Plantar support adaptations in healthy subjects after eight weeks of barefoot running training

Celso Antonio Sánchez-Ramírez[1], Luis María Alegre Durán[2]

[1] Escuela de Ciencias de la Actividad Física – Facultad de Ciencias Médicas, Universidad de Santiago de Chile, Santiago, Región Metropolitana, Chile.

[2] Grupo de Investigación GENUD, CIBER de Fragilidad y Envejecimiento Saludable, Universidad de Castilla-La Mancha, Toledo, Provincia de Toledo, España.

Corresponding Author:

Celso Sánchez-Ramírez[1]

175th Sophoras St., Santiago, Región Metropolitana, 9160000, Chile

Email address: celso.sanchez@usach.cl

Abstract

Background. Although the studies of barefoot running have intensified, it is still missing longitudinal work analyzing the effects of barefoot running on the phases of plantar support. The objective of this research was to analyze the modifications undergone by the Total Foot Contact (TFC) phase and its Flat Foot Phase (FFP) in subjects beginning the practice of barefoot running, in its acute and chronic effects.

Methods. 28 subjects were divided into Barefoot Group (BFGr) (n=16) and Shod Group (SHGr) (n=12), evaluated before (Baseline) and after running for 20 min at 3.05 $m \cdot s^{-1}$ (Post 20 min Running), and at the end of a running training protocol with an 8-week long progressive volume (Post- 8-week Training). The dynamic plantar support was measured with a baropodoscope. The duration of TFC (ms), the moment at which the FFP occurred, the maximum surface of TFC (MSTFC) (cm^2), the FFP surface (SFFP) (cm^2), the peak pressure of TFC (PP°TFC) ($kg \cdot cm^{-2}$), and the peak pressure of FFP (PP°FFP) ($kg \cdot cm^{-2}$) were recorded. The 3x2 ANOVA analysis was made to determine the effects and interactions that the condition produced (Shod / Barefoot), and the time factor (Baseline / Post20minRunning / Post8weekTraining).

Results. The condition factor caused more significant effects than the time factor in all the variables. Duration of TFC in BFGr showed significant differences between the Baseline and Post-8-week Training (p = 0.000) and between Post-20-min Running and Post-8-week Training (p = 0.000), with an increasing trend. In the moment at which the FFP occurred a significant (p = 0.029) increase was found in Post-20 min Running (48.5%) compared to the Baseline (42.9%). In MSTFC, BFGr showed in Post-8-week Training values significantly higher than the Baseline (p = 0.000) and than Post-20-min Running (p = 0.000). SHGr presented significant difference between the Baseline and Post-8-week Training (p = 0.040). SFFP in BFGr modified its values with an increasing trend (p = 0.000). PP°TFC in BFGr showed a significant decrease (p = 0.003) in Post-8-week Training (1.9 $kg \cdot cm^{-2}$) compared to the Baseline (2.4 $kg \cdot cm^{-2}$). In PP°FFP significant decreases were recorded in BFGr between Post-8-week Training and Baseline (p = 0.000), and Post-8-week Training and Post 20 min Running (p = 0.035).

44   **Conclusions.** The adaptations take place after the 8-week training. The adaptation to running
45   barefoot was characterized by causing an increase of the foot's plantar support in TFC and in FFP,
46   as well as a decrease of the plantar pressure peak in both phases. Also, there is an increased
47   duration of the TFC and FFP, which may be related to an acquired strategy to attenuate the impacts
48   of the ground's reaction forces.
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50

