EVALUATION OF ANKLE MOVEMENTS ON A SUDDEN INVERSION PLATFORM

AVALIAÇÃO DOS MOVIMENTOS DO TORNOZELO NA PLATAFORMA DE INVERSÃO SÚBITA

EVALUACIÓN DE LOS MOVIMIENTOS DEL TOBILLO EN LA PLATAFORMA DE INVERSIÓN SÚBITA

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Leandro Dias dos Santos[1,2]
(Physical Therapist)
César Augusto Martins Pereira[1]
(Engineering Technologist)
Raul Bolligner Neto[1]
(Physician)
Angélica Castilho Alonso[1]
(Physical Therapist)
Júlia Maria D'Andrea Greve[1]
(Physician)

1. Universidade de São Paulo, Faculdade de Medicina, Hospital das Clínicas, São Paulo, SP, Brazil.
2. Physical Therapy Department of the São Bernardo Futebol Clube, São Bernardo do Campo, SP, Brazil.

Correspondence:
Leandro Dias dos Santos
Rua Lucidalva da Silva, 148, Jd. Das Orquídeas, São Bernardo do Campo, São Paulo, Brazil.
09854-520.
e-mail: le.tribo@gmail.com

ABSTRACT

Introduction: Ankle sprains are frequent in sports activities and can lead to joint instability with clinical and performance consequences. Sudden ankle inversion platforms have been used to study the mechanism of ankle sprain. Objectives: To test a static platform that simulates the movement of ankle sprain (sudden inversion) in soccer players. Methods: A platform was developed to perform the sudden movement of an ankle sprain dissociated in three axes: inversion, plantar flexion, and medial rotation. A computer program was also created to read the angular velocity and the time to reach the maximum amplitude of the three axes of movement, synchronized with the platform movements. Thirty soccer players without ankle sprains were evaluated on the sudden inversion platform. Each athlete performed 10 randomly initiated tests, with five per leg. Results: There was no statistical difference in angular velocity or time to reach maximum range of motion of plantar flexion and medial rotation between the tests. During the tests, the angular velocity of the inversion increased. Conclusion: The sudden static platform evaluated the movements performed by the ankle during the sprain reliably in the 10 tests with no difference in the mechanical behavior. ***Level of evidence I; Therapeutic studies - Investigation of treatment outcomes.***

Keywords: Ankle; Athletes; Soccer; Supplies; Youth.

RESUMO

Introdução: A entorse do tornozelo é frequente nas atividades esportivas, podendo levar à instabilidade articular com consequências clínicas e de desempenho. As plataformas de inversão súbita do tornozelo têm sido usadas para estudar o mecanismo de entorse do tornozelo. Objetivos: Testar uma plataforma estática que simule o movimento de entorse do tornozelo (inversão súbita) em jogadores de futebol. Métodos: A plataforma foi desenvolvida para realizar o movimento súbito da entorse de tornozelo dissociado em três eixos: inversão, flexão plantar e rotação medial. Também foi criado um programa de computador para leitura da velocidade angular e do tempo para atingir a amplitude máxima dos três eixos de movimento, sincronizados com os movimentos da plataforma. Trinta jogadores de futebol sem entorse de tornozelo foram avaliados na plataforma súbita. Cada atleta fez 10 testes, iniciados de forma aleatória, sendo cinco em cada perna. Resultados: Entre os testes, não houve diferença estatística das velocidades angulares e tempo para atingir a amplitude máxima do movimento de flexão plantar e rotação medial. Durante os testes, a velocidade angular da inversão aumentou. Conclusão: A plataforma estática súbita, avaliada em 10 tentativas, foi confiável para avaliar os movimentos executados pelo tornozelo durante a entorse, e não houve diferença de comportamento mecânico. ***Nível de evidência I; Estudos terapêuticos - Investigação dos resultados do tratamento.***

