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The predictive value of the multiple hop test for first-time noncontact lateral ankle sprains

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1 The predictive value of the multiple hop test for first-time noncontact lateral ankle
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35

36

Abstract

The predictive value of the multiple hop test for first-time noncontact lateral ankle sprains.

Background: Lateral ankle sprains (LAS) are very common sports injuries, cause high health care costs and are associated with postural control deficits. From a preventive point of view, clinicians should dispose valid field tests to identify athletes at risk for a LAS. The aim of this study is to evaluate the predictive value of the multiple hop test (MHT) for first-time noncontact LAS.

Methods: Non-elite athletes (n=232) performed the MHT at baseline. During a 12-month follow-up period, all noncontact LAS related to health care costs were recorded. Outcomes of the MHT (completion time, balance errors and perceived difficulty) between the injured and uninjured group were compared and odds ratios (OR) and relative risks (RR) were calculated using a logistic regression analysis.

Results: Ten first-time noncontact LAS were recorded (4.3%). Injured athletes made significantly more change-in-support strategy (CSS) errors when compared to uninjured athletes ($p = .04$). The OR of the number of CSS errors was 1.14 ($p = .03$), the RR 4.1 ($p = .04$).

Conclusions: Athletes scoring > 12 CSS errors, have a four times increased risk for a first-time noncontact LAS. The MHT is a valid field test to identify athletes at risk for a first-time noncontact LAS.

Key words: prognosis, lateral ankle sprain, postural control, injury risk.

59 1. Introduction

60 Although participation in sport is beneficial for general health, it also increases the
61 risk of musculoskeletal injury. Noncontact lateral ankle sprains (LAS) are one of the
62 most common sports injuries (Barber Foss, Myer, & Hewett, 2014; Fong, Hong,
63 Chan, Yung, & Chan, 2007; Waterman, Owens, Davey, Zacchilli, & Belmont, 2010)
64 with an estimated incidence of 0.72 (adults) to 1.94 (adolescents) per 1000 athletes
65 exposure (Doherty et al., 2014).

66 Lateral ankle sprains cause high health care costs as in the Netherlands, e.g., the
67 annual health care costs are estimated to be € 84 to 200 million (Hupperets,
68 Verhagen, & van Mechelen, 2009; Janssen, Hendriks, van Mechelen, & Verhagen,
69 2014). Moreover, an initial LAS can result in recurrent injuries (Verhagen, Van der
70 Beek, Bouter, Bahr, & Van Mechelen, 2004), longstanding residual ankle symptoms
71 like anterior impingement (Vuurberg et al., 2018) and the development of chronic
72 ankle instability (CAI) (van Rijn et al., 2008). These findings emphasize the
73 importance of primary prevention of LAS.

74 Knowledge of modifiable risk factors may help reducing LAS incidence and the
75 related health care costs. Based upon a recent guideline, a postural control deficit is a
76 very important modifiable intrinsic risk factor for LAS (Vuurberg et al., 2018).

77 Balance and postural control can be defined as the ability to maintain and control the
78 centre of mass (COM) over the area of base of support during standing and
79 movement (Grassi et al., 2018; Maki & McIlroy, 1997; Pollock, Durward, Rowe, &
80 Paul, 2000). A postural control deficit may lead to larger corrective motions resulting
81 in larger shear forces. This may increase the inability of controlling the inversion
82 moment at the ankle when landing and increase the susceptibility for a LAS (Tropp,

