Effect of taping on multi-segmental foot kinematic patterns during walking in persons with chronic ankle instability

Bart Dingenen^a, Kevin Deschamps^{a,b,c}, Frauke Delchambre^a, Evelien Van Peer^a, Filip F. Staes^a, Giovanni A. Matricali^{d,e}

^a KU Leuven, Department of Rehabilitation Sciences, Musculoskeletal Rehabilitation Research Group, Belgium

^b KU Leuven, Laboratory for Clinical Motion Analysis, University Hospital Pellenberg, Belgium

^c Parnasse-ISEI, Department of Podiatry, Brussels, Belgium

^d KU Leuven, Department of Development & Regeneration, Belgium

^e KU Leuven, Department of Orthopaedics, Foot & Ankle Unit, University Hospitals Leuven, Belgium

Corresponding author: Bart Dingenen, PT, PhD. KU Leuven Musculoskeletal Rehabilitation Research Group, Department of Rehabilitation Sciences, Faculty of Kinesiology and Rehabilitation Sciences, Tervuursevest 101 b1501 3001 Heverlee, Belgium. Tel: +32 16 376534; Fax: +32 16 329197; E-mail: bart.dingenen@kuleuven.be

Word count: 2997

Abstract word count: 249

Number of tables: 1

Number of figures: 2

Number of supplementary files: 3

Effect of taping on multi-segmental foot kinematic patterns during walking in persons with chronic ankle instability

3

4

5

6

7

8

9

0

1

2

3

4

5

6 **Word count:** 2997

7 **Abstract word count: 249**

8 **Number of tables:** 1

9 **Number of figures: 2**

Number of supplementary files: 3

Abstract

Objectives: To evaluate multi-segmental foot kinematic patterns in chronic ankle instability (CAI) participants during walking, and to investigate the influence of high-Dye and low-Dye taping on these kinematic patterns.

Design: Cross-sectional study.

Methods: Kinematic data of 12 non-injured controls and 15 CAI participants were measured with a three-dimensional motion analysis system during barefoot walking. In addition, the CAI participants walked with high-Dye and low-Dye taping. A rigid Plug-in gait model and the Rizzoli 3D Multi-Segment Foot Model were used to measure multi-segmental foot kinematic patterns. One-dimensional statistical parametric mapping was used to compare barefoot walking of the control and CAI group, and to evaluate differences between walking barefoot and walking with high-Dye and low-Dye taping within the CAI group.

Results: Compared to the control group, CAI participants showed a decreased ankle dorsiflexion during loading response ($p=0.025$) and a more inverted calcaneus in relation to the shank during the initial swing phase ($p=0.024$). A more inverted position of the metatarsus in relation to the midfoot was observed after low-Dye taping during almost the entire stance phase ($p=0.017$). No significant differences were found for high-Dye taping.

Conclusions: Significant differences in kinematic patterns were found in the ankle joint and rearfoot, but not in the mid- and forefoot in CAI participants. The application of low-Dye taping resulted in a significantly increased inverted position of the forefoot, which can be considered as a less desirable effect for patients with CAI. No other effects of high-Dye and low-Dye taping on kinematic patterns were revealed.

Keywords: chronic ankle instability, taping, kinematics, foot

1. Introduction

Lateral ankle sprains are one of the most common injuries experienced during sports activities,[1, 2] but recent data also highlight the incidence of lateral ankle sprains during daily activities such as walking in the general population.[3] Despite the fact that lateral ankle sprains are generally regarded as benign injuries that resolve quickly, high recurrence rates and numerous residual symptoms have been reported after the initial lateral ankle sprain.[4] A major concern on the long term for both the individual sport participant as well as for the society as a whole is the development of chronic ankle instability (CAI), which has recently been re-defined by the International Ankle Consortium.[5]

Altered gait kinematics may be one of the possible risk factors to predispose individuals to develop and/or maintain CAI. Retrospective studies showed an increased foot inversion in CAI participants during terminal swing and loading response compared to non-injured control participants.[6, 7] Drewes et al.[8] found an increased foot inversion and external tibial rotation throughout the entire gait cycle, and a more out-of-phase shank-rearfoot coupling during the terminal swing phase in participants with CAI compared to non-injured controls. In the sagittal plane, a less dorsiflexed position during mid- to late stance during shod walking was reported in CAI participants.[9]