Descritores: *Tornozelo; Atletas; Futebol; Dispositivo; Jovens.*

RESUMEN

Introducción: El esguince de tobillo es frecuente en las actividades deportivas y puede provocar inestabilidad articular con consecuencias clínicas y de desempeño. Se han utilizado plataformas de inversión súbita del tobillo para estudiar el mecanismo del esguince de tobillo. Objetivos: Probar una plataforma estática que simule el movimiento de esguince de tobillo (inversión súbita) en jugadores de fútbol. Métodos: La plataforma fue desarrollada para realizar el movimiento brusco del esguince de tobillo disociado en tres ejes: inversión, flexión plantar y rotación medial. También se creó un programa informático para leer la velocidad angular y el tiempo para alcanzar la máxima amplitud de los tres ejes de movimiento, sincronizados con los movimientos de la plataforma. Treinta futbolistas sin esguince de tobillo fueron evaluados en la plataforma súbita. Cada atleta realizó 10 pruebas, iniciadas al azar, cinco en cada pierna. Resultados: Entre las pruebas, no hubo diferencias estadísticas en las velocidades angulares y el tiempo para alcanzar la amplitud máxima de los movimientos de flexión plantar y rotación medial. Durante las pruebas, la velocidad angular de la inversión aumentó. Conclusión: La plataforma estática súbita, evaluada en 10 intentos, fue confiable para evaluar los movimientos realizados por el tobillo durante el esguince, y no hubo diferencias en el comportamiento mecánico. ***Nivel de Evidencia I; Estudios terapéuticos - Investigación de los resultados del tratamiento.***

Descriptores: *Tobillo; Atletas; Fútbol; Suministros; Jóvenes.*

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INTRODUCTION

Ankle injuries are common and responsible for 15% of all sports injuries in American college athletes.[1] Ankle sprain occurs during landing from a jump or changes in direction while running.[2-4] It is a combination of plantar flexion (sagittal plane), adduction (transverse or coronal plane), and supination movements (frontal plane) that results in inversion, which occurs around the Henk's axis of the subtalar joint.[5,6]

When the subtalar joint is forced into a rapid inversion movement, the mechanoreceptors of the lateral compartment of the ankle and intramuscular axes of the fibularis muscles are activated to avoid inversion, along with the occurrence of dorsal flexion (tibialis anterior), which contributes to limit inversion.[7]

Muscle action is associated with the proprioceptive response and the initial position of the foot. The unexpected imbalance changes the posture and triggers muscle reflexes to restore balance.[8]

Sudden inversion platforms with one or two axes of movement[9-13] have been used to study ankle sprains, as well as to measure the response time of the fibularis and tibialis anterior muscles.[14-15] However, there are few studies with movement platforms that analyze three axes independently.

The objective of this study was to evaluate movements on a sudden inversion platform with 20°inversion, 20º plantar flexion, and 15º medial rotation of the ankle.

METHODS

Platform

The sudden inversion platform was developed at the Biomechanics Laboratory (LIM-41) of the Instituto de Ortopedia e Traumatologia of the Hospital das Clínicas da Faculdade de Medicina of the Universidade de São Paulo, after approval by CAPPesq and CONEP as number 1272/09.

Two adjustable plank-shaped supports were developed with a 30-centimeter space between them[11] capable of performing combined ankle movements of 20° inversion, 20º plantar flexion, and 15º medial rotation.[16,17] For the medial rotation, a 20-newton traction spring was attached to the lower front edge of each support. Angular sensors were coupled to the three articulation axes (Figure 1[a]). The planks had adjustable supports to accommodate different foot sizes. Two Velcro straps were used to secure the foot, keeping it immobile in relation to the plank. The release of each plank was activated electronically. The evaluator triggered the movement, but the subject did not know which of the planks would be released (Figure 1B).

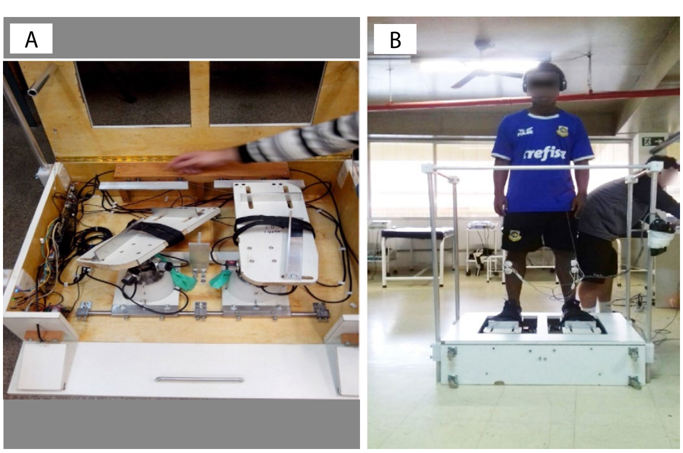

Figure 1. A. Sudden inversion platform with foot support and lateral support. B. Positioning the subject on the platform.