2002). It has been demonstrated that neuromuscular training, aimed at improving balance, significantly reduces the incidence of LAS and its associated costs (Hupperets et al., 2010; Hupperets et al., 2009). Athletic trainers and clinicians should dispose valid field tests measuring postural control in order to identify athletes at risk for a LAS. Particularly athletes with a postural control deficit may benefit from neuromuscular training. Several studies already investigated the predictive value of tests measuring balance or postural control for LAS (Grassi et al., 2018); (Hegedus, McDonough, Bleakley, Baxter, & Cook, 2015). However, many of these tests are just static tests, i.e. bilateral leg or one-leg stance tests mostly measuring postural sway (Beynnon, Murphy, & Alosa, 2002; McGuine, Greene, Best, & Levenson, 2000; Tropp, Ekstrand, & Gillquist, 1984; Watson, 1999; Willems, Witvrouw, Delbaere, Mahieu, et al., 2005; Willems, Witvrouw, Delbaere, Philippaerts, et al., 2005). The Star Excursion Balance Test (SEBT) or its variant (Y-balance test) are more dynamic field tests that have been used in earlier research (de Noronha, Franca, Hauptenthal, & Nunes, 2013; Gribble, Hertel, & Plisky, 2012; Gribble et al., 2016; Plisky, Rauh, Kaminski, & Underwood, 2006). During this test, subjects are also standing on one leg but must reach from a centre point as far as possible with the contralateral leg into three directions. Results of these studies indicate that athletes who perform significantly worse on the SEBT have an increased injury risk (de Noronha et al., 2013; Gribble et al., 2012; Gribble et al., 2016; Plisky et al., 2006). However, LAS mostly occur when landing after a jump or when performing a cutting manoeuvre (Vuurberg et al., 2018). In contrast to the SEBT, the multiple hop test (MHT) requires postural control during a jump-landing task and might thus be more representative of sport specific situations. Therefore, it is relevant to study the predictive value of the MHT for first-time noncontact LAS.

108 In earlier research, the multiple hop test (MHT) has been used to evaluate the
109 dynamic postural control in healthy subjects and subjects with CAI. It has been
110 demonstrated that the intrarater reliability (ICC = .83, 95% CI: .63-.92) as well as the
111 interrater reliability (ICC = .91, 95% CI: .85-.95) of the evaluation method of
112 balance errors is excellent (Eechaute, Vaes, & Duquet, 2009). CAI subjects
113 performed significantly worse (making significantly more balance errors) on the
114 MHT than healthy controls (Eechaute, Bautmans, De Hertogh, & Vaes, 2012;
115 Eechaute et al., 2017; Eechaute, Vaes, & Duquet, 2008; Eechaute, Vaes, Duquet, &
116 Van Gheluwe, 2009; Groeters, Groen, van Cingel, & Duysens, 2013). At present, it is
117 unknown whether the MHT is predictive for first-time noncontact LAS as well. From
118 a socioeconomic point of view, particularly LAS resulting in health care costs should
119 be prevented and therefore, athletes at risk for sustaining LAS should be identified.
120 So, the purpose of this study is to evaluate the predictive value of the MHT for first-
121 time noncontact LAS. We hypothesize that the MHT can identify athletes with an
122 increased risk for first-time noncontact LAS.

123

124 2. Methods.

125 2.1. Participants

126 College students from three universities (n= 234) were selected based on (1) age
127 between 18 and 25, (2) being non-elite athletes (i.e. playing competition at a
128 nonprofessional level), (3) playing sports associated with a high LAS incidence (e.g.
129 basketball, field soccer, indoor volleyball, handball, tennis) and (4) having no
130 previous history of a LAS.

131 Athletes were excluded if they had sustained a lower extremity injury in the
132 preceding six months prior to inclusion, if they were extremely fatigued, if they had
133 any signs of acute inflammation (pain, swelling, stiffness and impaired function) in
134 the lower extremities thus preventing the athlete from participating at the baseline
135 testing, or if they had any presence of vestibular disorders.

136 To check their eligibility, participants completed a questionnaire containing all
137 inclusion and exclusion criteria. In addition, participants were questioned about the
138 implementation of preventive training during the preseason period. At the moment of
139 baseline testing, athletes also underwent a brief clinical examination (conducted by a
140 physical therapist), this to check the last two exclusion criteria and to confirm their
141 eligibility. All eligible athletes signed a written informed consent. The ethical
142 committee of the University approved the study (NR 2012/168).

143

144

145 2.2. Baseline measurements.

146 Between the period September-October of two consecutive academic years, eligible
147 non-elite athletes were screened using the MHT (Eechaute et al., 2008; Eechaute,
148 Vaes, & Duquet, 2009). In brief, subjects stand on one leg, with the contralateral leg
149 flexed in hip and knee and the hands placed on the iliac crests (starting position).
150 From this position, subjects hop and land with the same limb on 10 different tape
151 markers, in a crossed direction (Figure 1). During the test, subjects are instructed to
152 try maintaining balance when hopping and landing and to avoid any postural
153 correction, as this was the primary goal of the test. Subjects were only allowed to
154 hop to the next tape marker when they stood still after landing and had taken the

155 starting position. Before testing, each subject performed one practice trial on each
156 limb. During this test trial, verbal instructions were given. Subsequently, subjects
157 performed three test trials with each leg. The decision to start with the left or right
158 leg was randomly chosen.

