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Title: Evaluation of combined prescription of rocker sole shoes and custom-made foot orthoses for the treatment of plantar fasciitis

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Abstract: Background: It is a routine practice to prescribe a combination of rocker shoes and custom-made foot orthoses for patients with plantar fasciitis. Recently, there has been a debate on this practice, and studies have shown that the individual prescription of rocker shoes or custom-made foot orthoses is effective in treating plantar fasciitis. The aim of this study was to evaluate and compare the immediate therapeutic effects of individually prescribed rocker sole shoes and custom-made foot orthoses, and a combined prescription of them on plantar fasciitis.

Methods: This was a cross-over study. Fifteen patients with unilateral plantar fasciitis were recruited; they were from both genders and aged between 40 and 65. Subjects performed walking trials which consisted of one 'unshod' condition and four 'shod' conditions while wearing baseline shoes, rocker shoes, baseline shoes with foot orthotics, and rocker shoes with foot orthotics. The study outcome measures were the immediate heel pain intensity levels as reflected by visual analogue scale pain ratings and the corresponding dynamic plantar pressure redistribution patterns as evaluated by a pressure insole system. **Results:** The results showed that a combination of rocker shoes and foot orthoses produced a significantly lower visual analogue scale pain score (9.7 mm) than rocker shoes (30.9 mm) and foot orthoses (29.5 mm). With regard to baseline shoes, it also significantly reduced the greatest amount of medial heel peak pressure (-33.58%) without overloading other plantar regions when compared to rocker shoes (-7.99%) and foot orthoses (-28.82%).

Discussion: The findings indicate that a combined prescription of rocker sole shoes and custom-made foot orthoses had greater immediate therapeutic effects compared to when each treatment had been individually prescribed.

Cover letter

Dear editor,

REF: Submission of manuscript “Evaluation of combined prescription of rocker sole shoes and custom-made foot orthoses for the treatment of plantar fasciitis”

The authors would like to submit this paper as a “Research Paper”. We declare that each author were fully involved in the study and preparation of the manuscript and that the material within has not been and will not be submitted for publication elsewhere. None of the authors has any commercial relationships which may lead to a conflict of interest.

For corresponding please contact Prof Daniel Tik-Pui Fong at Department of Orthopaedics and Traumatology, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong, China. (email: dfong@ort.cuhk.edu.hk)

Best regards

Kai-Yip Pang

Daniel Fong

Mandy Man-Ling Chung

Aaron See-Long Hung

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12th March 2012

Reviewers' comments:

Reviewer #1:

The authors have put considerable efforts in answering the questions. I still feel that the article needs edition by an English (native) speaker.

Thank you for your comments. This paper has been submitted to our university's academic editor for professional editing. An acknowledgement has also been added in Line 26-28.

With respect to the scientific value of the manuscript, I have no major remarks. Below you will find some final (minor) remarks which should be addressed in order to increase the readability of the paper.

Line 44-48: To my opinion the methods part is still not adequately organized and lacks good English vocabulary.

Thank you for your comments. We have reorganized the methods (Line 44-51) and also submitted the paper to our university's academic editor for professional editing.

Line 199: The authors have still not given an adequate definition of Peak Pressure (PP). Is the PP defined as the maximum pressure in the area considering the sensor with the peak value or making the sum of all sensors in the selected area. This is a critical point as FO will alter dramatically the contact area. Moreover, the fact that the authors are using pressure related parameters, it is imperative to mention the dimensions of the sensors.

The peak pressure is defined as the maximum pressure measured in any one sensor within the masked regions. Therefore, it is not the sum of all the sensors in the selected area.

The Novel Pedar system was used in our study. Each pair of Pedar insole was selected according to the subject's shoe size. In each Pedar insole, there are 84-99 embedded sensors. Further technical data of the insoles were obtained from the manufacturer and are shown below.

This information is added in Line 198-206.

Technical data

insole sizes	22 to 49 (european)
sensor thickness (mm)	1.9
thickness of leads	1.5
number of sensors	84 - 99
pressure range (kPa)	15 - 600
hysteresis (%)	< 7
resolution (kPa)	2.5
offset temperature drift (kPa/K)	< 0.5
frequency response (0-100 Hz)	< 2dB
min. bending radius (mm)	20
pressure change due bending (kPa)	< 20

Figure 1: Impossible to evaluate the added value of this table as poor readability due to resolution problems.

Sorry for the trouble. The figure has very good resolution when we downloaded the high resolution image from the generated pdf file. To further improve the figure quality, we have separated the single figure into five separate graphs.

Table 1: It is uncommon to provide not only the mean and standard deviation for specific demographic parameters but also the range. Normally, adequate selection of descriptive statistical parameters should reduce the amount of data.

We have removed the range from Table 1.

1 **Title Page**

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3 Evaluation of combined prescription of rocker sole shoes and custom-made foot
4 orthoses for the treatment of plantar fasciitis

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28 University of Hong Kong, for the effort in English proofreading.

30 **Keywords:** plantar fasciitis; rehabilitation; shoes

32 **Word count:** 271 (abstract); 3,439 (main text)

34 **No. of Figures:** 1

36 **No. of Tables:** 4

38 **Abstract**

39 *Background:* It is a routine practice to prescribe a combination of rocker shoes and
40 custom-made foot orthoses for patients with plantar fasciitis. Recently, there has
41 been a debate on this practice, and studies have shown that the individual
42 prescription of rocker shoes or custom-made foot orthoses is effective in treating
43 plantar fasciitis. The aim of this study was to evaluate and compare the immediate
44 therapeutic effects of individually prescribed rocker sole shoes and custom-made
45 foot orthoses, and a combined prescription of them on plantar fasciitis.