The results of these previous studies were acquired through investigations whereby the foot was considered as one rigid segment, hereby neglecting multi-segmental foot kinematics. To enhance our understanding of ankle and foot function in CAI participants, there is an obvious need for studies evaluating the complex multi-segmental foot kinematics.[10] De Ridder et al.[11] demonstrated that CAI participants showed a significantly greater inverted position of the medial forefoot in relation to the midfoot compared to the control group from 87-98% of the stance phase. In contrast, a significantly more everted foot and increased rearfoot eversion in relation to the shank was found from 11-73% and 56-73% of the stance phase, respectively. Only the stance phase was analyzed in this study. The swing phase was not included.

Ankle taping is often applied in patients with CAI,[12] and has been proved to be effective in reducing the incidence of lateral ankle sprains in persons with a history of lateral ankle sprains.[13] One of the

potential mechanisms of protection of ankle taping in patients with CAI is the correction and/or control of ankle joint motion.[14, 15] Many different taping techniques exist and these often vary across sports, type of injury and therapists. High-Dye taping includes the ankle and lower limb and reduces the degree of ankle plantar flexion and inversion in participants with CAI when walking shod, hereby putting the ankle in a more neutral position.[14] Low-Dye taping only includes the rear-, mid- and forefoot. Deschamps et al.[15] were the first to investigate the effect of both taping techniques on multi-segmental foot kinematics in CAI participants during running. To the best of our knowledge, no studies have evaluated these effects during walking. As lateral ankle sprains also often occur during walking,[3] a detailed investigation of these multi-segmental patterns can enhance our understanding of the therapeutic effects of ankle taping in participants with CAI.

The aim of this study was therefore twofold. First, we aimed to compare multi-segmental foot kinematic patterns between CAI participants and non-injured controls during walking. Second, we aimed to investigate the influence of two ankle taping techniques (high-Dye and low-Dye) on these kinematic patterns in CAI participants.

2. Methods

Twenty-seven recreationally active university students (defined by at least 1.5 h of cardiovascular activity per week) participated in this study.[15] Participants were recruited through advertisement at KU Leuven between February 2013 and February 2014, and are identical to the study of Deschamps et al.[15] Each participant was categorized in either the CAI group (6 men, 9 women) or the control group (5 men, 7 women) (Table 1).[15] A self-report questionnaire was used to determine if they met the inclusion criteria. Inclusion criteria for the CAI group were: (1) a history of at least one significant ankle sprain and (2) a history of the ankle joint giving way as defined by Delahunt et al.[16] This self-reported ankle instability was confirmed with the Cumberland Ankle Instability Tool (CAIT),[17] a validated ankle instability-specific questionnaire using a cut-off score of ≤ 24 . Exclusion criteria for both groups were (1) being younger than 18 years or older than 30 years, (2) previous surgery or

fracture in either lower extremity, (3) other lesions to the musculoskeletal structures of either lower extremity and/or back at the moment of testing that have an impact on joint integrity and function (except for CAI in the CAI group), (4) recent participation in a rehabilitation program and (5) systemic, neurological and orthopaedic diseases.[15] The current study was initiated prior to the position statement of the International Ankle Consortium.[5] However, our criteria matched those of the International Ankle Consortium statement in the majority of cases. Exceptions are the exclusion criteria (1) and (4). The study was approved by the local ethical committee and all participants voluntary agreed to sign an informed consent form.

Gait analysis was performed in a motion-analysis laboratory. A passive opto-electronic motion analysis system (Vicon Motion System Ltd., Oxford Metrics, UK) consisting of 10 T-10 cameras was used to track the kinematic data (100 Hz) of all participants while walking over a 10-meter walkway. In this walkway, a custom-made force plate (Advanced Mechanical Technology Inc., Watertown, MA, USA) was imbedded in the middle, covered with a pressure plate (Footscan, dimensions 0.5 x 0.4 m, 4096 sensors, 2.8 sensors per cm², RS scan International, Olen, Belgium). The current set-up provided an objective measurement of the foot strike pattern and formed the basis for calculating spatiotemporal parameters. Data from the force plate were sampled at 200 Hz.