51   ## Introduction
52
53   Currently, endurance running is one of the ways of practicing physical activity that has more adepts
54   in the world, reaching 55 millions practitioners only in the United States (Statista, 2018). In spite
55   of the health benefits that this type of physical activity gives its practitioners, it is usual for injuries
56   to occur, mainly in the lower members (Hamill, Miller, Noehren & Davis, 2008; Pohl, Mullineaux,
57   Milner, Hamill & Davis, 2008), affecting between 30%-75% of the runners every year
58   (Kluitenberg, van Middelkoop, Diercks & van der Worp, 2015). To date it is known that the most
59   common injuries in runners occur mainly in the knee joints (Taunton et al., 2002), which in turn
60   are related to the intensity of the ground reaction forces that occur in every stepping cycle (Daoud
61   et al., 2012), which can reach 1.5 to 3 times the runners' body weight (Lieberman et al., 2010).
62
63   The above has opened the plantar support pattern study focus during endurance running, with
64   several studies stating that when the runners set their forefoot in the first contact with the ground,
65   the recorded GRF values are smaller (Daoud et al., 2012). Due to this observation, there has been
66   reflection on methodologies that allow the runners to adopt plantar support with the forefoot. From
67   this, and with an evolutionary approach, a research line was started oriented to the study of running
68   shoeless, or Barefoot Running (BFR). The first studies (Bramble & Lieberman, 2004; Lieberman,
69   2006) theorized from an evolutionary approach, stating that the human foot evolved after adopting
70   the bipedal position, achieved by *Australopithecus afarensis* about 2.2 million years ago (Susman,
71   1983). This led to an interesting debate when it was stated that endurance running was a key factor
72   in the evolution of modern human beings and that during its practice for transportation and hunting
73   reasons there was no mediation of shoes to get the current foot of *Homo sapiens* (Bramble &
74   Lieberman, 2004). In this respect, it is interesting to mention that there are runners who regularly
75   and systematically incorporate that BFR to their training and competitions (Hollander et al., 2017).
76
77   Barefoot studies were at first made with an approach aimed at the analysis of kinematic, kinetic
78   variables, and of electric muscular activity that were produced acutely after a barefoot training
79   session (Franklin, Grey, Heneghan, Bowen & Li, 2015; Hall, Barton, Jones & Morrissey, 2013).
80   At present there has been progress toward the incorporation of new variables in the studies
81   (Alloway, Alloway, Magyari & Floyd, 2016; Berrones et al., 2016; Ekizos, Santuz & Arampatzis,
82   2017). However, there is still a lack of longitudinal type studies analyzing the effects that barefoot
83   running produces on variables that affect plantar support (Hollander, Heidt, Van der Zwaard,
84   Braumann & Zech, 2017). Furthermore, there have been few studies on the analysis by support
85   phase in the running technique, with no papers published to date referring to the moment at which
86   the support foot is resisting the whole body weight over the widest contact surface, which is known
87   as the Flat Foot Phase (FFP) and corresponds to Total Foot Contact (TFC) (De Cock, De Clercq,
88   Willems & Witvrouw, 2005).
89

90 Because of the above, the objective of this research was to analyze the modifications undergone
91 by Total Foot Contact and its Flat Foot Phase of young subjects beginning their practice of barefoot
92 running, in its acute and chronic effect after 8 weeks of BFR adaptation.
93
94 **Materials & Methods**
95
96 **Participants**
97
98 The sample consisted of 23 men and 5 women. All subjects in the sample were students of the
99 science of physical activity, aged 20.0 ± 1.5 years, 70.9 ± 10.4 kg body weight, 1.7 ± 0.1 m tall,
100 and a body mass index (BMI) of 24.1 ± 2.5 kg·m⁻². The subjects had no experience running
101 barefoot and were running regularly between 5 and 10 km per week. None of the participants had
102 suffered ankle and/or foot injury during the last six months before the beginning of this research.
103 The subjects participated voluntarily in this study, signing the informed consent form written and
104 approved according to the guidelines of the Institutional Ethics Committee of the Universidad de
105 Santiago de Chile (Ethics Report No.184-2018).
106
107 It was guaranteed that the subjects complied with the selection criteria through the information
108 gathered from a questionnaire of podalic and postural health and sports history (Sánchez, Alarcón
109 & Morales, 2017). On this form, they were also asked which was their dominant foot, defined as
110 that which they use to kick a ball (Lake, Lauder & Smith, 2011). Then two groups were formed:
111 Barefoot (BFGr) with n = 16, and Shod (SHGr) with n = 12, equal in the characterization variables.
112
113 **Acute effect protocol**
114
115 Before making the measurements, every subject rested for 10 min in supine position so as not to
116 alter the foot's postural dynamics (Jimenez-Ormeño, Aguado, Delgado-Abellan, Mecerreyes &
117 Alegre, 2011). Then the body weight and height were measured and the plantar support was
118 evaluated dynamically (Baseline).
119
120 Immediately after, each participant ran on a treadmill (Technogym, mod. Excite Run 500, Italy)
121 during 20 min at 3.1 m·s⁻¹ with a 5% slope. This speed was chosen because it has been used most
122 often in the studies of running kinematics and evaluation of plantar pressures related to BFR
123 (Warne et al., 2017). The subjects in the SHGr ran with their conventional sports shoes, and those
124 of the BFGr ran barefoot.
125
126 Immediately after finishing these trials, the subjects were evaluated again to determine the acute
127 effect produced by running barefoot (Post-20-min Running).
128
129 **Chronic effect protocol**
130
131 During the eight weeks following the Post 20 min Running, the subjects followed a training
132 protocol consisting in the continuous running practice at a self-chosen speed during 24 sessions
133 distributed in three weekly sessions, during eight weeks. SHGr did it with their conventional sports
134 shoes and BFGr did it completely barefoot.
135