46 *Methods:* This was a cross-over study. Fifteen patients with unilateral plantar
47 fasciitis were recruited; they were from both genders and aged between 40 and 65.
48 Subjects performed walking trials which consisted of one 'unshod' condition and
49 four 'shod' conditions while wearing baseline shoes, rocker shoes, baseline shoes
50 with foot orthotics, and rocker shoes with foot orthotics. The study outcome
51 measures were the immediate heel pain intensity levels as reflected by visual
52 analogue scale pain ratings and the corresponding dynamic plantar pressure
53 redistribution patterns as evaluated by a pressure insole system. *Results:* The results

54 showed that a combination of rocker shoes and foot orthoses produced a
55 significantly lower visual analogue scale pain score (9.7 mm) than rocker shoes
56 (30.9 mm) and foot orthoses (29.5 mm). With regard to baseline shoes, it also

57 significantly reduced the greatest amount of medial heel peak pressure (-33.58%)
58 without overloading other plantar regions when compared to rocker shoes (-7.99%)
59 and foot orthoses (-28.82%).

60 *Discussion:* The findings indicate that a combined prescription of rocker sole shoes
61 and custom-made foot orthoses had greater immediate therapeutic effects compared
62 to when each treatment had been individually prescribed.

63
64

65 **Introduction**

66 Plantar fasciitis is a musculoskeletal overuse disorder with high prevalence. It
67 affects people irrespective of gender, age, ethnicity, or physical activity (Singh *et al.*,
68 1997). It has been estimated that about 10% of the population, particularly those
69 aged between 40 and 65 years, are affected at some time during their lives (Riddle *et*
70 *al.*, 2004; Taunton *et al.*, 2002). Plantar fasciitis is characterized by localized pain or
71 tenderness under the medial heel during palpation or weight-bearing, and it results in
72 the limitation of physical activity (Tisdell *et al.*, 1999). To date, the etiology of
73 plantar fasciitis is still poorly understood, and it remains unknown in approximately
74 85% of cases (Schepssis *et al.*, 1991). The literature suggests that its risk factors are
75 multi-factorial, and they can be categorized as environmental, anatomical, and
76 mechanical. Risk factors hitherto identified include a decreased ankle joint range of

77 motion, obesity, and occupations that require prolonged standing (Riddle *et al.*,
78 2003).

79

80 There is no single universally accepted method for treating plantar fasciitis. The
81 condition frequently responds to a wide range of conservative treatments that
82 demonstrate variable levels of efficacy from 46% to 98% (Tisdell *et al.*, 1999;
83 Schepssis *et al.*, 1991; Crawford & Thomson, 2003; Lynch *et al.*, 1998; Wolgin *et al.*,
84 1994). Many studies have, however, indicated a higher success rate with mechanical
85 therapies than with other conservative forms and their efficacy is usually greater
86 than 70% (Lynch *et al.*, 1998; Wolgin *et al.*, 1994; Martin *et al.*, 2001; Walter *et al.*,
87 2004). Over the years, there has been an extensive debate regarding the most
88 effective form of mechanical treatment. Rocker shoes and Custom-made Foot
89 Orthoses (FO), known as pedorthic devices, have frequently been advocated to
90 manage the mechanical factors which precipitate the development of plantar fasciitis.
91 It has been a routine practice to prescribe them in combination (Hutchins *et al.*, 2009;
92 Janisse & Janisse, 2008). However, the justification for this was based on the
93 phenomena of subjective pain relief and symptom resolution. To date, scientific
94 evidence to confirm these observations is equivocal.

95

96 Rocker shoes, which are a type of therapeutic footwear with an external
97 modification of the outsole contour (Hutchins *et al.*, 2009), are routinely prescribed
98 to relieve the high-pressure plantar regions of the foot (Brown *et al.*, 2004). The
99 shoes' basic clinical function is to 'rock' the foot from heel-strike to toe-off, thus
100 altering the motion and the force distribution patterns (Schie *et al.*, 2000). A variety
101 of designs accommodating different pathological needs are available. Three of the
102 most commonly prescribed rocker soles are the toe-only, negative heel, and double
103 rocker (Janisse & Janisse, 2008). Previous investigations have consistently
104 demonstrated that prescribing rocker shoes on their own (*i.e.*, without the inclusion
105 of FO) could reduce the heel pressure by 10% to 30% (Brown *et al.*, 2004; Schie *et*
106 *al.*, 2000; Praet & Louwerens, 2003) without adversely the affecting ambulatory
107 ability (Long *et al.*, 2004; Myers *et al.*, 2006; Van Bogart *et al.*, 2005). Its average
108 efficacy on plantar fasciitis treatment ranged from 59% to 72% (Hutchins *et al.*,
109 2009). The literature has not verified whether the inclusion of custom-made FOs
110 could be a further enhancement of the rocker shoes' intrinsic offloading functions.

111

112 Despite the development of custom-made FOs, the functional approach is still firmly
113 established as the paradigm of design and fabrication in the field of podiatry (Root,
114 1994). It emphasizes the importance of dynamic interrelationships between the foot

115 joints during gait. The biomechanical principles in which FO works have remained
116 contentious (Pratt, 2000). However, custom-made FOs have been extensively shown
117 to have favorable therapeutic outcomes for plantar fasciitis on their own in
118 non-rocker shoes (Crawford & Thomson, 2003; Lynch *et al.*, 1998; Walter *et al.*,
119 2004). The average efficacy ranged from 50% to 70% with a 20% to 30% reduction
120 of medial heel pressure (Lynch *et al.*, 1998; Martin *et al.*, 2001; Pratt, 2000; Roos *et*
121 *al.*, 2006; Landorf & Keenan, 2000). To date, there has been no quantitative study to
122 characterize the offloading property of FO in rocker shoes.