Prior to testing, CAI participants were asked to fill in the CAIT (Version 3).[17] Reflective markers were placed using double-sided tape on foot and lower limb anatomical landmarks according to the Plug-in gait model[18] and the Rizzoli 3D multi-segment foot model.[19] Afterwards, participants were instructed to walk barefoot at a constant speed of 1.5 m/s ($\pm 10\%$). Walking speed was measured by monitoring the velocity of the reflective marker on the sacrum. The control group performed barefoot walking trials only, whereas the CAI group additionally performed trials with high-Dye and low-Dye taping. The order of these test conditions was randomly assigned. Every condition was repeated until at least three valid trials were registered. A valid trial consisted of a correct landing of the entire foot on the force plate, located at the center of the walkway.

Non-elastic sports tape (38 mm, All Products BVBA, Belgium) was applied when the subject was lying supine with the feet in a neutral position.[15] All tapes were applied by the same investigator (BD). The high-Dye taping technique was performed according to MacDonald[20] (Supplementary file 1). The low-Dye taping technique was performed according to Vicenzino et al.[21] (Supplementary file 2). The reflective markers of the foot were again attached after the application of the tape (Supplementary file 3).

The spatiotemporal variables measured in this study were walking speed, stride time, stance time and swing time. Normalization of the data to 100% of the gait cycle was performed within Matlab 2012a (The MathWorks, Inc., Natick, US). The dependent variable that was considered from the Plug-in gait model was the foot progression angle. Kinematic data from the Rizzoli foot model were computed throughout the Vicon Foot model Plug-in (Aurion Srl, Milano, Italy) using Nexus 1.5 software. This five-segment model defines the 3D rotations between the shank (Sha), foot (Foo), calcaneus (Cal), midfoot (Mid), metatarsus (Met) and hallux as rigid segments. The sagittal plane angle of the first metatarsophalangeal joint was also calculated.

Statistical analysis on demographical and spatiotemporal parameters was performed using the Wilcoxon Test and ANOVA respectively. Statistical calculations were performed in Matlab 2012a. Differences between the kinematic profiles across the entire gait cycle were analyzed with one-dimensional statistical parametric mapping.[22] We included four different groups: CAI barefoot (CAI_BF), CAI high-Dye (CAI_HD), CAI low-Dye (CAI_LD) and the control group. The most affected limb of the CAI participants was matched with the limb of the control group participants for between-group comparisons, based on the CAIT scores (mean $\pm$ SD: 17.6 ± 4.0). In case of an identical CAIT score for both legs (2 out of 15 participants), the dominant side, defined as the preferred leg to kick a ball, was selected. The presence of any significant differences between the kinematic patterns of the control group and the CAI_BF group was established with a two-sample t-test (SPM{t}) over the normalized time series (hypothesis testing 1).[15] The presence of any significant differences between kinematic patterns of the three CAI conditions was established by

applying an ANOVA (SPM{f}) analysis over the normalized time series (hypothesis testing 2).[15] If statistical differences were present, post-hoc t-tests (SPM{t}) were used to determine between-group differences. All one-dimensional statistical parametric mapping analyses were implemented using the open-source code (v.M0.1, www.spm1d.org) in Matlab (R2014a, 8.3.0.532, The Mathworks Inc, Natick, MA).

3. Results

All demographic and spatiotemporal parameters were not significantly different between groups ($p>0.05$) (Table 1).

Graphical representations of all average movement patterns according to the Plug-in gait model and the Rizzoli model are presented in Figures 1 and 2. For the sagittal plane Sha-Foo angle, a significant decreased dorsiflexion was found in the CAI_BF group compared to the control group during 6-11% of the gait cycle ($p=0.025$). The calcaneus was significantly more inverted in relation to the shank in the CAI_BF group compared to the control group during 63-72% of the gait cycle ($p=0.024$).