136 Both groups subjects trained together at the same horary and they were permanently controlled by
137 four research helpers, who registered its assistance and the training volume.
138
139 To reduce the possibility of the subjets suffering injuries, both groups practiced on a natural grass
140 football field. The amount of training was measured in minutes, and it was increased in a wavelike-
141 manner, as shown in Table 1.
142
143 At the end of the protocol, a third evaluation (Post-8-week Training) took place, taking care that
144 the subjects had between 48 and 72 hours of rest, aimed at the determination of chronic types of
145 changes. This evaluation was the same as the one carried out in Baseline. The temporal scheme of
146 the evaluations is shown in Figure 1.
147
148 **Data collection and processing**
149
150 To obtain the plantar print, a Presscam V4 (Sidas©, France) baropodoscope with 1600 receiving
151 sensors was used, and its platform was fixed to the floor, delivering a sequence of images that
152 allowed identifying time, surface, and pressure variables recorded during the plantar support.
153
154 The subjects ran on a smooth and horizontal surface 15 m long at a predetermined speed of 3.1
155 $m \cdot s^{-1}$. A music guide was used to indicate to the subjects at what time they had to start running
156 and at what time they had to put their foot on the platform. The duration of the music track was
157 4.8 s, the time needed to cover 15 m at a speed of 3.1 $m \cdot s^{-1}$. Five valid attempts were recorded for
158 each foot of the subjects. A valid attempt was considered when the foot was fully placed on the
159 platform, when the natural running mechanics was not altered (in step frequency and amplitude)
160 and when the support coincides with the time marked in the musical guide. This condition was
161 controlled by three judges trained in this task. Each of them watched the subjects' running and
162 issued his judgment. It was considered as a valid attempt only when the three judges gave their
163 approval. The platform's software was graduated at a receiving frequency of 100 Hz. For the
164 analyses, the average value obtained from the five valid attempts was used.
165
166 **Analysis**
167
168 All the analyses were made taking as reference the time at which a Flat Foot Phase was achieved,
169 a time that is part of the Total Foot Contact and was characterized by being the moment at which
170 the maximum value of the support surface is achieved (De Cock et al., 2005) and coincides with
171 the GRF peak (Lieberman et al., 2010). So, among the temporal variables, duration of TFC
172 (DTFC) (ms) and the moment at which FFP is produced were recorded, expressed as the
173 percentage of DTFC (FFP%DTFC). The maximum surface of the TFC (MSTFC) (cm^2) and the
174 surface obtained in the FFP (SFFP) (cm^2) were also registered. Also, the peak pressure of TFC
175 (PP°TFC) ($kg \cdot cm^{-2}$) and the peak pressure of FFP (PP°FFP) ($kg \cdot cm^{-2}$) were obtained.
176
177 From the images obtained from the baropodoscope, the foot strike pattern was identified from the
178 visualization of the foot zone that first made contact with the ground (Nunns, House, Fallow,
179 Allsopp & Dixon, 2013), yielding three support classifications: forefoot, midfoot, and hindfoot.
180
181