123

124 Conclusively, the individual prescription of rocker shoes and custom-made FOs has
125 been shown to be effective in treating plantar fasciitis. It is critical to quantitatively
126 justify their continued combined prescription in order to prevent the delivery of an
127 item which is of insignificant benefit to patients. Therefore, the purpose of this study
128 has been to explore the combined therapeutic effect of rocker shoes and
129 custom-made FOs on plantar fasciitis.

130

131 **Methods**

132 Subjects

133 A power analysis with a power of 0.8 and an α of 0.05 justified 15 subjects would be

134 sufficient to show a significant pressure reduction of 30%. This effect size was based
135 on previous study findings of rocker sole shoes on pressure relief at the medial heel
136 region (Brown *et al.*, 2004; Praet & Louwerens, 2003) and on the assumption of
137 clinically meaningful change for patients to experience pain relief (Farrar *et al.*,
138 2000; Williamson & Hoggart, 2005). Written informed consent was obtained from
139 all subjects before their admission to the study. Ethical approval was obtained from
140 the Joint Chinese University of Hong Kong (New Territories East Cluster) Clinical
141 Research Ethics Committee.

142

143 Fifteen Chinese patients (3 males, 12 females) with chief complaints of unilateral
144 plantar fasciitis (6 rights, 9 lefts) were recruited from a private podiatric clinic
145 during their first visit over 2.5 months. Their demographics are presented in Table 1.

146

147 The subject inclusion criteria were: (1) being aged between 40 and 65 years old
148 (Riddle *et al.*, 2004; Taunton *et al.*, 2002); (2) being referred by orthopaedic doctors
149 as having a confirmed diagnosis of plantar fasciitis; (3) having a persistent
150 complaint of plantar heel pain during ambulation and on the day of data collection;
151 (4) exhibiting abnormal foot pronation; and (5) having the ability of independent
152 non-aided heel-toe walking and being able to follow verbal instructions. Subjects

153 were excluded if they had a history or physical findings of: (1) traumatic injury in
154 the last six months; (2) previous plantar fascia surgery; (3) heel pain of neural origin,
155 fat pad atrophy and bursitis; (4) other associated pain at back, knee, or ankle and
156 foot affecting ambulation; and (5) biomechanical conditions contra-indicated either
157 for FO or rocker shoes (Long *et al.*, 2004; Myers *et al.*, 2006; Van Bogart *et al.*,
158 2005).

159

160 Materials

161 Each subject was well-fitted by the same certified pedorthist with two pairs of
162 testing shoes (baseline shoes, rocker sole shoes) and two pairs of testing inserts (flat
163 insoles, custom-made FOs). The baseline shoes were of an ordinary healthy style.
164 The rocker shoes were similar in all aspects to the baseline shoes except that the sole
165 was designed with a toe-only rocker profile. In accordance with the
166 recommendations of Schie *et al.* (2000), the rocker angle was 15° and the rocker
167 axis was positioned at 60% and oriented at 80° to the long axis of the shoes. Flat
168 insoles were made of 3-mm poron covered with a layer of fabric. Custom-made FOs,
169 in the Rootian functional approach, were fabricated by the Ezped Foot Orthotic
170 CAD/CAM System (Hong Kong) which was associated with a 3-D laser scanner. It
171 was an exact replication of a plaster technique by which a pair of 3-D electronic

172 casts in a non-weightbearing subtalar neutral position was captured and rectified
173 (Table 2). All FOs were prescribed in 3-mm polypropylene topped with 3-mm poron
174 and fabric cover. Both testing inserts were fabricated by a foot orthotic laboratory in
175 Hong Kong which was accredited by the Prescription Foot Orthotic Laboratory
176 Association (PFOLA) in the USA.

177

178 Experiment

179 This was a cross-over study in which every subject performed walking trials in each
180 of the five test conditions. These conditions consisted of: (1) an ‘unshod’ condition
181 (barefoot), and four ‘shod’ conditions using (2) Baseline Shoes with flat Insoles
182 (BSI), (3) Baseline Shoes with custom-made foot Orthoses (BSO), (4) Rocker Shoes
183 with flat Insoles (RSI), and (5) Rocker Shoes with custom-made foot Orthoses
184 (RSO). A cross-over design was chosen in order to minimize the within-group
185 variability and to lower the subject attrition; this was because these could potentially
186 create errors in the study.

187

188 The study outcome measurements were the ratings of medial heel pain intensity
189 associated with plantar fasciitis at the first step and during gait reflected by the
190 visual analogue scale (VAS) and their corresponding dynamic plantar pressure

191 redistribution evaluated by a pair of pressure insoles (Novel Pedar System,
192 Germany). Both the VAS pain score and plantar pressure insoles were well
193 documented as being valid and reliable for clinical pain rating (Williamson &
194 Hoggart, 2005; Bijur *et al.*, 2001) and shoe-foot interface plantar pressure
195 evaluation (Putti *et al.*, 2007). Similar outcome measures have been used in other
196 plantar fasciitis studies (Wearing *et al.*, 2003; Wearing *et al.*, 2007).

