

This item is the archived peer-reviewed author-version of:

There is a difference in functional ankle stability between different types of footwear in male athletes : a cross-sectional study

Reference:

Wagemans Jente, Kuppens Kevin, Peeters Greta, Baert Isabel.- There is a difference in functional ankle stability between different types of footwear in male athletes : a cross-sectional study
The foot - ISSN 0958-2592 - 46(2021), 101764
Full text (Publisher's DOI): <https://doi.org/10.1016/J.FOOT.2020.101764>
To cite this reference: <https://hdl.handle.net/10067/1764230151162165141>

There is a difference in functional ankle stability between different types of footwear in male athletes: A cross-sectional study

Submission type: Original Clinical Research Article

Abstract word count: 278 words

Text-only word count: 4244 words

Number of figures/tables: 2 figures, 3 tables

Declarations of interest: none

This research did not receive any specific grant from funding agencies in the public, commercial, or non-for-profit sectors.

ABSTRACT

Context:

Lateral ankle sprains (LAS) are among the most common injuries in sports, with a poor long – term prognosis due to high chronicity and recurrence rates. Chronic ankle instability (CAI) results up to 40% of people that endured a first – time LAS.

Objective:

The aim of this study was to compare ankle stability between groups characterised by the use of different types of footwear during their sport activities.

Design:

Cross-sectional study.

Setting:

Firm training surface, local sport clubs.

Participants:

Fifty - one male subjects were recruited, distributed in four groups based on the type of footwear they use during their sport activities.

Main outcome measures:

All subjects performed four clinical ankle stability tests, and completed the Dutch version of the Cumberland Ankle Instability Tool (CAIT) and Profile of Mood States (POMS). All clinical ankle stability tests were performed barefoot.

Results:

Subjects performing their sport activities barefoot scored better than subjects performing their sport with shoes at the multiple hop test ($p = .002$ to $.047$) and executed the figure-of-8 hop test significantly faster than subjects with submalleolar

ankle support (AS) ($p = .019$). Subjects with submalleolar AS and studs showed significantly better results than subjects with supramalleolar AS on the CAIT- score ($p = .024$, $p = .030$) and the side- hop test ($p = .050$, $p = .045$). They also scored significantly better than subjects with submalleolar AS for the side – hop test ($p = .032$), foot – lift test ($p = .019$) and figure-of 8 hop test ($p = .011$).

Conclusion:

Barefoot sports performing subjects appear to have better ankle stability compared to subjects performing their sports with shoe support. Subjects performing sports with high AS appear to have worst ankle stability.

LEVEL OF EVIDENCE

Level III, Cross – sectional study.

KEYWORDS

Ankle Injuries; Ankle stability; Chronic Ankle Instability; Physiotherapy; Sports; Footwear

INTRODUCTION

Lateral ankle sprains (LAS) are among the common injuries, mostly reported by sport practitioners^{1, 2}, with a poor long – term prognosis due to high chronicity and recurrence rates.²⁻⁵ Doherty et al., 2016 indeed showed that chronic ankle instability (CAI) resulted in 40% of a group of people that endured a first – time LAS.⁶

CAI is a heterogenic condition distinguished by continuous symptoms such as pain, weakness, or diminished range of motion (ROM), persistent episodes or perceptions of the ankle giving away, decreased self – reported function, and recurrent ankle sprains that persevere for more than one year after the primary injury.^{1, 7, 8} CAI develops after a preceding first - time LAS.⁷ Collagen fibres of the lateral ligaments get stretched or damaged, resulting in structural tissue damage.⁷ The structural tissue damage, and initial clinical signs and symptoms following a LAS affect sensorimotor function.⁷ This presents itself by deafferentation of the injured joints, altered recruitment of muscles, dysfunctional development of uncontrolled movement, impaired reflex stabilisation and a loss of joint stability, eventually leading to recurrent ankle sprains.^{7, 9-12}

Multiple factors can confound the occurrence and recurrence rates of ankle sprains in sports. Limited dorsiflexion ROM, reduced proprioception, limited postural control and balance, history of ankle injuries, shoes with air in the heels, absence of stretching before the game, contact sport, type of sport and level of competition are associated risk factors for ankle sprains in sports where practitioners wear shoes.¹³⁻¹⁶ To the best of our cognizance, such knowledge does not exist in a population of barefoot performing athletes, which is a severe shortcoming. Literature shows that the incidence of ankle sprains is the highest in sports that are characterized by running,

cutting and jumping, such as indoor volleyball, netball, football, rugby, basketball and American football.¹⁶⁻¹⁸

Recently, several studies have been published regarding the role of footwear in ankle injuries, biomechanics, balance and stability.¹⁹⁻²⁶ The role of shoe design among basketball players is examined for ankle sprain rate and prevention. There was no evidence of a difference between the different shoe designs for both ankle sprain rate and prevention.^{27, 28} An examination of the effect of shoe collar height and heel counter-stiffness in basketball shoes on ankle stability showed smaller initial and peak inversion angles, and fewer time to peak inversion during sidestep cutting manoeuvres in footwear with both high collar and increasing heel counter-stiffness.²³ These results suggest an improvement in ankle stability during sidestep cutting manoeuvres.²³ Minimalistic running shoes or “barefoot shoes”, such as the Vibram FiveFingers® (VFF) are argued to tend to imitate barefoot conditions.²⁶ In accordance with this assertion, measures of dynamic balance between barefoot conditions and the VFF conditions were similar.²⁶ The use of minimal support footwear while running contributes to an increase in cross-sectional areas (CSA) of the intrinsic foot muscles and a greater use of the spring-like function of the longitudinal arch of the foot.²⁹ A barefoot strike pattern induces a great deflection of the longitudinal arch, showing greater potential to store and return elastic energy.³⁰ The greater strength of the intrinsic foot muscles assist in the function of the plantar fascia, which is abundantly innervated with mechanoreceptors, resulting in a large contribution to proprioception.³⁰ Improving proprioception is essential whereas insufficient sensory feedback generates poor balance control, which correlates with high risk of sustaining an ankle sprain.³¹ Barefoot performance allows maximal sensory input to the lower

extremities, which is important for both static and dynamic stability.^{30, 32} Despite the recent literature about the role of footwear on ankle function, ankle stability and ankle injuries, the possible influence of different types of footwear on the occurrence of ankle instability is not conclusively examined, however.¹⁶