159

160 ***Figure 1 near here***

161 The MHT was evaluated using three outcome measures: the time to complete the
162 test, the perceived difficulty of the test and type and number of balance errors. The
163 completion times of the MHT were measured with a precision of 0.01 seconds
164 between the start- and stop signal using a digital hand chronometer (Digi Sports
165 instruments). After the final completion of the MHT, each subject rated the perceived
166 difficulty of the test on a 100-mm Visual Analogue Scale. The minimum score was
167 indicated “not difficult at all”, while the maximum score indicated “impossible to
168 perform”. The difficulty of the MHT was rated for each limb separately. Test
169 performances were recorded using a digital video camera (Sony handycam HDR-
170 CX200E), placed in front of and perpendicular to the hopping course. All video
171 images recorded during the first year were analysed by one observer. All video
172 images recorded during the second year were analysed by another observer. The
173 observers were blinded for the identity of the athlete (injured or uninjured). The
174 observer analysed the videos (if necessary in slow motion) in order to decide whether
175 or not the subject made a balance error at each landing. Each balance error was
176 categorized as a fixed-support-strategy (FSS) or a change-in-support-strategy (CSS)
177 (Horak, Nashner, & Diener, 1990; Maki & McIlroy, 1997). Only the first balance
178 error, observed at each landing, was taken into account. Balance errors classified as

179 FSS errors were: moving the trunk $> 30^\circ$ medially or laterally into the frontal plane,
180 holding the legs joined, swinging the non-supported leg $> 30^\circ$ laterally into the
181 frontal plane or flexing the trunk forward (see Figure 2). Balance errors classified as
182 CSS errors are: Displacing the supporting foot (shuffling or jumping), touching the
183 ground with the non-supporting leg or releasing the hands from the iliac crests (see
184 Figure 3).

185

186 ***Figures 2 and 3 near here***

187

188 2.3. Injury registration.

189 During a 12-month follow-up period, first-time noncontact LAS were recorded. All
190 participants were instructed to inform the researchers when they sustained a LAS
191 during the follow-up period. In addition, all athletes were contacted by e-mail on a
192 monthly basis to verify whether the athlete sustained an injury. If an athlete did not
193 respond to the e-mail within 2 weeks, the athlete was then contacted by phone. In the
194 case of an ankle sprain injury, researchers, who were blinded for baseline test results,
195 verified the nature and circumstances of the sustained injury by phone. The injury
196 was classified as being a noncontact LAS if (1) it implied an injury of the lateral
197 ligaments of the ankle during landing, (2) it was not the result of a direct contact
198 (push, pull or kick), (3) it caused the athlete to stop the training session or game
199 immediately, (4) the LAS was diagnosed by a medical doctor (e.g. general
200 practitioner, sports physician) and (5) the injury resulted in health care costs.

201 In the case of a noncontact LAS, each injured athlete received an electronic injury
202 registration form which contained detailed questions about the nature and date of
203 injury, localisation of symptoms, etc. On the same electronic registration form,
204 injured athletes collected continuously all medical investigations and all treatments
205 that were related to the LAS until the moment they were fully recovered and returned
206 into competition. A similar method for collecting health care costs using an
207 electronic diary has previously been used in earlier studies (Hupperets et al., 2009;
208 Janssen et al., 2014; Verhagen, van Tulder, van der Beek, Bouter, & van Mechelen,
209 2005). From this information, the direct socio-economic cost was calculated. These
210 direct costs were related to the diagnosing and treatment of the LAS (i.e. medical
211 imaging, visits to a general practitioner, sports physician, medical specialist, physical
212 therapy sessions, medical devices, plaster cast, ankle brace, medication, exercise
213 equipment like balance boards). The calculation of these direct costs was estimated
214 based on the Institute of Public Sickness Insurance and Handicaps (RIZIV). The
215 costs of drugs were estimated based on the Belgian Centre of Farmaceutical
216 Information (BCFI). As all participants were college students, no indirect costs were
217 obtained.

218 To estimate exposure time, researchers contacted the athletes by email and/or phone
219 on a monthly basis to verify whether the athlete participated normally to practices
220 and games in the past month or if he/she missed training sessions or competition
221 games.

222

223 2.4. Statistics.