Control system

A computer program was developed (using the Delphi language) to control the equipment during data collection. An electronic interface (USB) between the platform and the computer was established to:

1. Acquire the angular displacement of the six optical encoders;
2. Monitor the release of the planks by means of two electrical switches.

The evaluation of the platform was conducted in the Physical Therapy Sector of the São Bernardo Futebol Clube, with soccer players from the club's youth system.

Study sample

The participants agreed to participate by signing the Informed Consent Form (ICF). In cases where the participant was under 18 years of age, the ICF was obtained from the legal guardians.

Thirty male individuals between 16 and 19 years of age, who had played competitive soccer for two years or more and had a medical certificate authorizing them to participate in supervised physical activity, were included. Subjects with previous ankle sprains or recent injuries (15 days or less since return to sports activities) were excluded.

Evaluation

The athletes were evaluated on the sudden inversion platform and categorized according to the dominance of the lower limbs, defined as the kicking leg informed by the athlete.

The subjects were positioned on the bipedal support with their gaze fixed on a mark two meters high on a wall located four meters from the platform. The subjects wore model Q7 headphones[18-19] playing music, so as not to hear the platform release. The athletes could lean on the protective side bars during the platform trials.

Ten randomly distributed trials, five on the right side and five on the left, were conducted without the interference of the evaluator.

Data collection and storage

The movements executed by the platform during sudden inversion were collected. The platform parameters evaluated were angular velocity (degrees/second), time to reach maximum amplitude (milliseconds – ms) of inversion, plantar flexion, and medial rotation of the ankle.

Statistical analysis

The data obtained were processed in SPSS (Statistical Package for the Social Sciences) and a significance level of 5% ($p > 0.05$) was adopted.

Spearman's correlation was applied between the non-parametric quantitative variables. The Friedman statistical tests were conducted with related samples of non-parametric quantitative data within each group to evaluate platform movement velocities, comparing the five trials performed on each side and, in cases where there was significance, Dunn's posttest was performed.

The Wilcoxon test was conducted for a comparison between the evaluated and non-evaluated sides of the dominant and non-dominant groups to evaluate the platform movement velocities, comparing the five trials performed on each side. In all cases, a significance index of 5% ($p<0.05$) was adopted.

RESULTS

There was no difference between the dominant and non-dominant sides in terms of angular velocity during the platform movement in the analysis of all the trials executed. The plantar flexion angular velocity was higher in both groups evaluated (Figure 2).

No differences in plantar flexion velocity were identified between the tests of the same group. The plantar flexion velocity of the dominant group was higher than that of the non-dominant group in all tests (Figure 3A):

- Dominant test 2 was greater than non-dominant test 2.
- Dominant test 3 was greater than non-dominant test 3.
- Dominant test 4 was greater than non-dominant test 4.

No differences in inversion were identified between the dominant and non-dominant groups (Figure 3B). Differences were identified between the tests in the same group. There was an increase in angular velocity in both groups during the trials.

- Test 1 was different from Tests 2, 4, and 5 in the dominant group.
- Test 1 was different from Tests 4, and 5 in the non-dominant group.
- Test 2 was different from Tests 4, and 5 in the non-dominant group.

No differences were identified between the tests in the same group. The angular velocity of medial rotation in the non-dominant group was higher in all tests (Figure 3C).

- Dominant test 2 was lower than non-dominant test 2.
- Dominant test 3 was lower than non-dominant test 3.
- Dominant test 4 was lower than non-dominant test 4.

The dominant side took less time to reach the maximum plantar flexion range than the non-dominant side. The non-dominant side took less time to reach the maximum medial rotation range than the dominant side. The inversion movement took less time to reach the maximum range of motion (Figure 4).