Based on this we formulated the following research question: Is barefoot sports performance possibly related to ankle stability? To answer this question, the aim of this study is to investigate whether there is a difference in ankle stability between different types of footwear during sport activities (shoes with high ankle support, shoes with low ankle support, shoes with low ankle support with studs and barefoot) on functional measures of ankle stability. We hypothesize that sportsmen performing their sport activities barefoot have more ankle stability than sportsmen performing their sport with shoe support.

MATERIAL AND METHODS

Design

Cross-sectional study

Participants

This study was approved by the ethical committee of the University Hospital Antwerp (UZA; B300201420999). All subjects volunteered to participate and gave written informed consent. This consent was written in correspondence with the applicable national and international privacy regulations (<https://op.europa.eu/en/publication-detail/-/publication/44d8441b-5fc5-11e8-ab9c-01aa75ed71a1>).

Subjects were recruited from local sporting clubs between December 2018 and April 2019, by visiting and e- mail correspondence. Subjects were enlisted based on our

predetermined categories for different types of footwear used during sport activities: shoes with low ankle support (AS), which support the ankle sub malleolar; shoes with high AS, giving supra malleolar support of the ankle joint; shoes with low AS and studs, giving sub malleolar support but have studs underneath; and barefoot. To be included in this study, subjects had to be male, between 18 – 35 years old, and had to participate in their primary sport for at least 3 years with the same type of footwear and 4 hours per week while practicing a possible secondary sport for not more than 2 hours per week. Subjects were excluded when they had ankle injuries and/or complaints, a history of severe ankle injuries, severe injuries and/or complaints at the lower limbs, severe ocular impairment, and subjects with any neurological, cardiac, vascular or metabolic disease. We prepared a questionnaire for the volunteering subjects to fill in, to obtain information about: type of sports, weekly hours of sports participation, type of footwear they use during their sport activities, history of injury or current injury, and dominant foot. Dominant foot was defined as the foot which they would kick a ball with.

Procedures

All clinical ankle stability tests were conducted within one session of approximately 30 minutes, for each group of subjects. Questionnaires were filled in by the subjects before the clinical ankle stability test session. Order of testing was chosen randomly. Subjects carried out each test twice, with each foot.

Outcome measures

Ankle stability

Four functional ankle stability assessments were performed: Multiple hop test, foot – lift test, side – hop test and figure – of – 8 hop test. The multiple hop test assesses

dynamic ankle stability based on time interval, postural corrections and a visual analogue scale (VAS).³³ The VAS is used to rate the difficulty of the test.³³ Evaluation of the clinimetric properties of the multiple hop test in patients with CAI shows reliability and validity for either time values (ICC > 0.90; $p = .047$), postural corrections (ICC = 0.83; $p = .000$) and VAS - scores ($r_s > .80$; $p = .018$).^{34, 35} Time values for the test performance was assessed by using a digital hand chronometer in the studies evaluating the clinimetric properties^{34, 36}, while the observer in this study assessed time values by analysing the video images.

The side – hop test and figure – of – 8 hop test evaluate dynamic ankle stability based on the time interval.³⁷ The correlation between functional ankle instability and the performance of the side – hop test and the figure – of – 8 hop test was investigated by Docherty et al., 2005.³⁸ Their findings show a significant positive correlation for the side – hop test ($r = 0.35$; $p = .01$) and the figure – of – 8 hop test ($r = 0.31$; $p = .02$).³⁸ The outcome measure for the foot – lift test is the amount of foot lifts during a 30 – second period with the participants eyes closed.³⁷ Good test – retest reliability ($r = 0.78$; ICC = 0.73; 95% CI = 0.40 – 0.89) results show that the foot – lift test is also a reliable test for the assessment of static ankle stability.³⁹

Based on the methods described in literature³⁴⁻³⁸, all clinical ankle stability tests were conducted on a firm surface with subjects barefoot. All participants had one trial round to familiarise with the clinical tests. The average of the two attempts for each ankle was used for analysis. All clinical tests were filmed by using video cameras (GoPro, California, USA). The conducted CAIT was used complementary to the results of the clinical ankle stability tests. The Dutch version of the Cumberland Ankle Instability Tool was used. This is a questionnaire that assesses specifically symptoms

of instability, and is proven valid (SCC= 0.36 – 0.43) and reliable (ICC = 0.94) to evaluate the perception of ankle stability.⁴⁰

The multiple hop test was chosen as the primary outcome measure for this study, based on its clinimetric properties.³⁴⁻³⁶

Mood state

The Dutch version of the Profile of Mood States (POMS) is a questionnaire which indicates for 32 words or statements how the subject were feeling the day of the test. Each statement was scored on a 5–point scale.⁴¹ The POMS measures five different mood swings: tension, anger, vigor, fatigue and depression.⁴¹ This test was conducted to investigate whether mood states could be a contributing factor to the performance of the test subjects. This questionnaire was filled in at the same moment as the clinical tests and the CAIT.