224 The number of CSS- and FSS errors of the three hopping courses were summed up
225 for each limb (scores ranging from 0 to 30 errors). The completion times of the three
226 hopping courses were averaged and the perceived difficulty of the MHT was rated on
227 a 100 mm VAS for each limb separately. Results of the variables of the injured group
228 were compared to the uninjured group using a Mann-Whitney U test ($p < .05$).
229 Scores from the dominant limb in the uninjured group were compared with the
230 nondominant limb (limb dominance was defined as the limb chosen by the subject to
231 jump as far or as high as possible; (van Melick, Meddeler, Hoogeboom, Nijhuis-van
232 der Sanden, & van Cingel, 2017). As no significant differences between dominant
233 and nondominant limbs were observed (paired t-test; $p > .05$), scores of the uninjured
234 group were randomly chosen for the between-group comparison. Fisher exact tests
235 were used to determine the association between injury status and gender, and
236 between injury status and type of sport. For the variables from the MHT
237 demonstrating a significant between-group difference, the effect size according to
238 Cohen's d with 95% CI was calculated and this variable was included into a logistic
239 regression analysis to calculate the odds ratio (OR). A subgroup analysis was then
240 performed, dividing athletes into a low risk (LR) or a high-risk (HR) group. This
241 categorization was based upon the most optimal cutoff point (value that maximized
242 the sum of sensitivity and specificity) obtained by constructing a Receiver Operating
243 Characteristic curve (ROC). The corresponding relative risks (RRs) and likelihood
244 ratios (LRs) were then calculated. The RR indicates the probability of sustaining a
245 first-time noncontact LAS in the HR group compared to the probability of sustaining
246 a first-time noncontact LAS in the LR group. The LR+ indicates the probability of an
247 athlete with a score above the cutoff point who will sustain a first-time noncontact

248 LAS compared to the probability of an athlete with a score above the cutoff point
249 who will not sustain a first-time noncontact LAS. The LR- indicates the probability
250 of an athlete with a score below the cutoff point who will not sustain a first-time
251 noncontact LAS compared to the probability of an athlete with a score below the
252 cutoff point but, despite this, will sustain a first-time noncontact LAS. The
253 significance level was set at $p < .05$. MedCalc (v13.1.2; MedCalc Software) was used
254 for the calculation of the RR, LR, PPV and NPV. IBM SPSS Statistics 23 software
255 (SPSS Inc, Illinois, USA) was used for all other analyses. The sample size
256 calculation was based upon the difference in the number of balance errors observed
257 between healthy subjects and CAI subjects (Eechaute, Vaes, & Duquet, 2009) and
258 also on the prevalence of first-time LAS (Doherty et al., 2014). A sample size of at
259 least 140 athletes was required with an α of .05 and a β of .80.

260

261 3. Results.

262 Participants.

263 A total of 234 non-elite athletes met the criteria and were included in this study
264 (Figure 4). The athletic population consisted of 137 males (age: 19.2 ± 2.1 years;
265 height: $1.83 \pm .08$ m; mass: 74.5 ± 10.4 kg) and 97 females (age: 19.5 ± 3.1 years;
266 height: $1.70 \pm .06$ m; mass: 63.1 ± 7.8 kg). Forty-two percent of the athletes played
267 basketball, 32% field soccer, 17% indoor volleyball and 9% performed other ball
268 sports. During the follow-up period, 16 athletes (7%) dropped out of the study. Total
269 hours of sports participation during the one year follow-up period was 49510 hours.
270 Most athletes had two training sessions per week and one game (5 to 6 hours per

271 week) (Table 1). None of the participants implemented a preventive exercise
272 program during the preparation period of the season.

273

274 ***Figure 4 near here***

275

276 *** Table 1 near here***

277

278 Injury incidence.

279 Ten athletes (5 male; 5 female) sustained a first-time noncontact LAS (4.3%). Two
280 athletes (one male, one female), sustained a LAS just before baseline testing and
281 were therefore not able to perform the MHT. Six LAS occurred during a game and
282 four during practice. Six athletes sustaining a first-time noncontact LAS played
283 basketball, two injured athletes played field soccer and the two other injured athletes
284 played tennis or korfbal respectively. The mean time interval between date of first-
285 time noncontact LAS and date of returning into sport competition was 50.7 ± 24.5
286 days. The injury incidence per 1000 h sports exposure in the 12-month period was
287 .20 (95% CI: .08-.32). The mean time interval between baseline measurement and
288 date of first-time noncontact LAS was 162.6 ± 147.7 days. All health care cost
289 diaries were completed and accounted for. The total health care cost (direct cost) was
290 estimated at €4538.9. The mean total cost per injured athlete was $€460.4 \pm 38.2$. The
291 total health care cost was mostly explained by physical therapy visits (€2270.5) and
292 the purchase of an ankle brace (€954.2).