197 Measurement

198 The VAS pain score questionnaire was administered immediately after each test
199 condition (Dixon & Bird, 1981; Williamson & Hoggart, 2005). Each subject was
200 asked to make the respective marks on the same questionnaire to minimize the
201 variability of VAS scoring for repeated measures (Rosier *et al.*, 2002; Scott &
202 Huskisson, 1979). The VAS pain score has been shown to be linear with ratio
203 properties (Price *et al.*, 1983), and thus it is statistically robust for parametric
204 statistical analysis if the distribution of data is Normal or transformable to Normal
205 (Dexter & Chestnut, 1995). The dynamic variation of bipedal plantar pressure
206 distributions of all 'shod' conditions was used to supplement the objectivity of the
207 VAS pain ratings. There were 99-sensors embedded in each insole which recorded
208 data at a sampling rate of 100 Hz. Each insole was divided into 10 anatomical
209 regions, which were automatically masked by the system as medial heel (M01),

210 lateral heel (M02), medial mid-foot (M03), lateral mid-foot (M04), 1st metatarsal
211 head (M05), 2nd and 3rd metatarsal heads (M06), lateral metatarsal heads (M07),
212 hallux (M08), 2nd and 3rd toes (M09) and lateral toes (M10). Peak plantar pressure
213 was evaluated in each region during the stance phase. The peak plantar pressure is
214 defined as the maximum pressure measured by any one sensor within the masked
215 regions.

216

217 Test Protocol

218 All data for a given subject were collected on the same day. Each subject performed
219 three heel-toe walking trials for each test condition on a 6-meter long, straight,
220 carpet-covered linoleum concrete walkway. Because plantar pressure and perceived
221 pain intensity are associated with the walking speeds (Willson & Kernozek, 1999),
222 the subjects were instructed to walk naturally at their own self-selected speeds.
223 Consistency of walking speed was monitored in all trials by counting the time
224 required for six steps (Brown *et al.*, 1996). A trial was discarded if the walking was
225 not performed in a smooth natural gait, in a straight line, or with inconsistent speeds.

226

227 The evaluation always began with an unshod walking condition followed by four
228 shod walking conditions in a randomized sequence outputted by a random-number

229 generator program. All participants were blinded for the test conditions which were
230 prepared in a separate room. Between successive test conditions, the subjects were
231 given: (1) a five-minutes rest, extended on request, in order to avoid the pain being
232 aggravated during tests and carried over to the next test condition; (2) the VAS pain
233 level questionnaire immediately after each test condition; and (3) sufficient practice
234 walking trials to become accustomed to the next test condition at the desired speed
235 before data capture.

236

237 Analysis

238 The recordings of all walking trials were displayed, processed, edited and analyzed
239 by the associated software (Novel Pedar System, Germany). To negate the
240 acceleration and deceleration effects, the data of the first step and the last step of
241 each trial of the involved side were trimmed out. Four sequential steps were then
242 selected and their peak pressures during stance were averaged in each of the 10
243 anatomical regions. Data from all trials, all test conditions, and all subjects were
244 pooled together for statistical analysis.

245

246 For both VAS-immediate pain ratings and pressure data, if the Shapiro-Wilk
247 normality test was passed, repeated measures one-way ANOVA with Bonferroni

248 correction post-hoc pairwise comparisons was conducted to explore any significant
249 difference ($p < 0.05$) between the test conditions. Otherwise, non-parametric
250 Friedman one-way ANOVA was employed. All statistical tests were conducted by
251 SPSS 16 with significance level at $p < 0.05$.

252

253 **Results**

254 The self-selected walking speed of the subjects ranged from 96 to 120 steps per
255 minute. The p-values of the Shapiro-Wilk normality test of all data sets of
256 VAS-immediate pain ratings and regional peak pressures in all test conditions were
257 greater than 0.05. This indicated that the parametric statistical analyses were eligible.
258 The percentage changes of the VAS-immediate pain ratings, with respect to barefoot
259 walking, of the four 'shod' conditions and the results of repeated measures one-way
260 ANOVA with Bonferroni correction post-hoc pairwise comparisons are shown in
261 Table 3.

262

263 Descriptive statistics and the results of repeated measures one-way ANOVA and
264 Bonferroni corrected post-hoc test on peak pressures for each of the 10 anatomical
265 regions in four shod conditions are shown in Table 4. It was found that, except in the
266 region of the 2nd and 3rd toes, the rest of the other nine regions demonstrated a

267 significant difference in peak pressures between the four shod conditions. With
268 respect to BSI, the percentage changes of peak pressures for each of the 10
269 anatomical regions in RSI, BSO, and RSO are compared graphically in Figure 1.

270

271 **Discussion**

272 In this study, the immediate therapeutic effects on plantar fasciitis among rocker
273 shoes, FO and a combination thereof were evaluated and compared. Clinically, it
274 was more accurate to use a percentage reduction in the VAS pain ratings (rather than
275 the raw changes) as a means of comparing treatment (Williamson & Hoggart, 2005).

276 It was verified that a 33% reduction was a clinically meaningful change for patients
277 to experience pain relief (Farrar *et al.*, 2000). The immediate reduction of pain
278 intensities of RSI, BSO, and RSO were found respectively to be 52.5%, 54.6%, and
279 85.1% with respect to barefoot walking. All three reductions were greater than 33%;
280 however, RSO got a further 30% reduction in pain intensity compared to BSO and
281 RSI. Critically, statistical findings indicate that rocker shoes combined with FOs
282 produce significantly greater immediate pain relief in the medial heel than individual
283 prescription of rocker shoes and FOs.

284

285 As a mechanical treatment in plantar fasciitis, it was expected that the pedorthic

286 device could relieve overloads or undesirable pressures at the medial heel during
287 gait and, in turn, reduce the pain associated with plantar fasciitis. For the peak
288 pressures at medial heel, their means were 145.81, 112.80, and 105.25 kPa for RSI,
289 BSO, and RSO, respectively. The combination of rocker shoes and FOs
290 demonstrated significantly greater offloading in medial heel pressure than when
291 rocker shoes and FOs are used separately. The results of the VAS pain ratings were
292 objectively supported by peak pressure data.