Statistical analysis

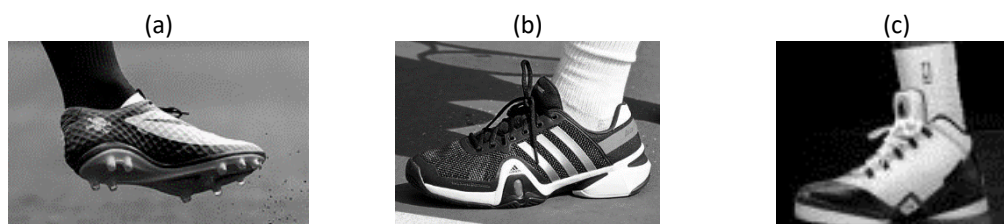
Statistical analysis was processed by IBM SPSS Statistics version 25 for Windows (IBM company, Armonk, New York, USA). Shapiro – Wilk test was used to test for normality, complemented by visual inspection of the applicable histograms. All outcome values were normally distributed. Therefore, one – way ANOVA test was used to compare test results between groups.

RESULTS

Participants

Eighty – five athletes were recruited from local sport clubs in Antwerp, Belgium. Thirty - one subjects were excluded from this study, based on their recent history of severe ankle injuries. Three subjects were excluded because of an ongoing injury at one of the lower extremities. Fifty - one subjects (male, mean age $25 \pm 4,4$ years, mean body height $1,83 \pm 0,08$ m, mean body weight $78,2 \pm 10,2$ kg) met the eligibility criteria and were included in the study. Twelve subjects perform sports barefoot, 16 subjects with shoes giving low ankle support with studs, 10 subjects with shoes giving low ankle support without studs and 13 subjects with shoes giving high ankle support (figure 1). Shoes giving low ankle support with studs were firm ground bladed cleat with low ankle cut with regular counter-stiffness.²⁵ Shoes without studs giving low ankle support were with low collar height and regular counter-stiffness, and shoes without studs giving high ankle support were high collar high and also regular counter-stiffness.²³ All types of footwear were commercially manufactured. No orthotic insoles or personally designed footwear was used.

Figure 1: *Types of footwear*



(a) Shoes giving low ankle support with studs, (b) Shoes without studs giving low ankle support, (c) shoes without studs giving high ankle support.

The barefoot group consisted of kickboxers, mixed martial artists and judo practitioners. Study participants in the group performing sports with shoes giving low

ankle support with study were footballers (soccer). Both groups of participants with shoes without studs consisted of volleyball players and basketball players.

Multiple hop test

Mean time value of barefoot performing subjects was 22.85 s with their dominant feet and 22.55 s with their non – dominant feet. This was significantly faster than subjects performing their sports with high AS for both dominant ($p = .002$) and non – dominant feet ($p = .017$). They executed the test in 28.41 s with their dominant feet and 26.57 s with their non – dominant feet, respectively. Barefoot performing subjects were also significantly faster than subjects performing their sports with shoes giving AS with studs with their dominant feet, namely 26.67 s ($p = .047$). Subjects performing sports with low AS and high AS needed an average of 7.90 and 8.27 postural corrections with their non – dominant feet. This was significantly more than the mean amount of postural corrections barefoot sports performing subjects needed to keep stability with their non – dominant feet, respectively 3.92 postural corrections ($p = .016$, $p = .003$). Subjects performing their sports with low AS with studs needed 4.88 postural corrections to maintain balance with their non – dominant feet. This was also statistically better than subjects with high AS ($p = .019$). The comparison between different types of footwear during sport activities for the outcome measures of the multiple hop test are stated in table 1.

Table 1: Ankle stability results of the multiple hop test

Primary outcome: Multiple hop test	Barefoot <i>n</i> = 12	Low AS with studs <i>n</i> = 16	Low AS <i>n</i> = 10	High AS <i>n</i> = 13	<i>P</i>	<i>P</i> barefoot - low AS	<i>P</i> barefoot - low AS with studs	<i>P</i> barefoot - high AS	<i>P</i> low AS with studs - low AS	<i>P</i> low AS - high AS	<i>P</i> low AS with studs - high AS
Dominant feet											
Time (s)	22.85 (3.11)	26.67 (2.33)	23.12 (3.01)	28.41 (5.33)	0.001 [†]	1.000	0.047 [†]	0.002 [†]	0.110	0.006 [†]	1.000
Postural corrections	4.83 (2.57)	5.81 (2.10)	7.85 (2.97)	8.62 (5.29)	0.030 [†]	0.275	1.000	0.051	0.887	1.000	0.203
VAS	4.27 (0.75)	4.69 (1.47)	4.58 (1.61)	5.15 (1.38)	0.432	1.000	1.000	0.639	1.000	1.000	1.000
Non – dominant feet											
Time (s)	22.55 (2.84)	25.13 (2.22)	23.43 (3.54)	26.57 (4.08)	0.014 [†]	1.000	0.234	0.017 [†]	1.000	0.138	1.000
Postural corrections	3.92 (2.07)	4.88 (2.59)	7.90 (3.29)	8.27 (3.61)	0.001 [†]	0.016 [†]	1.000	0.003 [†]	0.081	1.000	0.019 [†]
VAS	3.77 (1.06)	4.45 (1.48)	4.80 (1.50)	5.11 (1.59)	0.129	0.597	1.000	0.139	1.000	1.000	1.000

AS = ankle support; n = number of subjects; s = seconds; VAS = visual analogue scale

Data are presented as Mean (SD). The *P* value corresponds to an ANOVA (with post hoc tests) comparing the four groups.