182
183 **Statistical Analysis**
184
185 Descriptive statistics was used, expressed as mean and standard deviation. For the initial
186 comparison of both groups, for the comparison of the percent change, and for the comparison
187 between the dominant and the nondominant foot, the paired t-test was used, and the size of the
188 effect (ES) was calculated by means of Cohen's d.
189 To establish effects and interactions that the Time factor produces on each of the variables
190 (Baseline / Post-20-min Running / Post-8-week Training), as well as the effects and interactions
191 that the factor Condition of use of sports shoes produces (SHGr / BFGr), a 3 x 2 variance analysis
192 of repeated measures (ANOVA) was made. A post hoc analysis with Bonferroni correction was
193 performed. Homoscedasticity was calculated by means of e Lèvene's test, and sphericity based on
194 Mauchly's test. The size of the effect, expressed as partial eta squared (η^2_p), indicated the
195 percentage variance in each of the effects and their associated error which is explained by this
196 effect.
197
198 Statistical significance was determined as $p \leq 0.05$. The analyses were made using the statistical
199 SPSS (IBM, V23.0 Inc., Chicago, IL, USA) analysis software.
200
201 **Results**
202
203 Initially, the experiment had 42 subjects, but for the present research, the 28 who completed the
204 experimental protocol were considered. Only two subjects mentioned that they had suffered
205 abrasions of the foot sole's skin, a situation that did no allow them to complete the protocol. The
206 other subjects abandoned the protocol on their own decision. The two groups did not present
207 significant differences in the characterization variables of age, weight, height, and BMI (Table 2).
208
209 The comparison between dominant and nondominant foot did not show significant differences
210 between both groups in any of the variables and at any time during the evaluation. That is why in
211 the presentation of the results only the data of the dominant foot were used.
212
213 Table 3 shows the values obtained by each of the variables defined in each of the evaluation times
214 in each of the groups.
215
216 The shoe wearing condition factor (Shod Group / Barefoot Group) produced significant effects in
217 all the variables. Also, the evaluation time or moment (Baseline / Post-20-min Running / Post-8-
218 week Training) factor produced significant effects in all the variables, except in PP°TFC. The
219 variables that showed interaction between the time and group factors were DTFC, MSTFC, SFFP,
220 and PP°TFC.
221
222 In the duration of TFC variable, a significant effect of the time factor (F = 22.566, p = 0.000, η^2_p
223 = 0.465, statistical power = 1.000) and of the condition factor (F = 107.912, p = 0.000, η^2_p = 0.975,
224 statistical power = 1.000) was found separately. The value of partial eta squared indicates that the
225 time factor by itself affects only 46.5% of the differences, and the condition factor 97.5%. It had
226 significant interaction of both factors (F = 12.795, p = 0.000, η^2_p = 0.330, statistical power = 0.995).
227 Considering the whole sample, the comparison between pairs obtained from the post hoc analysis