When comparing the mean kinematic waveforms between the three conditions of the CAI group, the critical threshold associated to the SPM{f} analyses was only exceeded for the frontal plane Mid-Met angle. Post-hoc SPM{t} analyses demonstrated that the metatarsus was significantly more inverted in relation to the midfoot in the CAI_LD condition compared to the CAI_BF condition during 0-52% of the gait cycle ($p=0.017$).

4. Discussion

The present study is the first to measure multi-segmental foot kinematic patterns during both the stance and swing phase of walking in participants with and without CAI, and to evaluate the influence of high-Dye and low-Dye taping on these foot kinematic patterns.

While walking barefoot, the CAI group showed less dorsiflexion of the entire foot compared to the control group during 6-11% of the gait cycle, representing the loading response phase. These results are similar to Chinn et al.[9] where CAI participants showed less dorsiflexion during shod walking compared to a control group. It has been hypothesized that the decreased dorsiflexion in CAI participants can be attributed to arthrokinematic changes at the talocrural joint.[9, 23]

In addition to this altered sagittal plane movement pattern, an increased inversion of the calcaneus in relation to the shank was found in the CAI group compared to the control group. This movement pattern may contribute to a less optimal positioning of the rearfoot at initial contact and loading response, hereby potentially increasing lateral ankle sprain injury risk. Previous studies reported an increased inverted foot position during terminal swing and loading response[6, 7] or during the whole stance phase[8] in CAI participants compared to a non-injured control group. However, De Ridder et al.[11] found an increased everted foot position and increased rearfoot eversion in relation to the shank from 11-73% and 56-73% of the stance phase during walking, respectively. Based on these contrary findings between different studies, caution is warranted when only evaluating inversion and eversion movements of the (rear)foot in relation to CAI.

A detailed visual observation of the kinematic waveforms of the CAI_BF and control group (Figures 1 and 2) shows a trend towards more calcaneus adduction in relation to the shank across the whole gait cycle. Furthermore, a trend toward a more internally rotated foot progression angle across the entire gait cycle was found, which was previously also reported by Nawata et al.[24] The increased adduction of the calcaneus in relation to the shank could be a compensation for this overall decreased externally rotated position of the foot with respect to the walking direction. Even though the reasons to use these altered movement patterns remain somewhat unclear, it is generally believed that a loss of dorsiflexion in combination with an inverted and adducted calcaneus in relation to the shank, and a more internally rotated foot progression angle prevents the ankle reaching a more stable close-packed position, which is considered less favorable to absorb the external ground reaction forces to prevent lateral ankle sprains to occur in persons with CAI.

No significant differences between the CAI_BF and control group were found in mid- and forefoot kinematic patterns. De Ridder et al.[11] found a significantly greater inverted position of the medial forefoot (first ray) in relation to the midfoot compared to the control group from 87-98% of the stance phase during walking, which would result in a mechanically less stable forefoot.[25] This discrepancy with the results of our study may be explained by the fact that we used a 1-segment forefoot, whereas those authors used a 2-segment forefoot (medial and lateral forefoot).

The second aim of this study was to evaluate the influence of high-Dye and low-Dye taping on kinematic patterns in participants with CAI. The statistical significant differences quantified by the one-dimensional statistical parametric mapping analyses were limited to the frontal plane Mid-Met angle. When walking with the low-Dye tape, the metatarsus stayed in a significantly more inverted position during almost the entire stance phase. This phenomenon was previously also observed during running,[15] and may have been found because the metatarsus is “pulled” in an inverted position by the mini-stirrups of the low-Dye tape. Previous research proved that CAI participants showed an increased eversion movement in the entire foot during 11-73% of the stance phase.[11] However, it is not of interest to excessively counteract this compensation strategy by creating more inversion because a more inverted position of the entire foot complex during walking is suggested to increase lateral ankle sprain injury risk.[6, 7] In addition, the limited eversion of the metatarsals during push-off may prohibit an effective propulsion over the hallux. As a consequence, the windlass mechanism, which is important to generate a powerful and stable push-off, may become less efficient.