[†]Significant difference between groups (*P* < 0.05)

Secondary outcome measures

The average time value for the execution of the side – hop test by subjects performing their sports with low AS with studs was 9.23 s with their dominant feet and 9.09 s with their non – dominant feet. This was significantly faster than the mean time values of subjects performing their sports with high AS, namely 10.58 s with their dominant feet and 10.30 s with their non – dominant feet ($p = .050$, $p = .045$). Barefoot sports performing subjects executed the figure – of – 8 hop test in meanly 12.86 s with their dominant feet and 12.87 s with their non – dominant feet, while subjects with low AS did it significantly slower ($p = .019$, $p = .011$), in meanly 14.70 s with their dominant feet and 14.73 s with their non – dominant feet. The average time subjects with low AS and studs needed to execute the figure – of – 8 hop test was also significantly faster compared to subjects with low AS for the non – dominant feet ($p = .011$). Subjects performing their sports with low AS and studs had average scores of 27.62 for dominant feet and 28.00 and non – dominant feet on the Dutch version of the CAIT. This was significantly higher ($p = .024$, $p = .030$) than the mean scores of subjects performing their sports with high AS, respectively 22.31 for dominant feet and 22.54 for non – dominant feet. Table 2 informs about all secondary outcome measures.

Table 2: Ankle stability results of the secondary outcome measures

Secondary outcome	Barefoot <i>n</i> = 12	Low AS with studs <i>n</i> = 16	Low AS <i>n</i> = 10	High AS <i>n</i> = 13	<i>P</i>	<i>P</i> barefoot - low AS	<i>P</i> barefoot - low AS with studs	<i>P</i> barefoot - high AS	<i>P</i> low AS with studs - low AS	<i>P</i> low AS - high AS	<i>P</i> low AS with studs - high AS
Dominant feet											
Side – hop test (s)	9.61 (1.33)	9.23 (1.55)	10.52 (0.85)	10.58 (1.23)	0.023 [†]	0.669	1.000	0.436	0.108	1.000	0.050 [†]
Figure- of- 8 hop test (s)	12.86 (1.06)	13.20 (1.88)	14.70 (1.37)	13.52 (0.75)	0.019 [†]	0.019 [†]	1.000	1.000	0.057	0.289	1.000
Foot- lift test	14.71 (8.95)	8.28 (6.47)	11.55 (9.68)	13.89 (5.28)	0.116	1.000	0.185	1.000	1.000	1.000	0.319
CAIT	24.83 (4.09)	27.62 (2.75)	24.50 (5.80)	22.31 (6.03)	0.034 [†]	1.000	0.758	1.000	0.633	1.000	0.024 [†]
Non – dominant feet											
Side – hop test (s)	9.22 (0.89)	9.09 (1.61)	10.45 (0.37)	10.30 (1.07)	0.006 [†]	0.097	1.000	0.145	0.032 [†]	1.000	0.045 [†]
Figure- of- 8 hop test (s)	12.87 (0.94)	12.99 (1.80)	14.73 (1.38)	13.77 (0.69)	0.005 [†]	0.011 [†]	1.000	0.569	0.011 [†]	0.519	0.724
Foot- lift test	12.33 (7.93)	8.53 (6.39)	20.35 (15.68)	15.73 (7.54)	0.022 [†]	0.321	1.000	1.000	0.019 [†]	1.000	0.282
CAIT	25.83 (4.04)	28.00 (2.86)	25.40 (5.28)	22.54 (7.17)	0.044 [†]	1.000	1.000	0.621	1.000	1.000	0.030 [†]

AS = ankle support; n = number of subjects; s = seconds; CAIT = Cumberland ankle instability tool

Data are presented as Mean (SD). The *P* value corresponds to an ANOVA (with post hoc tests) comparing the four groups.

[†]Significant difference between groups (*P* < 0.05)

Profile Of Mood States

Figure 1 shows the results of the categories of the POMS sorted by type of footwear. Statistical analysis is stated in table 3. All types of footwear score high on vigor while the results of the other categories are lower but differ from one another. There is no significant difference.

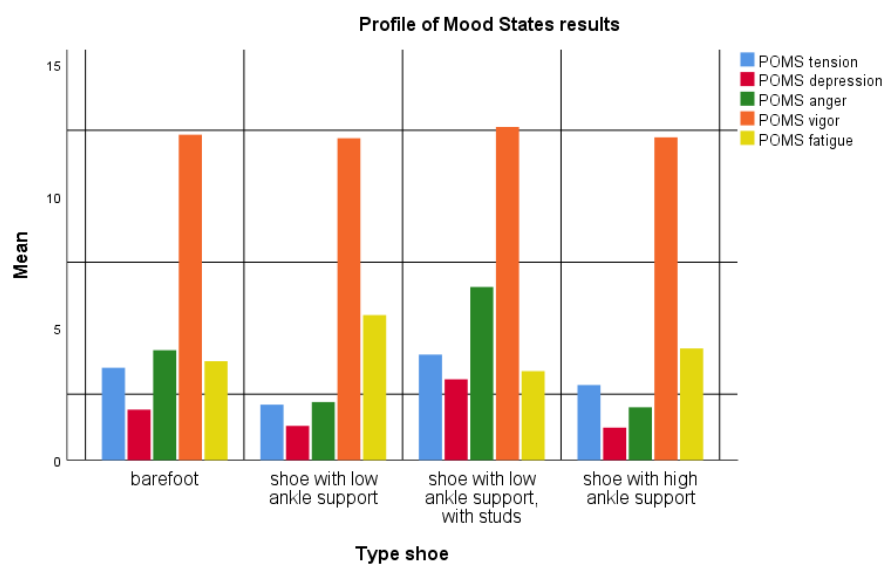


FIGURE 2: Graphical representation of the POMS results between groups ($n = 51$ subjects)