228 expressed significant differences thanks to the condition factor (p = 0.005) and the time factor,
229 expressed in the fact that the Post-8-week Training evaluation was different from the Baseline (p
230 = 0.000) and a Post-20-min Running (p = 0.000). In the Baseline (SHGr = 218 ms against BFGr =
231 168 ms, p = 0.001) and in the Post-20-min Running (SHGr = 221 ms against BFGr = 160 ms; p =
232 0,000), a significant difference was found between the groups. It is therefore seen that the groups
233 begin unequal, but in the last evaluation they become equal. In SHGr no differences were seen
234 between the evaluation times, but in BFGr the changes were seen because there were significant
235 differences between Baseline and Post-8-week Training (p = 0.000), and between Post-20-min
236 Running and Post-8-week Training (p = 0.000), tending to increase in time.
237
238 The moment in which FFP is produced expressed as percent of total TFC time was influenced by
239 the time factor in 13.2% of the variance (F = 3.943, p = 0.025, η^2_p = 0.132, statistical power =
240 0.684). The condition factor had a more important effect, accounting for 99.1% of the variance (F
241 = 2831.420, p = 0.000, η^2_p = 0.991, statistical power = 1.000), but no significant differences were
242 established between groups (p = 0.724). In the whole sample, a significant increase (p = 0.029)
243 was only found in Post-20-min Running (48.5%) respect to the Baseline (42.9%), indicating that
244 in the acute effect the moment at which FFP occurs is delayed.
245
246 Maximum surface of TFC also presented significant effects of the Time factor (F = 27.224, p =
247 0.000, η^2_p = 0.511, statistical power = 1.000) and of the shod condition (F = 629.425, p = 0.000,
248 η^2_p = 0.960, statistical power = 1.000) separately. The time factor affects significantly in MSTFC,
249 the partial eta squared value indicates that this factor accounts for 51.1% of variance. The condition
250 factor is significant and accounts for 96.0% of the variance. A significant interaction of both factors
251 (F = 6.131, p = 0.006, η^2_p = 0.191, statistical power = 1.000) was seen, its partial eta squared value
252 accounting for 19.1% of the variance. Considering the whole sample, the comparisons by pairs
253 indicated significant differences between groups (p = 0.013) and at all evaluation times (p < 0.05).
254 This variable increased throughout the training protocol. In the Baseline (SHGr = 104.6 cm^2
255 against BFGr = 73.6 cm^2, p = 0.001) and in Post-20-min Running (SHGr = 109.8 cm^2 against
256 BFGr = 83.8 cm^2, p = 0.015) there were significant differences between groups, but in the last
257 evaluation both groups presented statistical equality of the variable (SHGr = 118.6 cm^2 against
258 BFGr = 111.6 cm^2, p = 0.424). Within BFGr it was found that the last evaluation presented values
259 significantly greater than the Baseline (p = 0.000) and the Post-20-min Running (p = 0.000). SHGr
260 presented significant difference between Baseline and Post-8-week Training (p = 0.040).
261
262 The surface of FFP presented similar results. The time factor presented a significant effect on the
263 variable (F = 23.897, p = 0.000, η^2_p = 0.479, statistical power = 1.000), the same as the condition
264 factor (F = 718.469, p = 0.000, η^2_p = 0.965, statistical power = 1.000). The latter has a greater
265 effect on the variance (96.5%). A significant interaction was seen between both factors (F =
266 10.622, p = 0.000, η^2_p = 0.290, statistic power = 0.985). Considering the whole sample, the analysis
267 of comparisons by pairs showed that SHGr presents greater support surface values than BFGr (p
268 = 0.004). Also, there are significant differences between all the evaluation times (p = 0.000),
269 characterized by an increase of the variable in Post-8-week Training (85.8 cm^2) and a decrease in
270 Post-20-min Running (71.2 cm^2) with respect to the Baseline (78.9 cm^2). In the Baseline and in
271 the Post-20-min Running, significant differences were found between both groups (p < 0.01), with
272 SHGr presenting the largest values. The differences disappear in Post-8-week Running (p = 0.530).