Based on visual observation of the sagittal plane Sha-Foo and Sha-Cal kinematic patterns, it may be concluded that high-Dye taping somehow neutralized the decreased dorsiflexion between the shank and the entire ankle/foot complex, hereby positioning the ankle in a more closed packed position. These findings agree with the previous studies where high-Dye taping was found to be an effective method to restrict the plantar flexion range of motion during running,[15] shod walking[14] and single-leg drop landings.[26] In contrast with the high-Dye taping, the kinematic pattern of the sagittal plane Sha-Foo and Sha-Cal angles remained largely unchanged when using the low-Dye taping. The

exclusion of the talocrural joint with low-Dye taping may provide a reasonable explanation for this finding. The inverted position of the calcaneus in relation to the shank in the CAI_BF condition was not significantly neutralized by the taping conditions, although a firm trend towards less inversion can be visually observed. The alterations in foot progression and transversal Sha-Cal angles observed in CAI participants cannot be favorably controlled with ankle taping during walking.

The findings that some less optimal movement patterns are still present despite the application of ankle taping may imply that other or complementary mechanisms (e.g. proprioceptive, neuromuscular, psychological or placebo) might also be important to explain the injury-reduction effect of ankle taping. Other interventions (e.g. balance training)[27] targeting the generator of these movement patterns (the central nervous system)[28] may be needed to effectively alter foot kinematics during walking. Alternatively, one should be aware that some more subtle kinematic alterations of the foot resulting from the application of ankle taping may not be quantified with the current one-dimensional statistical parametric mapping analyses. This statistical methodology was used in the current study in order to pursue an adequate answer to the hypotheses of the study (e.g. topological analysis of the kinematic waveforms). Based on the results of the current study and the visually observed kinematic patterns (Figures 1 and 2), it seems that other hypothesis testing may be worthwhile to consider in future studies, e.g. hypothesis related to summary metrics or joint coupling. For example, a reduced transversal plane range of motion in the Cal-Mid angle and frontal plane range of motion in the Cal-Met angle can be observed in both taping conditions (more flattened curves), especially during the terminal stance phase.

Based on the cross-sectional design of the study, it remains unknown whether kinematic alterations are the cause or the result of CAI. Furthermore, it is possible that the kinematic effects of taping become more obvious during more strenuous activities such as running or jumping. Because of the multi-segmental foot kinematics measured in this study, we could only measure barefoot conditions. Caution is warranted when extrapolating these results to shod conditions. The application of the reflective markers on the foot was challenging in the taping conditions, although the anatomical landmarks were

still accurately palpable. Only one experienced clinician (KD) performed the marker positioning, which has been highlighted to be important with respect to the repeatability of measuring multi-segmental foot kinematics.[29]

5. Conclusions

A decreased ankle dorsiflexion during loading response and an increased inversion of the calcaneus in relation to the shank during the initial swing phase were found in CAI participants compared to non-injured control participants while walking barefoot. No significant different mid- and forefoot kinematic patterns were found. The application of low-Dye taping resulted in a significantly increased inverted position of the forefoot, which can be considered as a less desirable effect for persons with CAI. No other significant effects on kinematic patterns of high-Dye and low-Dye taping were revealed.

6. Practical implications

- Therapeutic interventions should aim optimizing ankle and rearfoot positioning during walking.
- Low-Dye taping resulted in negative kinematic effects in the forefoot.
- Patients with CAI may benefit more from high-Dye taping compared to low-Dye taping.

Acknowledgments

This project was supported by a research grant from the Belgische Vereniging voor Orthopedie en Traumatologie.

