irão garantir o encerramento imediato do teste e assistência primária ao participante ao perceber algum risco ou danos à saúde, informe sobre o tempo de duração e orientações para lidar com a dor/desconforto muscular. O participante terá o direito de assistência integral e imediata (Resolução 466/2012: II.3.1 e II.3.2) em situações que necessite. O participante poderá sentir medo e/ou desconforto com a divulgação de dados confidenciais. A equipe garantirá o limite ao acesso aos prontuários, o zelo pelo sigilo dos dados fornecidos e pela guarda adequada das informações coletadas e o compromisso de não publicar qualquer identificação do participante.

Benefícios:

Os benefícios que os participantes terão ao participar deste estudo serão: receber resultados detalhados de sua condição física com avaliações usando tecnologia de ponta e conduzidas por profissionais altamente especializados, incluindo medidas antropométricas, nível de força muscular, potência, preferência lateral e estimativa de riscos de lesão de membros inferiores na prática esportiva. No caso de serem identificados fatores de risco para lesão, os participantes serão orientados quanto a estratégias para prevenção. Considerando o público alvo do projeto,



esse tipo de informação tem um grande potencial de contribuição para um estilo de vida mais ativo, a prática segura de atividade física, e favorecimento de melhora no rendimento esportivo.

Comentários e Considerações sobre a Pesquisa:

Projeto de pesquisa com objetivo de verificar a associação entre o desempenho em testes clínicos e características biomecânicas associadas com desempenho e risco de lesão. Não apresentou a abrangência de realização do estudo (municipal, estadual ou nacional), tamanho da amostra de 70 participantes, período de execução: 04/2023 a 12/2026.

Considerações sobre os Termos de apresentação obrigatória:

Vide Conclusões ou Pendências e Lista de Inadequações.

Recomendações:

Vide Conclusões ou Pendências e Lista de Inadequações.

Conclusões ou Pendências e Lista de Inadequações:

Trata-se de análise de resposta ao parecer pendente n°5.971.328 emitido pelo CEP em 29/03/2023.

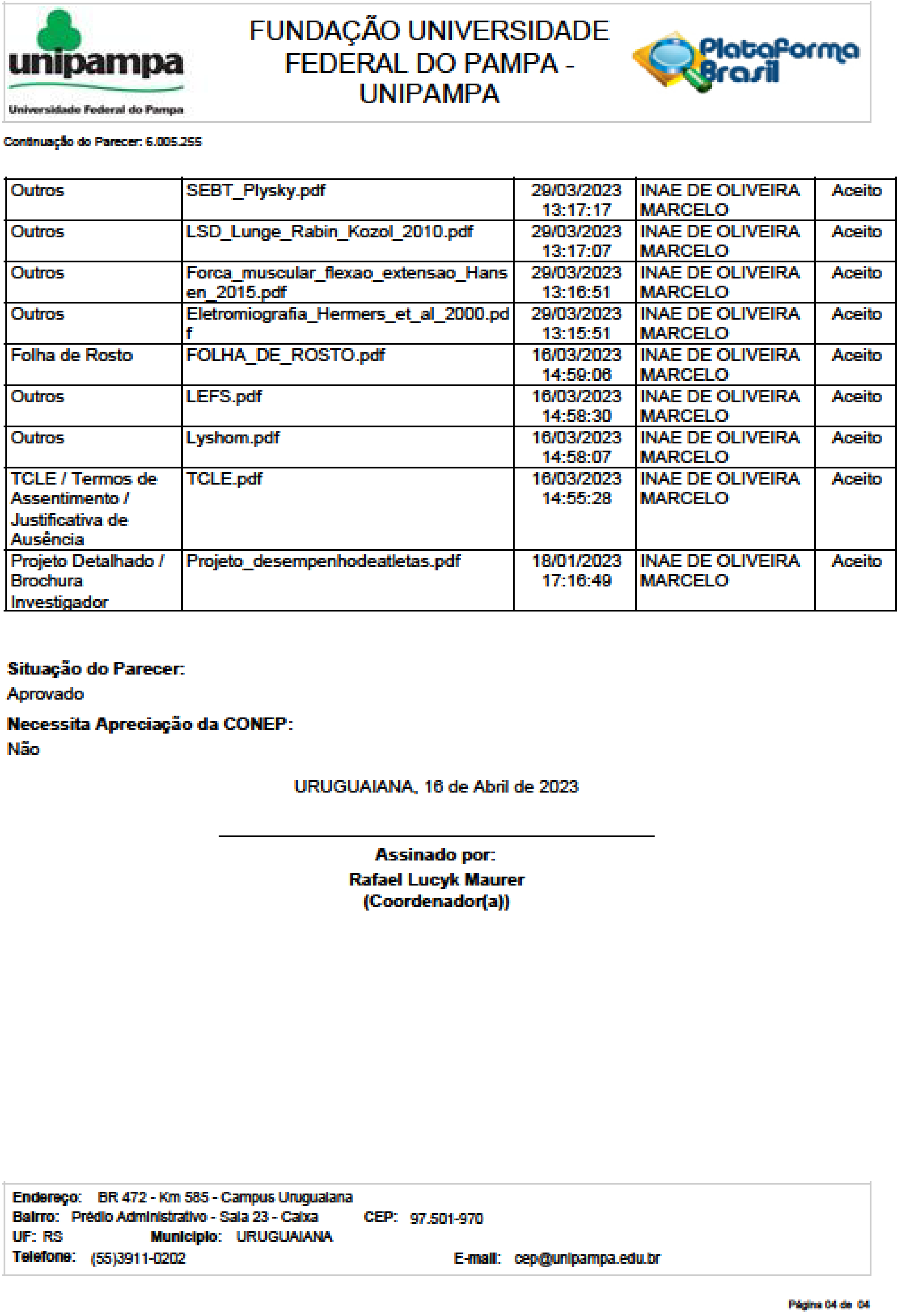
Pendências atendidas.