273   In SHGr there were no differences between the evaluation moments, but BFGr modified its values
274   throughout the experiment with a marked increasing trend (p = 0.000).
275
276   Peak Plantar Pressure of the TFC was characterized by tolerating significant effects of the
277   condition factor (F = 818.872, p = 0.000, η^2_p = 0.969, statistical power = 1.000) and because both
278   factors interacted significantly (F = 3.646, p = 0.033, η^2_p = 0.123, statistical power = 0.647). In the
279   analysis by pairs no significant differences could be established between groups (p = 0.792), and
280   only in BFGr a significant decrease (p = 0.003) was verified in Post-8-week Training (1.9 kg·cm^{-2}
281   ) respect to the Baseline (2.4 kg·cm^{-2}).
282   Peak Plantar Pressure of FFP was influenced significantly by the time factor (F = 8.670, p = 0.001,
283   η^2_p = 0.250, statistical power = 0.960), and by the condition factor (F = 486.601, p = 0.000, η^2_p =
284   0.949, statistical power = 1.000) The latter factor influenced in 94.9% of the variance, a value
285   greater than that obtained by the time factor (25.0%). In the whole sample, the pressure values
286   decreased significantly in time, finding a greater difference (p = 0.001) between Post-8-week
287   Training (1.5 kg·cm^{-2}) and Baseline (1.9 kg·cm^{-2}). Significant differences were recorded only in
288   BFGr between Post-8-week Training and Post-20-min Running (p = 0.035).
289
290   Table 4 shows the distribution of the sample according to the registered plantar support pattern,
291   where it was seen that both groups started with different distributions of the plantar support pattern,
292   marked by a greater percentage of subjects who stepped on their hindfoot in SHGr at all the
293   evaluation times. BFGr shows an increase of the proportion of subjects who stepped on the
294   hindfoot in Post-8-week Training.
295
296   Due to the differences found for both groups in the Baseline plantar support, an analysis was made
297   of the percent differences detected at each of the evaluation times with respect to the measurements
298   recorded in the Baseline. The comparisons of the groups can be seen in graphs 1 through 6, whose
299   results indicate that the differences were greater and significant for almost all the variables in Post-
300   8-week Training, showing DTFC (p = 0.0002, ES = 1.66), MSTFC (p = 0.0003, ES = 1.30), SFFP
301   (p = 0.0001, ES = 1.74), PP°TFC (p = 0.0064, ES = 1.09) and PP°FFP (p = 0.0221, ES = 0.89),
302   with the BFGr always as the group presenting the largest percent changes, which varied between
303   -27.6% and 58.6%. It should be noted that there were no significant differences in any of the Post-
304   20-min Running variables.
305

306 **Discussion**
307
308   The objective of this study was to analyze the modifications undergone by the plantar support in
309   its Total Foot Contact Phase and its Flat Foot Phase of young subjects who are beginning barefoot
310   practice running, both in its acute and chronic effects after eight weeks of adaptation. Practically
311   all the dependent variables were found to be influenced by the time factors and the use of shoes,
312   with the latter factor as the one that had the most important influence.
313
314   Of the 42 participants who started the study, two could not continue because they suffered skin
315   abrasions during the diagnostic evaluations. These injuries occurred during the diagnostic
316   evaluation due to friction between the treadmill and the foot's sole. According to various studies
317   (Altman & Davis, 2016; Hollander et al., 2017; Hryvniak, Dicharry & Wilder, 2014), the
318   frequency of injuries in subjects who run barefoot is the same as that in those who wear shoes, but