293

294 The only difference between baseline shoes and rocker shoes was their outsole
295 profiles. Comparative analysis on the patterns of dynamic regional peak pressure
296 was therefore conducted to explore the plantar pressure redistribution behavior of
297 the rocker soles. The findings revealed a significant reduction in peak pressures
298 across the forefoot and medial heel regions. Such consistent reductions were then
299 balanced by elevated plantar pressure in the mid-foot. This observation was in
300 agreement with previous studies (Hutchins *et al.*, 2009). However, it was noted that
301 the rocker shoes were more effective in reducing pressure in the forefoot than in the
302 heel. The significant decreases of forefoot pressure ranged approximately from 13%
303 to 25%, whereas there was only an 8% decrease in medial heel pressure. In the
304 literature, heel pressure reductions generally ranged from 10% to 30% (Brown *et al.*,

305 2004; Long *et al.*, 2004; Myers *et al.*, 2006; Van Bogart *et al.*, 2005). However,
306 direct comparisons in terms of pressure values were not reliable because of two
307 fundamental reasons. Firstly, the design of rocker sole profiles employed in previous
308 studies varied considerably in the rocker angles. Secondly, subjects in most of the
309 previous studies were either asymptomatic or diabetic neuropathic individuals who
310 were all pain-free. Therefore, the values so obtained were not representative. It was
311 a merit of this study to recruit subjects whose demographics most reflect those that
312 are commonly referred for pedorthic treatment (Taunton *et al.*, 2002). Furthermore,
313 it should be noted that the current findings highlight profound pressure elevation
314 across the mid-foot after rocker shoes had been prescribed. This has important
315 clinical implications for future rocker shoes prescription; this is because it may be a
316 potential source of irritation or even pain particularly for patients who suffer from
317 mid-foot pathologies.

318

319 By comparing the dynamic regional peak pressures between BSO and BSI, the
320 effects of the inclusion of FOs on the redistribution of the shoe-foot interface plantar
321 pressure were examined. The results demonstrated that the FOs used in this study
322 were able to significantly reduce the medial heel pressure by 28.82%. This finding is
323 comparable to those in previous studies, which demonstrated a reduction in medial

324 heel pressure from 20% to 30% (Pratt, 2000; Roos *et al.*, 2006; Kandorf & Keenan,
325 2000). In contrast to a rocker sole acting as a powerful forefoot offloader, FOs
326 worked as a strong heel offloader. FOs significantly reduced medial heel and lateral
327 heel pressure by nearly 30% and 28%, whereas the rocker sole reduced it by only
328 8% and 5%. Another fundamental difference between their behaviors was the
329 strategy of pressure redistribution at mid-foot. A rocker sole demonstrated
330 significant pressure increases of 18.5% and 14.4% at medial mid-foot and lateral
331 mid-foot, respectively. Conversely, FOs decreased medial mid-foot and lateral
332 mid-foot pressure significantly by 15.1% and 19.4%; this was because of the
333 increased contact area of mid-foot via the custom-casted contour of the orthotics
334 (Kogler *et al.*, 1996). Thus, rocker soles and FOs possessed their own strengths and
335 drawbacks in accordance with their pressure redistribution behaviors. Rocker soles
336 reduced the pressures in the heel and forefoot by redistributing the pressure to
337 mid-foot, thereby potentially overloading that region. On the other hand, FOs
338 reduced the pressure at mid-foot by redistributing the pressure to the forefoot, and
339 this may potentially cause forefoot overloads.

340

341 The comparative analysis of regional peak pressure between RSO and BSI was
342 equivalent to characterizing the interactive redistribution behavior of rocker soles

343 and FOs in combination. To date, the literature has focused chiefly on the interaction
344 of FOs and medical shoes, which were non-rocker-soled, on the plantar pressure
345 distribution of diabetic patients with or without neuropathy (Ashry *et al.*, 1997; Lord
346 & Hosein, 1994; Lotta *et al.*, 2007; Tsung *et al.*, 2004).

347

348 The study findings reveal that RSO served as a powerful offloader both of the heel
349 and the forefoot pressure during gait. As compared to rocker behavior, RSO was a
350 stronger forefoot offloader with less risk of mid-foot overloads when compared to a
351 rocker sole acting alone. Referring to orthotics behavior, further decreases in
352 forefoot pressure would likely be caused by the effects from FO. In other words, the
353 rocker behavior of RSO was enhanced because of the inclusion of the FO. As
354 compared to orthotics behavior, RSO reduced more pressure at the heel than FO.
355 Similarly, referring to the rocker behavior, such a decrease could be the contribution
356 of the rocker shoes. Due to presence of a rocker sole, RSO acted as a stronger heel
357 offloader than when FO was used alone. At the same time, a satisfactory
358 redistribution of forefoot pressure was possible.

359

360 In conclusion, these findings suggest that the RSO utilized the pressure
361 redistribution benefits both of the rocker sole and FO. The rocker sole reduced

362 forefoot plantar pressure by redistributing the plantar pressure to the mid-foot, which
363 was reduced by the FO. Insignificant pressure difference across the mid-foot was
364 thus elucidated. Additional studies should be conducted on the details of their
365 interactive biomechanics.

366

367 Only the immediate effect of a combination of rocker shoes and FOs was evaluated
368 by using a subjective VAS pain score. Because of the meaningful findings, further
369 studies on its efficacy in the treatment of plantar fasciitis are justified. In future
370 studies, randomized controlled trials should also be conducted to assess the
371 long-term effects of the combined prescription of rocker sole shoe and custom-made
372 FO.

373

374 **Conclusion**

375 The statistical results show that the combination of rocker shoes and FOs produce a
376 significantly lower VAS pain score (9.7 mm) than rocker shoes (30.9 mm) and FOs
377 (29.5 mm). With respect to baseline shoes, it also significantly reduced the greatest
378 amount of medial heel peak pressure (-33.58%) without overloading other plantar
379 regions when compared to rocker shoes (-7.99%) and FOs (-28.82%). RSO was a
380 safer mechanical modality of plantar fasciitis. Therefore, the practice of combined

381 prescription of custom-made FOs and rocker sole shoes was justified to provide

382 greater immediate therapeutic effects on plantar fasciitis.