Table 3: mood states results of de POMS

Profile of Mood Stated	Barefoot <i>n</i> = 12	Low AS with studs <i>n</i> = 16	Low AS <i>n</i> = 10	High AS <i>n</i> = 13	<i>P</i>	<i>P</i> barefoot vs low AS	<i>P</i> barefoot vs low AS with studs	<i>P</i> barefoot vs high AS	<i>P</i> low AS vs low AS with studs	<i>P</i> low AS vs high AS	<i>P</i> low AS with studs vs high AS
Tension	3.50 (3.00)	4.00 (3.92)	2.10 (1.91)	2.85 (3.98)	0.550	1.000	1.000	1.000	1.000	1.000	1.000
Depression	1.92 (2.31)	3.06 (4.51)	1.30 (1.95)	1.23 (3.03)	0.426	1.000	1.000	1.000	1.000	1.000	0.855
Anger	4.17 (5.00)	6.56 (6.56)	2.20 (2.86)	2.00 (2.55)	0.052	1.000	1.000	1.000	0.169	1.000	0.083
Vigor	12.33 (3.17)	12.63 (3.28)	12.20 (2.70)	12.23 (3.61)	0.985	1.000	1.000	1.000	1.000	1.000	1.000
Fatigue	3.75 (2.99)	3.38 (3.42)	5.50 (3.81)	4.23 (3.32)	0.867	1.000	1.000	1.000	0.753	1.000	1.000

AS = ankle support; n = number of subjects

Data are presented as Mean (SD). The *P* value corresponds to an ANOVA (with post hoc tests) comparing the four groups.

[†]Significant difference between groups (*P* < 0.05)

DISCUSSION

The aim of this cross - sectional study was to investigate ankle stability in athletes using different types of footwear during their sport activities (shoes with high ankle support, shoes with low ankle support, shoes with low ankle support with studs and barefoot), measured by the multiple hop test as primary outcome. Although there is growing interest in barefoot and minimalistic shoe performance in sports and rehabilitation, to our knowledge, this is the first study that thoroughly investigates the possible influence of barefoot sports performance on ankle stability and the difference in ankle stability between footwear. Studies regarding ankle stability seem to be more focussed on global treatment and prevention interventions, external support by braces or tape, and risk factors such as range of motion and type of sport.^{1, 2, 6, 16, 42}

To explore the research question, there are multiple clinical tests for the assessment of ankle stability. Generally applied clinical tests are the y- balance test, the star-excursion balance test and various types of hop tests. Eechaute, Bautmans, De Hertogh & Vaes, 2012 showed that the multiple hop test is a proper discriminative tool for the assessment of functional ankle instability.³⁶ Eechaute, Vaes & Duquet, 2009 also showed that the multiple hop test is a reliable and valid clinical test for the assessment of impaired dynamic postural control related to functional ankle stability.³⁴ The ranges of performance in our study were in keeping with the results of previous studies concerning the multiple hop test. The participants in our study performed the multiple hop test in meanly 22.55 sec to 28.41 sec, with meanly 3.92 to 8.62 postural corrections and a mean VAS – score of 3.77 to 5.15 cm. The study of Eechaute and colleagues, 2012 showed mean results of 31.4 seconds, 9.0 postural corrections and 4.04 cm on the VAS – scale for healthy subjects, and 41.5 seconds,

17.2 postural corrections and 5.0 cm on the VAS – scale for the CAI group.³⁶ Furthermore, the study of Linens et al., 2014 noted significant cut-off scores for dynamic instability for the side-hop test and figure-of-8 hop test of 12.88 seconds and 17.36 seconds, respectively.³⁷ All participants in our study performed both tests faster than the cut-off time values.

Subjects performing barefoot scored significantly better at the multiple hop test than subjects performing sports with low ankle support with and without studs, and subjects performing with shoes giving high ankle support on time interval and/ or postural corrections. They also executed the figure – of – 8 hop test significantly faster than subjects performing their sport with low ankle support. These results partially confirm our hypotheses that sportsmen performing their sport activities barefoot have better ankle stability than sportsmen performing with shoe support. The significantly worse results of subjects performing with high ankle supporting shoes on the multiple hop test and the side – hop test support the findings of Miller et al., reporting the effect of minimal shoes on the arc structure and intrinsic muscle strength, when we apply this to ankle.²⁹ These results possibly contradict the studies of Curtis et al. and Barret et al. since they did not find evidence between different shoe designs in the rate and prevention of ankle sprains.^{27, 28} More recently, Fu et al. compared the effect of high-top and low-top shoes on ankle inversion kinematics and muscle activation during landing tasks.²² Their results showed no difference in ankle kinematics during landing between groups, supporting the results of Curtis et al. and Barret et al.²² They did find significantly delayed muscle onset activity of the m. Tibialis Anterior and m. Peroneus brevis muscles, and electromyographic disturbances of the ankle evertor muscles before landing in the group with the high-cut shoes, however,

suggesting diminished muscular reflex activity, altered proprioception, possibly leading to impaired functional ankle stability.²² This could explain why subjects performing their sports with shoes giving high ankle support scored worst on the functional ankle stability tests.