There was no difference in the inversion movement between the dominant and non-dominant groups, but there was a difference between the tests in the same group (Figure 5A):

- Test 1 was superior to tests 4 and 5 in the dominant group.
- Test 1 was superior to test 5 in the non-dominant group.

There was no difference in plantar flexion (Figure 5B) or medial rotation (Figure 5C) movements between the dominant and non-dominant sides, or between the tests.

DISCUSSION

Our study presents an ankle assessment platform that simulates a mechanical sprain of the ankle in inversion. It performs movements in three axes of the joint, limited to 20º of inversion, 20º of plantar flexion, and 15º of medial rotation. The platform was developed according to Chan et al.,[14] who state that ankle sprains occur with combined movements in three axes.

Platform evaluation in three axes is not common in the literature, where most of the publication use two movements during ankle sprain simulation.

The current platform proved to be safe and effective for assessing ankle behavior during a mechanical sprain. The movement limit of each axis was respected to prevent the occurrence of injuries. There were no participant incidents during the experiment, which involved 300 tests on 30 athletes. Also, there was no report of pain or discomfort after the tests were performed, showing that the three-axis combined platform was safe while posing minimal risks to the test subjects.

The use of headphones during the tests was to prevent the subject from hearing the noise of the platform release[18-20] and avoid any possible premature contraction of the ankle muscles.

The time elapsed for the platform to reach the maximum limit of movement allowed ranged from 78 - 89ms, longer than the transmission time of a spinal reflex, which varies from 32-72ms,[12] but sill insufficient to have an effective motor response to avoid spraining the ankle.

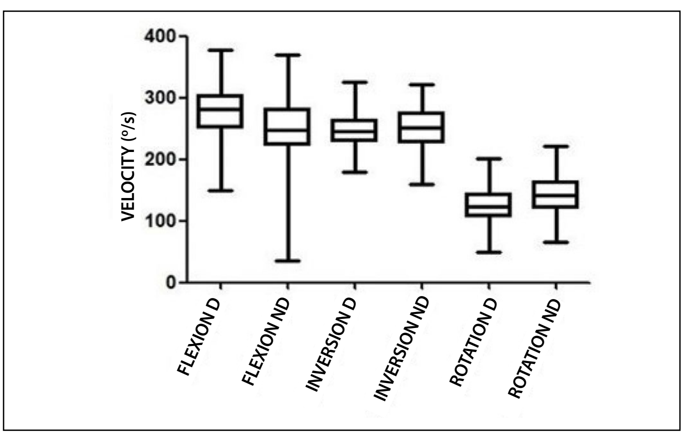

Figure 2. Dominant and non-dominant angular velocity (degrees/second) of medial rotation, plantar flexion, and inversion of the ankle during the sudden inversion movement in 30 soccer athletes.

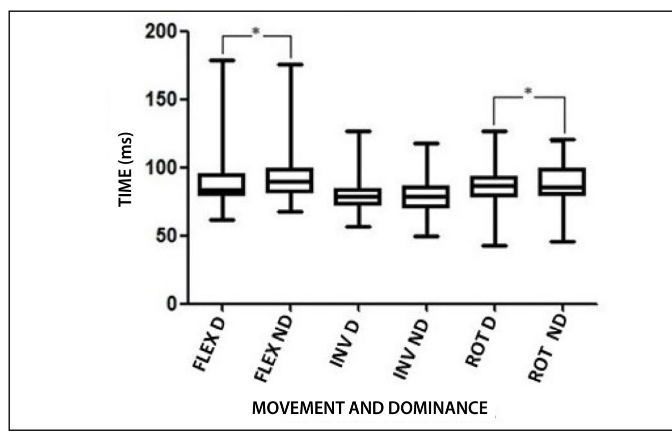

Figure 4. Time to the maximum range of movement for plantar flexion, inversion, and medial rotation on the platform (milliseconds) for the dominant and non-dominant sides during the sudden inversion movement in 30 soccer athletes.