Considerações Finais a critério do CEP:

Ressalta-se que cabe a pesquisadora responsável encaminhar os relatórios parciais e final da pesquisa, por meio da Plataforma Brasil, via notificação do tipo "relatório" para que sejam devidamente apreciadas no CEP, conforme Norma Operacional CNS n° 001/13, item XI.2.d.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_2074475.pdf	29/03/2023 13:22:34		Aceito
Outros	termo_2903.pdf	29/03/2023 13:21:49	INAE DE OLIVEIRA MARCELO	Aceito
Outros	CARTA_RESPOSTA.docx	29/03/2023 13:20:50	INAE DE OLIVEIRA MARCELO	Aceito
Outros	Avalicao_biomec_Barr_etal_2011.pdf	29/03/2023 13:19:57	INAE DE OLIVEIRA MARCELO	Aceito
Outros	Forca_muscular_abducao_e_aducao_de_quadril_Guadagnin_et_al_2019.pdf	29/03/2023 13:18:14	INAE DE OLIVEIRA MARCELO	Aceito
Outros	Hop_tests_Ross_et_al.pdf	29/03/2023 13:17:29	INAE DE OLIVEIRA MARCELO	Aceito



Continuação do Parecer: 6.005.255

Outros	SEBT_Plysky.pdf	29/03/2023 13:17:17	INAE DE OLIVEIRA MARCELO	Aceito
Outros	LSD_Lunge_Rabin_Kozol_2010.pdf	29/03/2023 13:17:07	INAE DE OLIVEIRA MARCELO	Aceito
Outros	Forca_muscular_flexao_extensao_Hansen_2015.pdf	29/03/2023 13:16:51	INAE DE OLIVEIRA MARCELO	Aceito
Outros	Eletromiografia_Hermers_et_al_2000.pdf	29/03/2023 13:15:51	INAE DE OLIVEIRA MARCELO	Aceito
Folha de Rosto	FOLHA_DE_ROSTO.pdf	16/03/2023 14:59:06	INAE DE OLIVEIRA MARCELO	Aceito
Outros	LEFS.pdf	16/03/2023 14:58:30	INAE DE OLIVEIRA MARCELO	Aceito
Outros	Lyshom.pdf	16/03/2023 14:58:07	INAE DE OLIVEIRA MARCELO	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.pdf	16/03/2023 14:55:28	INAE DE OLIVEIRA MARCELO	Aceito
Projeto Detalhado / Brochura Investigador	Projeto_desempenhodeatletas.pdf	18/01/2023 17:16:49	INAE DE OLIVEIRA MARCELO	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

URUGUAIANA, 16 de Abril de 2023

Assinado por:
Rafael Lucyk Maurer
(Coordenador(a))