Neither Fu et al., Curtis et al. and Barret et al. included barefoot as a type of footwear in their comparative study.^{22, 27, 28} Our study did include participants performing barefoot (kickboxers, mixed martial artists and judo practitioners). These subjects would have been conditioned to move and jump barefoot, whereas subjects performing their sports with shoe support are not. As a result, barefoot performing athletes could have had more confidence in their feet and ankles due to the conditioning. Although this could be an advantage for the testing procedure, we do not believe that kickboxers, mixed martial artists and judo practitioners, or other athletes performing their sports barefoot, train this specific testing procedure. Participants performing their sports with shoe support were basketball, volleyball and football players. These sports include explosive change of direction and sidestep cutting manoeuvres, which would require traction.²⁰ Cleats play a crucial part in the traction process in football,²⁵ while shoe-surface friction in indoor sports is generally high.⁴³ However, high friction between footwear and surface is a presumed risk factor for non-contact injuries in sports due to greater stress,²⁰ with the majority of ankle sprains as non-contact injuries.^{44, 45} Wannop et al. found no difference in speed of movement and stance time between high traction and low traction shoes, suggesting that athletes can still perform despite fewer traction, and reduce their risk of injury due to decreased joint stress.²⁰ Liu et al. investigated difference in ankle stability between different types of collar height and heel counter-stiffness by means of

maximum-effort sidestep cutting tasks.²³ Although sidestep cutting manoeuvres are included in basketball, volleyball and football, the clinimetric properties of these tasks as measurements for ankle stability are not investigated. We used the side-hop test and figure-of-8 hop test to replicate sidestep cutting and change of direction. A positive relationship is showed to exist between functional ankle stability deficits and self-reported ankle instability for the figure-of-8 hop test and side-hop test.³⁸ Although sidestep cutting manoeuvres and changes of direction are characteristics of basketball, volleyball and football, there were no significant differences for the side-hop test and figure-of-8 hop test in favour of the participants wearing shoes during their sport activities compared to participants performing their sports barefoot.

There is no statistically significant difference between groups in VAS – scores and in POMS – scores. Although VAS – scores are globally used, it is a subjective measure to rate the difficulty of the test. It does not measure ankle stability itself. We conducted the POMS to objectify the mood states of our participants. The results of the POMS - scores possibly indicate that the results of the clinical ankle stability tests are not influenced by mood states of the subjects. However, no regression analysis is done. Subsequently no conclusion can be formed concerning the relation between the mood state of the participants of this study and the results of the clinical ankle stability tests. To the best of our knowledge, there is no mention in literature of any association between mood states and ankle stability. Psychological factors show significant relationship with functional test performance and validated outcome measures after Anterior Cruciate ligament reconstruction.⁴⁶ There was no observed difference in knee stability though.⁴⁶ In addition to the clinical ankle stability tests, participants completed the Dutch version of the CAIT. Significant differences were found in favour

of subjects performing their sports with shoes giving low AS and studs in comparison with subjects performing their sports with high AS shoes, in both dominant and non – dominant feet. This means that subjects performing their sports with shoes with low AS and studs seem to have better perceived ankle stability than subjects performing sports with high ankle supporting shoes, according to their own opinion about the stability of their ankles. The minimal clinical important difference of the CAIT is >3 points.⁴⁷ The difference between subjects performing their sports with shoes giving low AS and subjects performing their sports with high AS shoes was 5.31 for dominant feet and 5.46 points for non-dominant feet. This means that there is also a clinically relevant difference in perceived ankle stability between those groups of footwear.

Strengths and limitations of this study

This study intended to determine whether there is a possible difference in ankle stability between sportsmen using different types of footwear during their sport activities is not without limitations. First, although there is a statistical difference in ankle stability results between subjects with different types of footwear used during their sport activities, there can be other factors contributing to the influence of ankle stability. Furthermore, even though we excluded possible subjects based on recent history of ankle and/ or lower limb injuries, a long term history of severe ankle and/ or lower limb injuries can also have an adverse effect on the stability mechanisms of the ankle, and could therefore also be a confounding factor.⁴⁸ Other possible confounding factors related to ankle stability in sports are level of competition, BMI and contact during sport activities.^{13, 14, 48-50} We have not accounted for all possible confounding factors. Second, because of the small sample size, caution is advised for the generalisation of the results of this study. We could have included the 31 excluded

subjects as a sub group of previous injury. However, the possible impairments and sequelae associated with severe ankle injuries could have been additional confounding factors. Third, there can be structural differences in feet, which can result in different measures and function⁵¹. The different characteristics of feet can possibly influence the results of the clinical ankle stability tests.

This study is the first study that thoroughly investigates the difference in ankle stability between footwear, with the inclusion of barefoot as a type of footwear. Every group of subjects was tested in one session, and all groups were tested in similar circumstances to obtain standardisation. To also obtain accuracy and standardisation in the assessment of time values of the clinical ankle stability tests, we analysed video recordings of the clinical ankle stability tests instead of using a digital hand chronometer. The cross – sectional design of this study makes it impossible to determine causality. However, the results of this study could give relevant information for a rationale regarding a prospective longitudinal study researching the influence of different types of footwear on ankle stability.

CLINICAL RELEVANCE

Subjects performing their sports with high ankle support scored worst on the clinical tests for ankle stability, and showed to have least perceived stability. When there are multiple types of shoes applicable for the same sport, advising sportsmen with their choice of shoes could have an influence on the prevalence of ankle sprains. Using other types of footwear for additional non – sport specific exercises could also benefit stability of the ankle. This should be further investigated. The results of this study could also be beneficiary for the treatment of CAI, and for possible research about barefoot rehabilitation exercises in the treatment of CAI.

CONCLUSIONS

This cross – sectional study investigated whether there is a difference in ankle stability between sports practitioners performing their sports with different types of footwear. After statistical analysis, we determined that sportsmen performing barefoot have the best results on the multiple hop test and possibly have the best ankle stability compared to sportsmen performing with shoe support. We may also conclude that barefoot performing sportsmen, sportsmen performing with low ankle support with and without studs show better results than sportsmen performing with shoes giving high ankle support, based on the results of the other clinical assessments. Further prospective research is recommended with a greater sample size of subjects to evaluate whether different types of footwear during sport activities have an influence on ankle stability.