272 **References**

- 273 1. Fong DTP, Hong YL, Chan LK et al. A systematic review on ankle injury and ankle sprain in
274 sports. *Sports Med* 2007; 37(1):73-94.
- 275 2. Doherty C, Delahunt E, Caulfield B et al. The incidence and prevalence of ankle sprain injury: a
276 systematic review and meta-analysis of prospective epidemiological studies. *Sports Med* 2014;
277 44(1):123-140.
- 278 3. Gribble PA., Bleakley CM, Caulfield BM et al., Evidence review for the 2016 International
279 Ankle Consortium consensus statement on the prevalence, impact and long-term consequences
280 of lateral ankle sprains. *Br J Sports Med* 2016; 50(24):1496-1505.
- 281 4. van Rijn RM, van Os AG, Bernsen RM et al. What is the clinical course of acute ankle sprains?
282 A systematic literature review. *Am J Med* 2008; 121(4):324-331.
- 283 5. Gribble PA, Delahunt E, Bleakley C et al. Selection criteria for patients with chronic ankle
284 instability in controlled research: a position statement of the International Ankle Consortium. *J*
285 *Orthop Sports Phys Ther* 2013; 43(8):585-591.
- 286 6. Monaghan K, Delahunt E, Caulfield B. Ankle function during gait in patients with chronic ankle
287 instability compared to controls. *Clin Biomech* 2006; 21(2):168-174.
- 288 7. Delahunt E, Monaghan K, Caulfield B. Altered neuromuscular control and ankle joint
289 kinematics during walking in subjects with functional instability of the ankle joint. *Am J Sports*
290 *Med* 2006; 34(12):1970-1976.
- 291 8. Drewes LK, McKeon PO, Paolini G et al. Altered ankle kinematics and shank-rear-foot coupling
292 in those with chronic ankle instability. *J Sport Rehabil* 2009; 18(3):375-388.
- 293 9. Chinn L, Dicharry J, Hertel J. Ankle kinematics of individuals with chronic ankle instability
294 while walking and jogging on a treadmill in shoes. *Phys Ther Sport* 2013; 14(4):232-239.

- 295 10. Morrison KE, Kaminski TW. Foot characteristics in association with inversion ankle injury. *J*
296 *Athl Train* 2007; 42(1):135-142.
- 297 11. De Ridder R, Willems T, Vanrenterghem J et al. Gait kinematics of subjects with ankle
298 instability using a multisegmented foot model. *Med Sci Sports Exerc* 2013; 45(11):2129-2136.
- 299 12. Verhagen EA, Bay K. Optimising ankle sprain prevention: a critical review and practical
300 appraisal of the literature. *Br J Sports Med* 2010; 44(15):1082-1088.
- 301 13. Olmsted LC, Vela LI, Denegar CR et al. Prophylactic ankle taping and bracing: A numbers-
302 needed-to-treat and cost-benefit analysis. *J Athl Train* 2004; 39(1):95-100.
- 303 14. Chinn L, Dicharry J, Hart JM et al. Gait kinematics after taping in participants with chronic
304 ankle instability. *J Athl Train* 2014; 49(3):322-330.
- 305 15. Deschamps K, Dingenen B, Pans F et al. Effect of taping on foot kinematics in persons with
306 chronic ankle instability. *J Sci Med Sport* 2016; 19(7):541-546.
- 307 16. Delahunt E, Coughlan GF, Caulfield B et al. Inclusion criteria when investigating insufficiencies
308 in chronic ankle instability. *Med Sci Sports Exerc* 2010; 42(11):2106-2121.
- 309 17. Hiller CE, Refshauge KM, Bundy AC et al. The Cumberland ankle instability tool: a report of
310 validity and reliability testing. *Arch Phys Med Rehabil* 2006; 87(9):1235-1241.
- 311 18. Davis RB, Ounpuu S, Tyburski D et al. A gait analysis data-collection and reduction technique.
312 *Hum Mov Sci* 1991;10(5):575-587.
- 313 19. Leardini A, Benedetti MG, Berti L et al. Rear-foot, mid-foot and fore-foot motion during the
314 stance phase of gait. *Gait Posture* 2007; 25(3):453-462.
- 315 20. MacDonald R. *Taping techniques: principles and practice*, 2nd ed., Edinburgh, Butterworth
316 Heinemann, 2004.