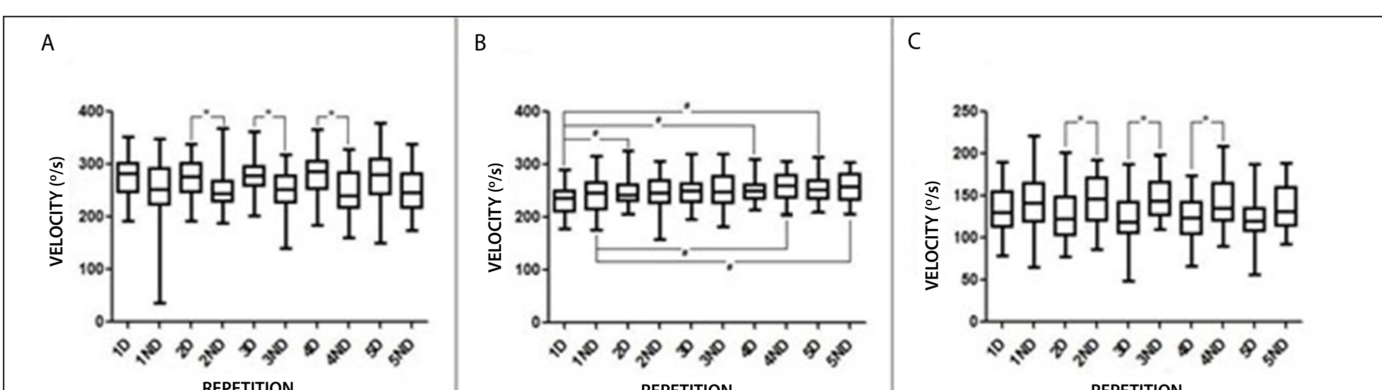

Figure 3. Comparison of angular velocity (degrees/second) between the five dominant and non-dominant repetitions of plantar flexion (A), inversion (B), and medial rotation (C) during the sudden inversion movement in 30 soccer athletes.

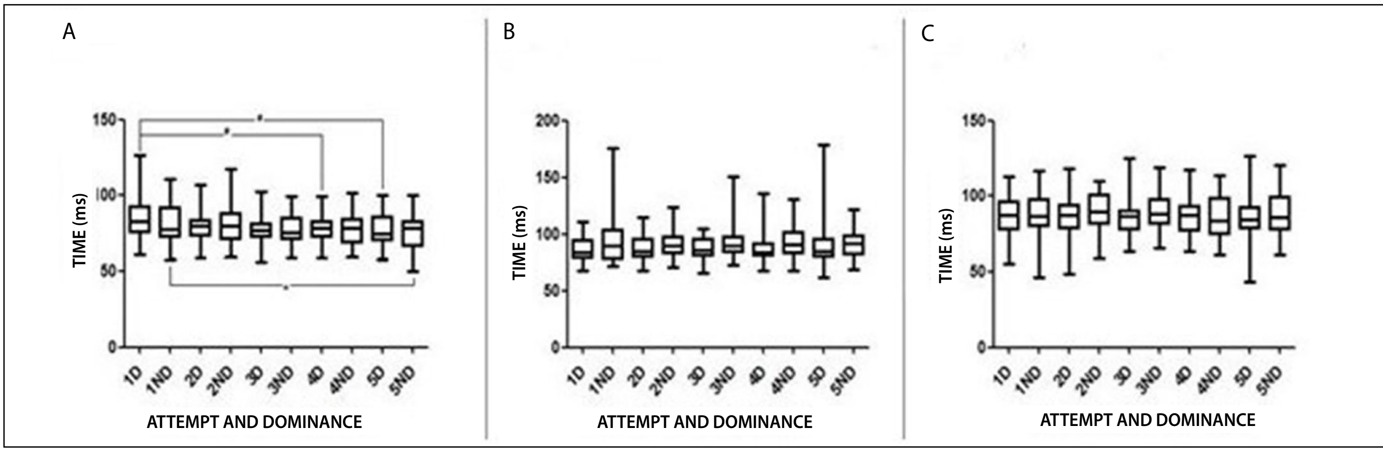

Figure 5. Maximum range of movement (milliseconds) of inversion (A), plantar flexion (B), and medial rotation (C) of the dominant vs. non-dominant groups during the sudden inversion movement in 30 soccer athletes.