383

384

385

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489

490 **Figure and Table Legends**

491 Figure 1a–e: Dynamic plantar pressure redistribution between test conditions. BSI:
492 Baseline shoes with flat insoles; RSI: Rocker shoes with flat insoles; BSO: Baseline
493 shoes with custom-made foot orthoses; RSO: Rocker shoes with custom-made foot
494 orthoses. (M01: Medial heel, M02: Lateral heel, M03: Medial mid-foot, M04:
495 Lateral mid-foot, M05: 1st Metatarsal head, M06: 2nd and 3rd Metatarsal heads,
496 M07: Lateral metatarsal head, M08: Hallux, M09: 2nd and 3rd Toes, M10: Lateral
497 toes.) * = statistical significant difference with $p < 0.05$.

498 Table 1: Subjects demographics of the study

499 Table 2: The standard of cast rectification

500 Table 3: VAS-immediate pain ratings of the test conditions

501 Table 4: Dynamic regional peak pressure (kPa) of the ‘shod’ conditions

Table 1: Subjects demographics of the study

	Mean (S.D.)
Age (yr)	50.6 (5.3)
Weight (kg)	64.3 (24.9)
Height (cm)	158.7 (7.2)
Shoe size (Eur)	38.2 (2.5)
Duration of symptoms (months)	11.0 (2.5)

Table 2: The standard of cast rectification

Type of rectification	Standard
Medial addition	2-mm
Lateral expansion	3-mm
Heel cup height	Posterior:13-mm Medial: 13-mm Lateral: 13-mm
Extrinsic rearfoot posting (EVA: 80)	Up to the level of sustentaculum tali
Intrinsic forefoot posting	5-mm and 3-mm beyond the 1 st and 5 th metatarsophangeal joints respectively

Table 3: VAS-immediate pain ratings of the test conditions

Test Conditions ^a	Mean	S.D.	% Δ VAS _(barefoot) ^b	Statistical analysis <i>p</i> -value ^c	Bonferroni ^d
BF	65.0	15.57	----	< 0.05	BF>A, BF>B, BF>C, BF>D
(A) BSI	49.1	11.19	24.5	< 0.05	A>B, A>C, A>D
(B) RSI	30.9	11.30	52.5	< 0.05	B>D
(C) BSO	29.5	13.63	54.6	< 0.05	C>D
(D) RSO	9.7	6.10	85.1	----	----

^a BF = Barefoot; (A) BSI = Baseline shoes; (B) RSI = Rocker shoes; (C) BSO = Baseline shoes with FO; (D) RSO = Rocker shoes with FO

^b % Δ VAS _(barefoot): percentage change of VAS pain rating compared with barefoot

^c Repeated measures one-way ANOVA test of the test conditions

^d Results of Bonferroni corrected post hoc test showing significant difference between conditions with $p < 0.05$

Table 4: Dynamic regional peak pressure (kPa) of the ‘shod’ conditions

Anatomical Regions	(A) BSI (SD)	(B) RSI (SD)	(C) BSO (SD)	(D) RSO (SD)	Statistical analysis p-value ^b	Bonferroni ^c
M01 Medial Heel	158.47 (31.80)	145.81 (28.85)	112.80 (24.77)	105.25 (21.40)	< 0.05	A>B, A>C, A>D, B>C, B>D, C>D
M02 Lateral Heel	182.90 (41.59)	174.08 (39.28)	131.80 (29.53)	125.70 (26.42)	< 0.05	A>C, A>D, B>C, B>D
M03 Medial mid-foot	105.91 (26.31)	125.50 (30.39)	89.93 (18.65)	100.08 (24.33)	< 0.05	A<B, A>C, B>C, B>D
M04 Lateral mid-foot	122.18 (21.92)	139.79 (30.98)	98.54 (20.24)	108.25 (27.14)	< 0.05	A<B, A>C, B>C, B>D
M05 1 st Met head	175.07 (24,60)	152.34 (20.18)	156.27 (31.08)	128.22 (20.65)	< 0.05	A>B, A>C, A>D, B>D, C>D
M06 2 nd & 3 rd Met heads	203.60 (29.72)	166.01 (28.19)	195.92 (37.92)	162.42 (38.58)	< 0.05	A>B, A>D, B<C, C>D
M07 Lateral met heads	143.78 (40.90)	123.07 (30.44)	148.89 (40.43)	121.11 (35.90)	< 0.05	A>B, A<C, A>D, C>D
M08 Hallux	214.99 (71.46)	180.16 (57.10)	212.60 (91.38)	173.65 (59.35)	< 0.05	A>B, A>D, C>D
M09 2 nd & 3 rd Toes	118.75 (30.45)	107.72 (50.45)	123.33 (34.40)	108.37 (27.56)	No significant difference	
M10 Lateral toes	82.14 (31.73)	61.71 (25.11)	81.47 (26.12)	63.54 (26.68)	< 0.05	A>B, A>D, B<C, C>D

(A) BSI = Baseline shoes; (B) RSI = Rocker shoes; (C) BSO = Baseline shoes with FO; (D) RSO = Rocker shoes with FO

^b Repeated measures one-way ANOVA test of the four 'shod' conditions

^c Results of Bonferroni corrected post hoc test showing significant difference between conditions with $p < 0.05$