- 317 21. Vicenzino B, Feilding J, Howard R et al. An investigation of the anti-pronation effect of two
318 taping methods after application and exercise. *Gait Posture* 1997; 5(1):1-5.
- 319 22. Pataky TC. One-dimensional statistical parametric mapping in Python. *Comput Methods*
320 *Biomech Biomed Engin* 2012; 15(3):295-301.
- 321 23. Drewes LK, McKeon PO, Kerrigan DC et al. Dorsiflexion deficit during jogging with chronic
322 ankle instability. *J Sci Med Sport* 2009; 12(6):685-687.
- 323 24. Nawata K, Nishihara S, Hayashi I et al. Plantar pressure distribution during gait in athletes with
324 functional instability of the ankle joint: preliminary report. *J Orthop Sci* 2005; 10(3):298-301.
- 325 25. Perez HR, Reber LK, Christensen JC. The effect of frontal plane position on first ray motion:
326 forefoot locking mechanism. *Foot Ankle Int* 2008; 29(1):72-76.
- 327 26. Delahunt E, O'Driscoll J, Moran K. Effects of taping and exercise on ankle joint movement in
328 subjects with chronic ankle instability: a preliminary investigation. *Arch Phys Med Rehabil*
329 2009; 90(8):1418-1422.
- 330 27. McKeon PO, Paolini G, Ingersoll CD et al. Effects of balance training on gait parameters in
331 patients with chronic ankle instability: a randomized controlled trial. *Clin Rehabil* 2009;
332 23(7):609-621.
- 333 28. Hass CJ, Bishop MD, Doidge D et al. Chronic ankle instability alters central organization of
334 movement. *Am J Sports Med* 2010; 38(4):829-834.
- 335 29. Deschamps K, Staes F, Bruyninckx H et al. Repeatability in the assessment of multi-segment
336 foot kinematics. *Gait Posture*, 2012; 35(2):255-260.
- 337

338 **Table 1.** Demographic characteristics and spatiotemporal data of all groups.

Demographic characteristics	Control	CAI				p-value
Participants	12	15				
Age (years) (M $\pm$ SD)	23.6 $\pm$ 4.1	22 $\pm$ 2.7				> 0.05
BMI (kg/m ²) (M $\pm$ SD)	22.2 $\pm$ 2.0	23.6 $\pm$ 3.0				> 0.05
Male (n) / Female (n) ratio	4/7	6/9				> 0.05
Spatiotemporal parameters	Control	CAI_BF	CAI_LD	CAI_HD		
Walking speed (m/s) (M $\pm$ SD)	1.4 $\pm$ 0.1	1.4 $\pm$ 0.2	1.5 $\pm$ 0.2	1.5 $\pm$ 0.2	> 0.05	
Stride time (s) (M $\pm$ SD)	1.0 $\pm$ 0.1	1.1 $\pm$ 0.1	1.0 $\pm$ 0.1	1.0 $\pm$ 0.1	> 0.05	
Stance time (% GC) (M $\pm$ SD)	57.8 $\pm$ 4.1	59.1 $\pm$ 1.3	58.2 $\pm$ 1.8	58.2 $\pm$ 1.7	> 0.05	
Swing time (% GC) (M $\pm$ SD)	40.1 $\pm$ 3.3	40.9 $\pm$ 1.3	41.9 $\pm$ 1.8	41.9 $\pm$ 1.7	> 0.05	

BMI: body mass index; M: mean; SD: standard deviation; GC: gait cycle; CAI_BF: chronic ankle instability group, barefoot condition; CAI_LD: chronic ankle instability group, Low-Dye taping condition; CAI_HD: chronic ankle instability group, High-Dye taping condition.

339

340

Figure legends

Figure 1. Graphical representation of kinematic pattern between-group comparisons with standard deviation cloud (control group) for the foot progression angle and the sagittal plane angle of the first metatarsophalangeal joint (F2Ps) angle. (CAI_BF (red line), CAI_HD (green line), CAI_LD (blue line)). The vertical (black) line represents the average toe off of all conditions. Stance phase joint motion is depicted on the left side of the toe off line and swing phase joint motion is depicted on the right side.