293 Predictive value.

294 Neither gender ($p = .72$) nor type of sports ($p = .28$) were significantly associated
295 with injury status. A significant between-group difference was observed for the
296 number of CSS balance errors ($p = .04$) and the total number of balance errors ($p =$
297 $.04$) (Table 2).

298 The area under curve (AUC) for both variables was $.71$ (CSS errors, $p = .04$; total
299 errors; $p = .04$). The optimal cutoff point for both the number of CSS errors and total
300 number of balance errors was 12.5 errors (Tables 3 and 4).

301

302 *****Table 2 near here*****

303

304 The OR for both the number of CSS errors and the total number of balance errors
305 was 1.14 (CSS errors, $p = .03$; total errors, $p = .04$). This indicates that the odds for
306 sustaining a first-time noncontact LAS will increase by 14% for each increase in
307 (CSS) error. The total number of balance errors and the number of CSS errors
308 explained 7% and 8% of the variation in injury status respectively (Nagelkerke R^2).

309 The RR was only significant for the number of CSS errors (CSS errors: $RR = 4.1$, $p =$
310 $.04$; total errors: $RR = 3.4$, $p = .12$). The statistical measures of the predictive validity
311 of the MHT are presented in Table 5.

312

313 ***** Tables 3, 4 and 5 near here*****

314 4. Discussion.

315 The purpose of this study was to evaluate the predictive value of the MHT for first-
316 time noncontact LAS related to health care costs. Our findings indicate a significant
317 relationship between ankle sprain injury status and baseline score of the number of
318 CSS errors when performing the MHT. Injured athletes performed significantly
319 worse on the MHT at baseline when compared to uninjured athletes. The observed
320 significant differences indicate a moderate to large effect size (Table 3). The results
321 of our study are consistent with other studies demonstrating poor dynamic balance
322 (i.e. performance on the SEBT) as a risk factor for a LAS (de Noronha et al.,
323 2013{Gribble, 2016 #235). Athletes scoring poor on the SEBT (anterior reach
324 distance) are three times more likely to sustain a LAS (Gribble et al., 2016).
325 However, their test results were also related to previous LAS and contact LAS. In the
326 present study, athletes scoring more than 12 CSS errors on the MHT are four times
327 more likely to sustain a first-time noncontact LAS. The MHT requires postural
328 control during a jump-landing task which has been demonstrated to be an important
329 risk factor for LAS (Vuurberg et al., 2018). Therefore, the MHT may be even more
330 appropriate for identifying athletes at risk for a first-time noncontact LAS than the
331 SEBT.

332 Comparable to subjects with CAI, injured athletes also rely on a change-in-support
333 strategy during landing. The rationale behind this observation remains unclear.
334 Athletes who sustained a non-contact LAS demonstrated a significant hip abductor
335 muscle weakness at baseline (Powers, Ghoddosi, Straub, & Khayambashi, 2017). It
336 is thus not improbable that the CSS exhibited by the eventually injured athletes could
337 be a result of a decreased medial-lateral stability caused by an existing hip abductor
338 muscle weakness (Lee & Powers, 2014).

339 The corresponding LR+ of the best cutoff point of CSS errors only generates small
340 (but sometimes important) changes in probability (Jaeschke, Meade, Guyatt, Keenan,
341 & Cook, 1997). Neuromuscular training exercises used to prevent LAS, are highly
342 effective, easy to implement and have little complications (Schiftan, Ross, & Hahne,
343 2015). It may therefore be more appropriate to use a cutoff point with a high
344 sensitivity rather than using the “optimal “ cut-off point showing the highest
345 sensitivity and specificity (Bahr, 2016). When looking at the Receiver Operating
346 Characteristic (ROC) curve of the CSS errors, athletes with a score of 6 CSS errors
347 (or lower) have almost no risk for sustaining a first-time noncontact LAS and may
348 therefore require less preventive strategies than athletes with a score above this
349 cutoff point (Figure 5).