Figure 1a

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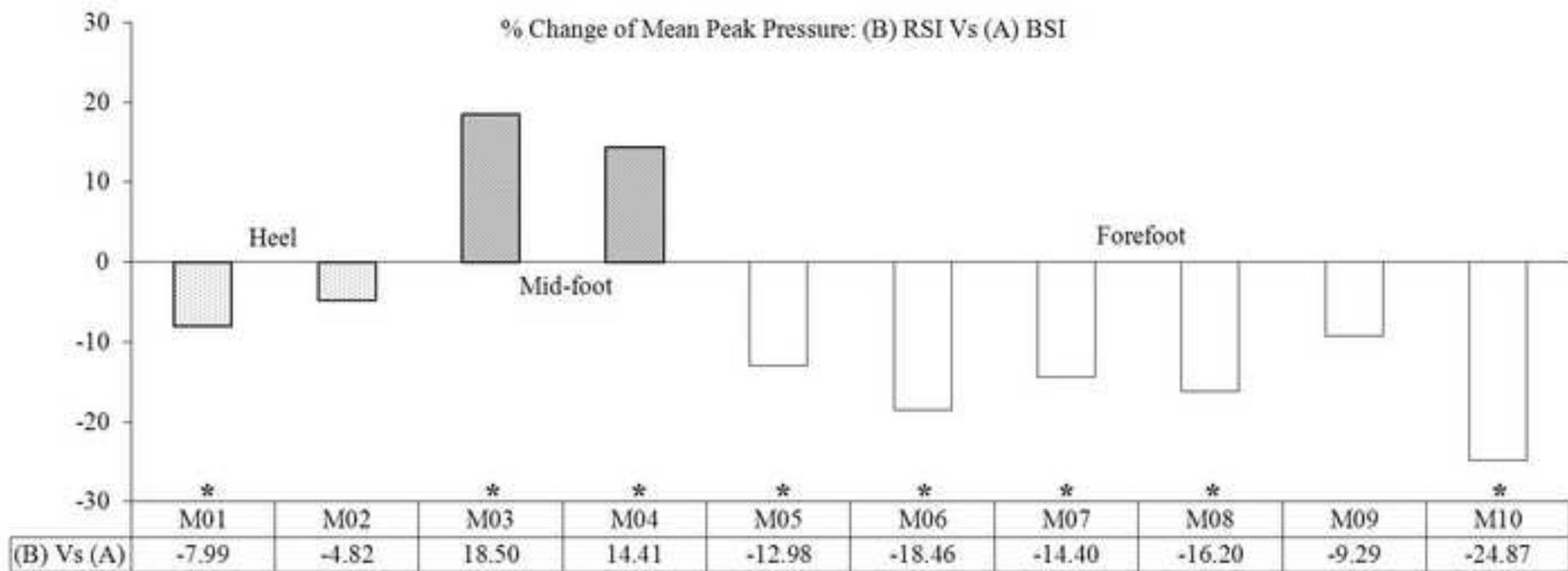


Figure 1b

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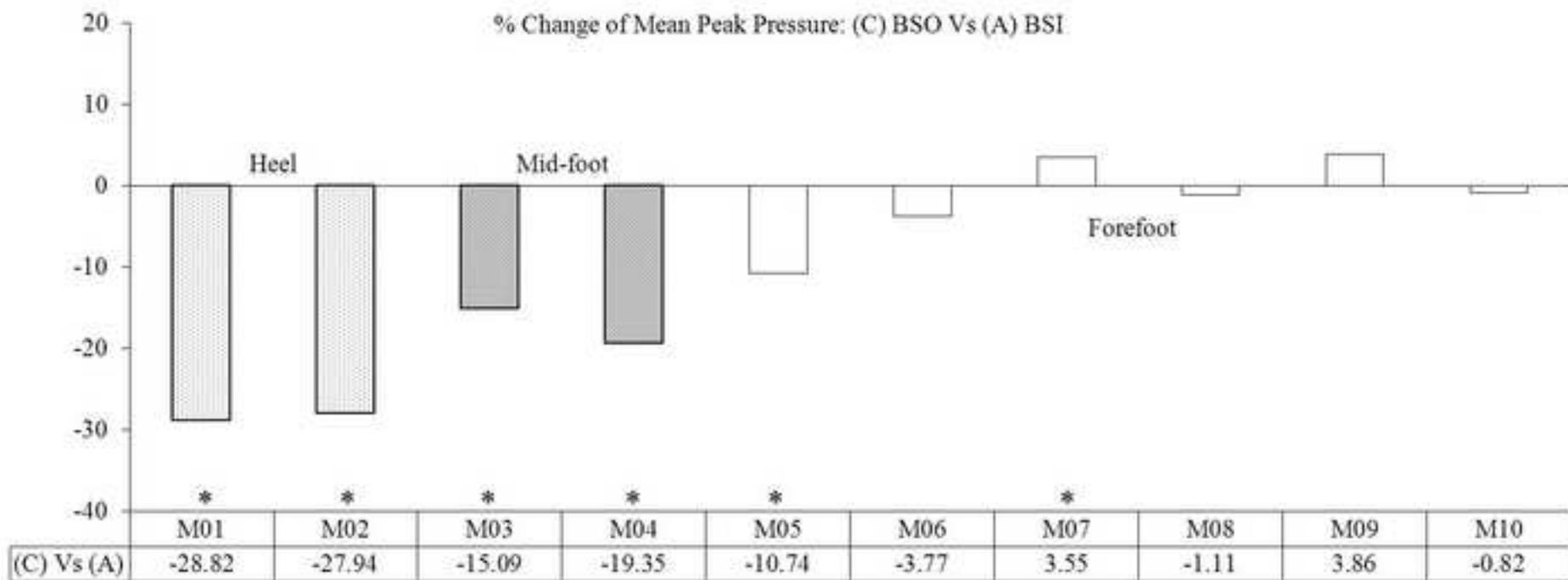