BRIEF SUMMARY

What is known

- Barefoot performance maximises sensory input

What this study adds

- The results of this study suggest that athletes performing sports barefoot have better ankle stability than athletes performing sports with footwear.
- Athletes performing sports with shoes giving supramalleolar ankle support seem to have worse ankle stability than athletes performing their sports barefoot or with shoes giving submalleolar ankle support.

REFERENCES

1. Bleakley CM, Taylor JB, Dischiavi SL, Doherty C, Delahunt E. Rehabilitation Exercises Reduce Reinjury Post Ankle Sprain, But the Content and Parameters of an Optimal Exercise Program Have Yet to Be Established: A Systematic Review and Meta-analysis. *Arch Phys Med Rehabil*. 2019;100(7):1367-75.
2. Doherty C, Bleakley C, Delahunt E, Holden S. Treatment and prevention of acute and recurrent ankle sprain: an overview of systematic reviews with meta-analysis. *British journal of sports medicine*. 2017;51(2):113-25.
3. Hertel J. Functional Anatomy, Pathomechanics, and Pathophysiology of Lateral Ankle Instability. *J Athl Train*. 2002;37(4):364-75.
4. Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. *British journal of sports medicine*. 2005;39(3):e14; discussion e.
5. Konradsen L, Bech L, Ehrenbjerg M, Nickelsen T. Seven years follow-up after ankle inversion trauma. *Scand J Med Sci Sports*. 2002;12(3):129-35.
6. Doherty C, Bleakley C, Hertel J, et al. Recovery From a First-Time Lateral Ankle Sprain and the Predictors of Chronic Ankle Instability: A Prospective Cohort Analysis. *The American journal of sports medicine*. 2016;44(4):995-1003.
7. Hertel J, Corbett RO. An Updated Model of Chronic Ankle Instability. *J Athl Train*. 2019;54(6):572-88.
8. Khalaj N, Vicenzino B, Heales LJ, Smith MD. Is chronic ankle instability associated with impaired muscle strength? Ankle, knee and hip muscle strength in individuals with chronic ankle instability: a systematic review with meta-analysis. *British journal of sports medicine*. 2020.
9. Braun BL. Effects of ankle sprain in a general clinic population 6 to 18 months after medical evaluation. *Arch Fam Med*. 1999;8(2):143-8.
10. Comerford MJ, Mottram SL. Functional stability re-training: principles and strategies for managing mechanical dysfunction. *Man Ther*. 2001;6(1):3-14.
11. Gerber JP, Williams GN, Scoville CR, Arciero RA, Taylor DC. Persistent disability associated with ankle sprains: a prospective examination of an athletic population. *Foot Ankle Int*. 1998;19(10):653-60.
12. Freeman MA, Dean MR, Hanham IW. The etiology and prevention of functional instability of the foot. *J Bone Joint Surg Br*. 1965;47(4):678-85.
13. McKay GD, Goldie PA, Payne WR, Oakes BW. Ankle injuries in basketball: injury rate and risk factors. *British journal of sports medicine*. 2001;35(2):103-8.
14. Waterman BR, Belmont PJ, Jr., Cameron KL, et al. Risk factors for syndesmotic and medial ankle sprain: role of sex, sport, and level of competition. *The American journal of sports medicine*. 2011;39(5):992-8.
15. Woods C, Hawkins R, Hulse M, Hodson A. The Football Association Medical Research Programme: an audit of injuries in professional football: an analysis of ankle sprains. *British journal of sports medicine*. 2003;37(3):233-8.
16. Vuurberg G, Hoorntje A, Wink LM, et al. Diagnosis, treatment and prevention of ankle sprains: update of an evidence-based clinical guideline. *British journal of sports medicine*. 2018;52(15):956.
17. Fong DT, Hong Y, Chan LK, Yung PS, Chan KM. A systematic review on ankle injury and ankle sprain in sports. *Sports Med*. 2007;37(1):73-94.
18. Herzog MM, Kerr ZY, Marshall SW, Wikstrom EA. Epidemiology of Ankle Sprains and Chronic Ankle Instability. *J Athl Train*. 2019;54(6):603-10.
19. Butler RJ, Russell ME, Queen R. Effect of soccer footwear on landing mechanics. *Scand J Med Sci Sports*. 2014;24(1):129-35.
20. Wannop JW, Worobets JT, Stefanyshyn DJ. Footwear traction and lower extremity joint loading. *The American journal of sports medicine*. 2010;38(6):1221-8.