350

351 ***** Figure 5 near here*****

352

353 In the future, these cutoff points of the MHT could be used to identify athletes at risk
354 for a first-time noncontact LAS and to investigate the effect of preventive
355 neuromuscular training on the LAS incidence in this subpopulation of athletes
356 displaying a dynamic postural control deficit. As the Area Under Curve (AUC) of the
357 number of CSS errors only indicates moderate accuracy for predicting first-time
358 noncontact LAS (Akobeng, 2007), the screening and identification of athletes at risk
359 for a LAS should not solely be based on the results of the MHT. In the future, it may
360 be of interest to study the predictive value of a set of risk factors (also including
361 dorsiflexion ROM and other factors such as players’ position) for LAS. The use of
362 such a set of risk factors may identify athletes at risk for a first-time noncontact LAS

363 even more accurately. On the other hand, using such a set of risk factors will
364 complicate its practical applicability.

365 Some limitations should be taken into account when considering the results of this
366 study. Because of the low injury incidence and the stringent criteria that were used to
367 define LAS, one might assume that injuries were missed or misclassified. However,
368 during the 12-month follow-up period, each athlete was instructed to contact one of
369 the researchers in the case of a LAS. In addition, all athletes were monthly contacted
370 by e-mail or phone. This resulted in a response rate above 90% during the entire
371 follow-up period. Further on, the researchers checked the collected injury
372 information on the registration form by phone. This limited the possible risk of
373 registration bias. Moreover, the injury incidence of first-time LAS in our study is in
374 accordance to the LAS incidence observed in the study of Verhagen et al (7%)
375 (Verhagen et al., 2004). From a socioeconomic point of view, our study focused on
376 LAS resulting in health care costs. Therefore, we should keep in mind that the results
377 of our study are difficult to compare to studies that used other LAS definitions and
378 also included LAS that may not be related to health care costs (de Noronha et al.,
379 2013; Powers et al., 2017).

380 Results may be affected by differences in how tests were scored because videos were
381 analyzed by two different observers. However, these observers were well instructed
382 and trained in how to score videos. In addition, previous research has shown, the
383 interrater reliability of the evaluation of balance errors to be excellent.

384 In our study, we did not register players' position. The lack of this information may
385 have affected the results of our study, as it has been demonstrated that players'
386 position is a significant risk factor for sustaining a LAS (Vuurberg et al., 2018).

387 Conclusions.

388 Non-elite athletes sustaining a first-time noncontact LAS during a 12-month follow-
389 up period performed significantly worse on the MHT at baseline. Athletes making
390 more than 12 CSS errors, have a four times higher risk for sustaining a first-time
391 noncontact LAS. The MHT is a useful tool to evaluate dynamic postural control and
392 identify athletes at risk for a first-time noncontact LAS.

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hopping course left limb

hopping course right limb

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521 Fig 1. Hopping courses

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524 Fig 2. Example of FSS strategy

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527 Fig 3. Example of a CSS strategy

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Fig 4. Flow-chart of the prognostic study

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Fig. 5. Bar graph of individual values for uninjured and LAS athletes.

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The upper horizontal line represents the optimal cutoff point of the CSS score (12.5 errors). The lower horizontal line represents the cutoff point of the CSS score with the highest sensitivity (6 errors). Note that dots on the vertical line of uninjured athletes represent multiple scores of athletes with an identical score.

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Table 1. Demographic characteristics of sports categories.

	Basketball	Field soccer	Indoor volleyball	Other sports
	N = 97	N = 74	N = 39	N = 22
	Mean $\pm$ sd.	Mean $\pm$ sd.	Mean $\pm$ sd.	Mean $\pm$ sd.
Age (yrs)	20.5 $\pm$ 3.4	18.4 $\pm$ 1.0	18.3 $\pm$ 0.6	18.9 $\pm$ 1.1
Height (cm)	179.2 $\pm$ 10.1	177.4 $\pm$ 8.2	172.4 $\pm$ 9.0	176.7 $\pm$ 9.6
Mass (kg)	71.7 $\pm$ 10.7	71.1 $\pm$ 10.9	64.5 $\pm$ 9.7	66.9 $\pm$ 11.9
Sports hours (per wk)	6.5 $\pm$ 1.6	6.0 $\pm$ 1.8	6.6 $\pm$ 1.3	6.4 $\pm$ 3.0
Total sports hours (12 mnth)	217.9 $\pm$ 54.4	202.5 $\pm$ 61.2	223.2 $\pm$ 45.2	212.7 $\pm$ 100.3