Figure 2. Graphical representation of kinematic pattern between-group comparisons with standard deviation cloud (control group) for the Sha-Foo, Sha-Cal, Cal-Mid, Mid-Met and Cal-Met angles. (CAI_BF (red line), CAI_HD (green line), CAI_LD (blue line)). The vertical (black) line represents the average toe off of all conditions. Stance phase joint motion is depicted on the left side of the toe off line and swing phase joint motion is depicted on the right side.

Table 1. Demographic characteristics and spatiotemporal data of all groups.

Demographic characteristics	Control	CAI				p-value
Participants	12	15				
Age (years) (M ± SD)	23.6 ± 4.1	22.0 ± 2.7				> 0.05
BMI (kg/m²) (M ± SD)	22.2 ± 2.0	23.6 ± 3.0				> 0.05
Male (n) / Female (n) ratio	4/7	6/9				> 0.05
Spatiotemporal parameters	Control	CAI_BF	CAI_LD	CAI_HD		
Walking speed (m/s) (M ± SD)	1.4 ± 0.1	1.4 ± 0.2	1.5 ± 0.2	1.5 ± 0.2	> 0.05	
Stride time (s) (M ± SD)	1.0 ± 0.1	1.1 ± 0.1	1.0 ± 0.1	1.0 ± 0.1	> 0.05	
Stance time (% GC) (M ± SD)	57.8 ± 4.1	59.1 ± 1.3	58.2 ± 1.8	58.2 ± 1.7	> 0.05	
Swing time (% GC) (M ± SD)	40.1 ± 3.3	40.9 ± 1.3	41.9 ± 1.8	41.9 ± 1.7	> 0.05	

BMI: body mass index; M: mean; SD: standard deviation; GC: gait cycle; CAI_BF: chronic ankle instability group, barefoot condition; CAI_LD: chronic ankle instability group, Low-Dye taping condition; CAI_HD: chronic ankle instability group, High-Dye taping condition.

Figure 1
[Click here to download high resolution image](#)

Figure 2
[Click here to download high resolution image](#)

Supplementary file 1. High-Dye taping technique according to MacDonald (2004)

A) First, semi-circular anchoring on the distal 1/3 of the tibia (proximal anchor) and on the distal forefoot (distal anchor) was applied. B) Then a stirrup was placed from medial proximal anchor, along the sole of the foot to be anchored on the lateral proximal anchor with tension. C) Following this stirrup, a horizontal strip was applied from lateral distal anchor to the medial distal anchor around the achilles tendon. D) The two stirrups were repeated alternating three times where the tape is covered by half of its width each time. E) Then a heel lock was applied, which starts medially on the proximal anchor, runs distally to the lateral malleolus, dorsally over the achilles tendon, turns over the calcaneus to go under the heel and anchors parallel to the starting point on the medial side of the proximal anchor. This heel lock was repeated on the lateral side. F) Semi-circular anchoring was repeated in order to lock and strengthen the whole taping construction.

Supplementary file 2. Low-Dye taping technique according to Vicenzino et al. (1997)

A) A first strip was applied by placing it just proximal to the first metatarsophalangeal joint and then laying the tape along the medial side of the foot. B) Then a second strip starting medially just proximal to the first metatarsophalangeal joint is wrapped around the posterior aspect of the calcaneus and laid along the lateral side of the foot to the fifth metatarsophalangeal joint. Some longitudinal traction was applied to the tape, opposing forefoot abduction, in order to gain a neutral alignment. C) Following this strip, a series of mini-stirrups was applied. These started at the strip on the lateral side of the foot, running perpendicularly to the strip and were then placed along the sole of the foot to be anchored at the strip on the medial side of the foot. Some traction was applied. The mini-stirrups covered each other by half of its width and were placed from distal to proximal until the calcaneus was covered. D) A last strip was applied the same way as the first strip, to lock the mini-stirrups.

Supplementary file 3. Foot marker placement in the barefoot, high-Dye taping and low-Dye taping condition.

A) Barefoot, B) high-Dye taping, C) low-Dye taping