The angular velocities of the platform movements were lower than those reported in the literature. The lowest speeds were used because of the three simultaneous movements, as Fong et al.[21] report that angular velocities greater than 500º/s can be harmful to the joint, especially due to medial rotation.

The velocities of platforms that cause only inversion range from 180º to 700º, with angulation ranging from 25º to 42º.[5,12,19,22-25] On the current platform, the highest velocity observed in plantar flexion was 280º, close to that used by Ohta et al.,[25] which was 300º in the inversion. The medial rotation velocity (153º/s) of the current platform was like that used by Fu et al.[26] on a two-axis platform with inversion and plantar flexion.

The movement velocity implemented on the platform varies significantly and depends on the architecture of each platform.[27] The current platform, executing movement in the three axes, has a slower angular velocity, but still fast enough to produce movement like a real sprain in the ankle, where there is no time for a corrective muscle response.

The angular velocity of the inversion increased on the dominant and non-dominant sides during the tests, possibly due to the action of fatigue and stress, factors that could reduce antagonistic muscle reaction to movement.[23]

The velocity of medial rotation in the dominant group decreased during the tests, but the non-dominant side maintained the velocity patterns. A possible explanation for the decrease in velocity of the dominant group could be more proprioceptive conditioning to prevent medial rotation, a common gesture in soccer players due to the need for precise, coordinated movements during technical sports gestures to control the ball.

The plantar flexion velocity was lower in the non-dominant group in all the tests conducted. A possible explanation could be the greater stability and balance conditioning of the non-dominant limb that normally is used as a unipedal support while playing the sport.

The differences observed between platform speeds occur because the axes are free and there is no control during movement, thus allowing the interference of displacement of the center of gravity or of muscle behavior.

The time to reach the maximum amplitude of the current platform is like the 80ms reported by Thain et al.,[7] measured on a biaxial platform with 30º of inversion and 20º of plantar flexion.

The time to reach maximum platform amplitude was less for inversion, followed by medial rotation and then flexion. This time is related to the angular velocity of each of the movements. Inversion would thus be the most rapid movement during the test, reaching the amplitude limit before the others, and the slowest movement would be plantar flexion. The slower response may result from the type of stimulus being more efficient to evaluate the inversion. The plantar flexion movement can occur more slowly due to the biomechanics of the platform movement, which induces inversion more easily, followed by medial rotation, and finally plantar flexion.

The main limitations of the study are related to the construction of the platform itself, which enables simultaneous movement in three planes while maintaining the safety of the subject. Thus, the effect of gravity was maintained in plantar flexion, which may have affected the time to maximum amplitude. A traction spring that artificially forced the movement to occur in all releases of the platform was used for medial rotation. Thus, the faster occurrence of the inversion movement would be related to the biomechanics of the ankle itself. Also, regarding the number of attempts, because they were randomly drawn by the computer, the number of the attempt corresponded to the sequence of the side being evaluated and not to the total number of attempts.

Even with these limitations, the platform that makes the dissociation of the sprain in the three movement axes identified inversion as the main movement through time of occurrence and amplitude of the movement.

One of the suggestions to improve the use of the ankle inversion platform with three axes of movement is the association with virtual reality to simulate an ankle sprain.

Furthermore, the platform could be used as a pre-intervention measure in a proprioceptive exercise training program, seeking to reduce the latency time of the tibialis anterior and fibularis muscles, a result achieved by Keles et al.[9] in a six-week program.

CONCLUSION

It was possible to develop a platform that proved to be safe and efficient for evaluating the behavior of the ankle joint in a simulated mechanical sprain, dissociating the phenomena that occur temporally and spatially in the three axes evaluated. Inversion is the fastest movement, followed by medial rotation and plantar flexion. The platform helps in understanding the sprain mechanism and can be useful in the evaluation and prevention of ankle sprains.

All authors declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: Each author made significant individual contributions to this manuscript. LDDS: data collection, writing the article, and contribution to the development of the platform; CAMP: statistical data analysis and technical development of the platform; RBN: statistical data analysis and review; ACA: contribution to the preliminary platform tests; JMDG: intellectual concept of the article and elaboration of the research project.

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