Figure 1c

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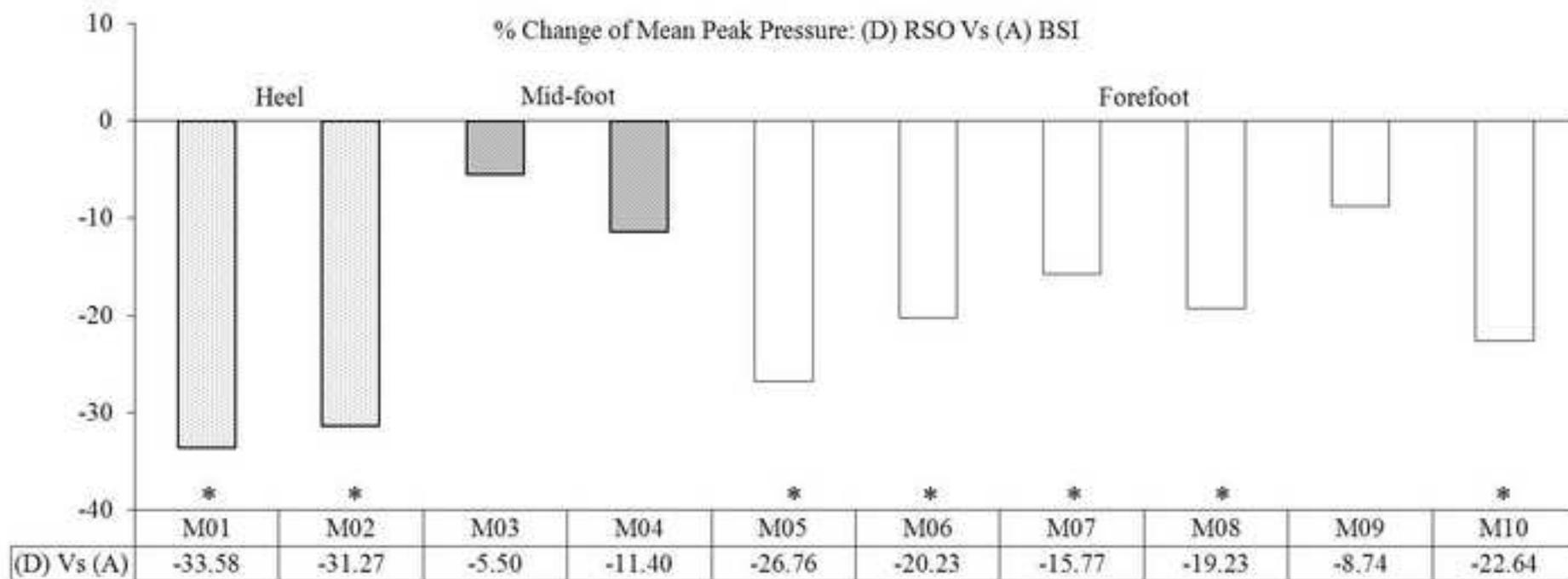


Figure 1d

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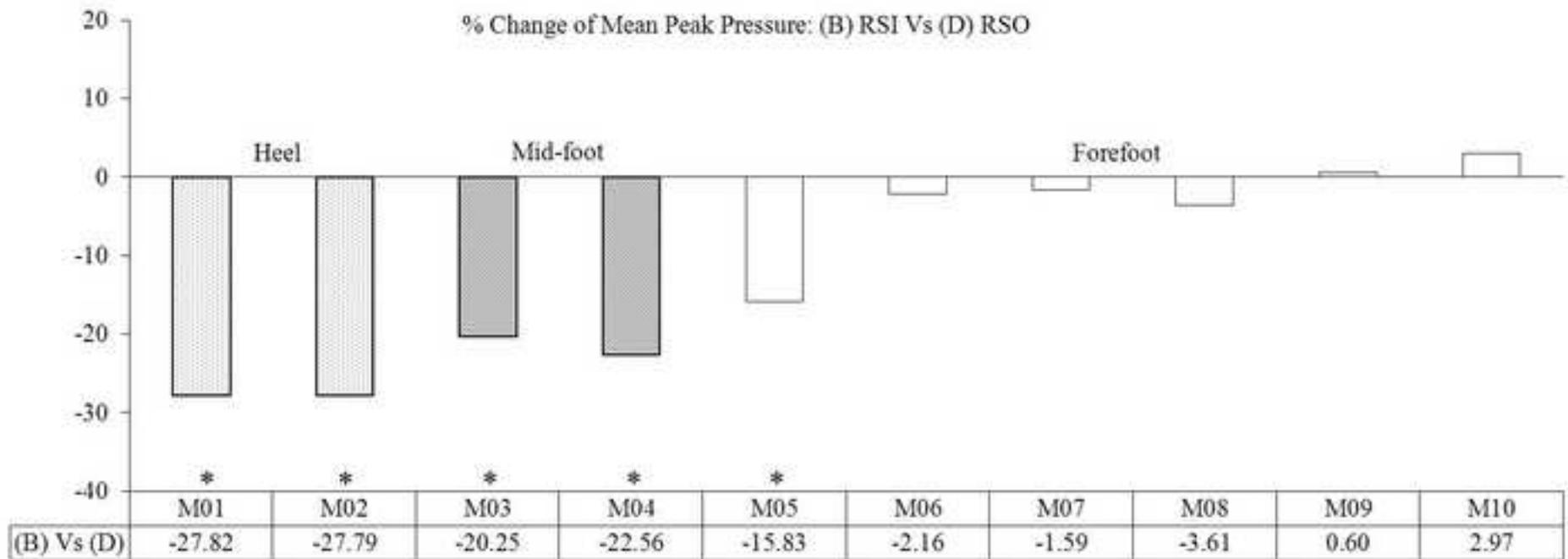


Figure 1e

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