21. Silva DCF, Santos R, Vilas-Boas JP, et al. Different Cleat Models Do Not Influence Side Hop Test Performance of Soccer Players with and Without Chronic Ankle Instability. *Journal of human kinetics*. 2019;70:156-64.
22. Fu W, Fang Y, Liu Y, Hou J. The effect of high-top and low-top shoes on ankle inversion kinematics and muscle activation in landing on a tilted surface. *Journal of foot and ankle research*. 2014;7(1):14.
23. Liu H, Wu Z, Lam WK. Collar height and heel counter-stiffness for ankle stability and athletic performance in basketball. *Research in sports medicine (Print)*. 2017;25(2):209-18.
24. Lysdal FG, Bandholm T, Tolstrup JS, et al. Does the Spraino low-friction shoe patch prevent lateral ankle sprain injury in indoor sports? A pilot randomised controlled trial with 510 participants with previous ankle injuries. *British journal of sports medicine*. 2020.
25. Blanchard S, Palestri J, Guer JL, Behr M. Current Soccer Footwear, Its Role in Injuries and Potential for Improvement. *Sports medicine international open*. 2018;2(2):E52-e61.
26. Smith BS, Hartman AH, Martin DM, et al. Young Adults Performance of Unipedal Dynamic Balance with Various Footwear Conditions. *International journal of exercise science*. 2020;13(4):206-15.
27. Barrett JR, Tanji JL, Drake C, et al. High- versus low-top shoes for the prevention of ankle sprains in basketball players. A prospective randomized study. *The American journal of sports medicine*. 1993;21(4):582-5.
28. Curtis CK, Laudner KG, McLoda TA, McCaw ST. The role of shoe design in ankle sprain rates among collegiate basketball players. *J Athl Train*. 2008;43(3):230-3.
29. Miller EE, Whitcome KK, Lieberman DE, Norton HL, Dyer RE. The effect of minimal shoes on arch structure and intrinsic foot muscle strength. *Journal of Sport and Health Science*. 2014;3(2):74-85.
30. Davis IS, Rice HM, Wearing SC. Why forefoot striking in minimal shoes might positively change the course of running injuries. *J Sport Health Sci*. 2017;6(2):154-61.
31. Waddington G, Adams R. Football boot insoles and sensitivity to extent of ankle inversion movement. *British journal of sports medicine*. 2003;37(2):170-4; discussion 5.
32. Warne JP, Smyth BP, Fagan JO, et al. Kinetic changes during a six-week minimal footwear and gait-retraining intervention in runners. *Journal of sports sciences*. 2017;35(15):1538-46.
33. Riemann BL CN, Lephart SM. Examination of a clinical method of assessing postural control during a functional performance task. *Journal of Sport Rehabilitation*. 1999;171 - 183:12.
34. Eechaute C, Vaes P, Duquet W. The dynamic postural control is impaired in patients with chronic ankle instability: reliability and validity of the multiple hop test. *Clin J Sport Med*. 2009;19(2):107-14.
35. Eechaute C, Vaes P, Duquet W. Functional performance deficits in patients with CAI: validity of the multiple hop test. *Clin J Sport Med*. 2008;18(2):124-9.
36. Eechaute C, Bautmans I, De Hertogh W, Vaes P. The multiple hop test: a discriminative or evaluative instrument for chronic ankle instability? *Clin J Sport Med*. 2012;22(3):228-33.
37. Linens SW, Ross SE, Arnold BL, Gayle R, Pidcoe P. Postural-Stability Tests That Identify Individuals With Chronic Ankle Instability. *Journal of Athletic Training*. 2014;49(1):15-23.
38. Docherty CL, Arnold BL, Gansneder BM, Hurwitz S, Gieck J. Functional-Performance Deficits in Volunteers With Functional Ankle Instability. *J Athl Train*. 2005;40(1):30-4.
39. Hiller CE, Refshauge KM, Herbert RD, Kilbreath SL. Balance and recovery from a perturbation are impaired in people with functional ankle instability. *Clin J Sport Med*. 2007;17(4):269-75.
40. Vuurberg G, Kluit L, van Dijk CN. The Cumberland Ankle Instability Tool (CAIT) in the Dutch population with and without complaints of ankle instability. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(3):882-91.

41. Wicherts JM, Vorst HCM. Modelpassing van de Verkorte Profile of Mood States en meetinvariantie over mannen en vrouwen. *Nederlands tijdschrift voor de psychologie en haar grensgebieden*. 2004;59(1):11-20.
42. Donovan L, Hertel J. A new paradigm for rehabilitation of patients with chronic ankle instability. *Phys Sportsmed*. 2012;40(4):41-51.
43. Olsen OE, Myklebust G, Engebretsen L, Holme I, Bahr R. Relationship between floor type and risk of ACL injury in team handball. *Scand J Med Sci Sports*. 2003;13(5):299-304.
44. Doherty C, Delahunt E, Caulfield B, et al. The incidence and prevalence of ankle sprain injury: a systematic review and meta-analysis of prospective epidemiological studies. *Sports Med*. 2014;44(1):123-40.
45. Gribble PA, Bleakley CM, Caulfield BM, et al. Evidence review for the 2016 International Ankle Consortium consensus statement on the prevalence, impact and long-term consequences of lateral ankle sprains. *British journal of sports medicine*. 2016;50(24):1496-505.
46. Christino MA, Fleming BC, Machan JT, Shalvoy RM. Psychological Factors Associated With Anterior Cruciate Ligament Reconstruction Recovery. *Orthopaedic journal of sports medicine*. 2016;4(3):2325967116638341.
47. Wright CJ, Linens SW, Cain MS. Establishing the Minimal Clinically Important Difference and Minimal Detectable Change for the Cumberland Ankle Instability Tool. *Arch Phys Med Rehabil*. 2017;98(9):1806-11.
48. Tyler TF, McHugh MP, Mirabella MR, Mullaney MJ, Nicholas SJ. Risk factors for noncontact ankle sprains in high school football players: the role of previous ankle sprains and body mass index. *The American journal of sports medicine*. 2006;34(3):471-5.
49. Yeung MS¹ CK, So CH, Yuan WY. An epidemiological survey on ankle sprain. *British journal of sports medicine*. 1994;5.
50. Berger BG, Motl RW. Exercise and mood: A selective review and synthesis of research employing the profile of mood states. *Journal of Applied Sport Psychology*. 2000;12(1):69-92.
51. Hillstrom HJ, Song J, Kraszewski AP, et al. Foot type biomechanics part 1: structure and function of the asymptomatic foot. *Gait & posture*. 2013;37(3):445-51.