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Table 2. Demographics and postural control values for the uninjured and LAS group.

	uninjured group	LAS group		
	n= 224	n=8		
	Mean $\pm$ sd	Mean $\pm$ sd	P	Cohen d (95% CI)
Age (yrs)	19.3 $\pm$ 2.6	19.4 $\pm$ 2.2	.48	
Height (cm)	177.3 $\pm$ 9.7	175.3 $\pm$ 6.7	.45	
Mass (kg)	69.8 $\pm$ 10.9	72.4 $\pm$ 12.7	.70	
Sports hours (per wk)	6.3 $\pm$ 1.8	6.6 $\pm$ 2.0	.68	
Total hours (12 mnth)	214.6 $\pm$ 61.1	178.9 $\pm$ 53.2	.05	
Time value (sec)	36.3 $\pm$ 8.3	37.1 $\pm$ 6.1	.78	
Total errors (n)	12.3 $\pm$ 5.2	16.1 $\pm$ 4.9	.04	.73 (.02-1.44)
CSS errors (n)	9.6 $\pm$ 5.3	14.0 $\pm$ 6.2	.04	.83 (.11-1.53)
FSS errors (n)	2.6 $\pm$ 2.4	2.1 $\pm$ 1.9	.64	
VAS score (mm)	38.7 $\pm$ 18.1	36.0 $\pm$ 12.5	.81	

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LAS, lateral ankle sprain; CSS, Change-in-Support-Strategy; FSS, Fixed-Support-Strategy; VAS, Visual Analogue Scale; sd., standard deviation; P, probability

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Table 3. Coordinates of the curve of the total number of balance errors.

Positive if greater than or equal	Se	1-Spec
2.00	1.000	1.000
3.50	1.000	.982
4.50	1.000	.951
5.50	1.000	.924
6.50	1.000	.879
7.50	1.000	.795
8.50	1.000	.723
9.50	1.000	.638
10.50	.750	.589
11.50	.750	.527
12.50	.750	.455
13.50	.625	.397
14.50	.625	.353
15.50	.500	.281
16.50	.500	.219
17.50	.375	.147
18.50	.375	.112
19.50	.375	.103
20.50	.250	.071
21.50	.250	.045
22.50	.000	.036
24.00	.000	.018
25.50	.000	.009
27.50	.000	.004
30.00	.000	.000
2.00	1.000	1.000
3.50	1.000	.982

564 Se= sensitivity; Spec= specificity

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Table 4. Coordinates of the curve of the number of CSS errors.

Positive if greater than or equal	Se	1-Spec
1.50	1.000	.978
2.50	1.000	.938
3.50	1.000	.879
4.50	1.000	.830
5.50	1.000	.772
6.50	.875	.665
7.50	.875	.598
8.50	.750	.513
9.50	.625	.455
10.50	.625	.402
11.50	.625	.330
12.50	.625	.277
13.50	.500	.219
14.50	.375	.188
15.50	.375	.143
16.50	.375	.116
17.50	.375	.089
18.50	.250	.067
19.50	.250	.058
20.50	.250	.040
21.50	.250	.027
22.50	.000	.013
23.50	.000	.009
26.00	.000	.004
29.00	.000	.000

Se= sensitivity; Spec= specificity

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Table 5. Statistical measures of the predictive validity of the MHT

Measure	CSS errors	Total number
Best cutoff	12.5	12.5
AUC	.71 (.53-.89) *	.71 (.55-.87) *
Se (%)	63 (24.5-91.5)	75 (34.9-96.8)
Spec (%)	72 (65.9-78.1)	55 (47.7-61.1)
OR	1.14 (1.01-1.3) *	1.14 (1.01-1.3) *
RR	4.1 (1.01-16.7) *	3.4 (.71-16.7)
LR+	2.3 (1.3-4.0)	1.7 (1.1-2.5)
LR-	.52 (.20-1.3)	.46 (.10-1.5)

572 AUC= area under curve; Se= sensitivity; Spec= specificity; OR=odds ratio; RR= relative
573 risk; LR+= positive likelihood ratio; LR-= negative likelihood ratio, * = $p < .05$; values
574 in parentheses are 95% CIs

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