319   the former tend to suffer more injuries on the foot sole, as happened in the present study. To date
320   there are studies of cases referring to miotendinous injuries (Cauthon, Langer & Coniglione, 2013)
321   and bone edema (Ridge et al., 2013), but not to skin abrasions. Studies are needed on this issue
322   which has an influence at the beginning of the adaptation to barefoot running.
323
324   One aspect to discuss in this paper is the fact that the sample studied had no experience training
325   long distances running, an aspect that could have influenced the effects recorded because of the
326   training protocol. However, it is possible to indicate that the statistical analysis allowed to
327   discriminate against the effects that the protocol produced in the whole sample and the sample
328   divided by groups, thus identifying intra-group and inter-group effects. In this regard, the results
329   showed that the significant changes experienced in four of the six variables studied corresponded
330   to the subjects of the group that trained barefoot. Likewise, and according to the graphs shown in
331   Figure 2, it was possible to determine that the magnitude of the changes was always greater in the
332   group that trained barefoot. This allows us to ponder that if the training effect alone was the main
333   one, the changes would have been the same in both groups, a situation that did not occur.
334
335   The decrease of the duration time of TFC has been reported frequently in research dealing with
336   the acute effect of running barefoot (Wit, Clercq & Aerts, 2000; Mei et al., 2015; Fleming et al.,
337   2015; Lieberman et al., 2015), an aspect that could be verified in this research, although not with
338   significant effects in BFGr. In the long term however, it was shown that the duration time of total
339   TFC in both groups increased in time, but only in the group that trained barefoot this 33.3%
340   increase was significant after the eight weeks of training. It should be noted that this result agrees
341   with a recent 12-week experimental study of adaptation (Muñoz et al., 2018). It seems that long-
342   term adaptations go in the opposite direction as short-term adaptations, and they tend to equal those
343   subjects who wore shoes. However, it should be mentioned that SHGr always showed longer
344   plantar support time values.
345
346   The maximum TFC and FFP surface has not been reported as a studied variable in any of the
347   revisions published on this matter (Hall et al., 2013; Hollander et al., 2016), but in the present
348   research this variable increased significantly in both groups over time, with a greater change in
349   BFGr, which underwent a 58.6% increase, and 55.2% in TFC and FFP, respectively, compared to
350   15.2% and 8.8% in TFC and FFP, respectively, of SHGr after the eight-week training. There are
351   two studies that may shed light on the plantar support surface which would have as protagonist the
352   increased cross section of intrinsic foot muscles in subjects running with minimalist footwear
353   (Miller et al., 2014; Johnson et al., 2015), although this is not necessarily related to modifications
354   of the foot's dimensions (Sánchez & Alegre, 2019). The use of shoes marked differences between
355   both groups in the first evaluations, but in the last one both groups were statistically equalized.
356   SHGr always showed higher values.
357
358   In this research, it was also shown that the pressure peak obtained during TFC and FFP decreased
359   significantly after the eight-week protocol in BFGr, showing a variation of -17.3% and -27.3,
360   respectively. The increase of the plantar pressure values has been related mainly to the forefoot
361   strike pattern and secondarily with the non-use of shoes or the use of minimalist shoes (Kernozek
362   et al., 2014), where it was possible to see a pressure increase in the metatarsal heads (Szulc et al.,
363   2017). A longitudinal study looked into this variable after four weeks of adaptation to the running
364   with minimalist shoes, finding that the subjects underwent an increase of the maximum support

365   pressure values and an increase of the proportion of subjects who adopt a forefoot strike pattern
366   (Warne et al., 2014). In spite of the discordant results, it is interesting to note that the obtained
367   pressure values can be associated with the decrease of the force peak registered in barefoot runners
368   in most studies (Hall et al., 2013; Hollander et al., 2016), considering that, due to the
369   characteristics of the equipment used, the maximum value recorded over the whole surface of the
370   foot was obtained. This makes it possible to infer that this decrease could be related to the increases
371   of the recorded plantar support surface, presumably due to a uniform distribution of the foot sole
372   pressures. The latter variable has not been studied intensively, so it is proposed to continue its
373   study.
374
375   The time at which FFP occurs showed a significant increase of the acute effect, showing a delay
376   in the appearance of this phase in both groups, in agreement with what was reported in another
377   study in which it was shown that the GRF peak time, which coincides with the FFP moment
378   (Lieberman et al., 2010) occurs at 39% of the total duration of the support in barefoot runners and
379   at 41.4% in shod runners running at 3.5 m·s^{-1} (De Wit et al., 2000). With this result it is possible
380   to infer that the runner takes more time in the first foot contact sub-phase as a force absorption
381   strategy (De Cock et al., 2005).
382
383   The use of sports shoes, due to the additional shock absorption delivered by the foot, makes people
384   support the foot with a greater tendency to a rearfoot strike. When a person is deprived of the shoe,
385   it is probable that, as a shock-absorbing strategy, that person begins striking the forefoot,
386   otherwise, the impact can have a greater effect, causing injuries (Altman & Davis, 2016). In this
387   research the plantar support pattern started differently, but it became equal after the eight weeks
388   of intervention. The BFGr subjects tended to a hindfoot strike and the SHGr subjects almost did
389   not modify their plantar support pattern, results which are quite discordant with the previous
390   studies, which show changes in this variable oriented to forefoot strike. However, it is interesting
391   to indicate that the evidence which supports these statements is still not conclusive (Hollander
392   et al., 2016). This study contributes to other results that require deeper research.
393

Conclusions

395
396   The adaptations to barefoot running undergone by plantar support take place after an eight-week
397   training period and not after a 20-minute session. In this respect, the adaptation to running barefoot
398   produces an increase of the plantar support of the foot in the total foot contact and in the flat foot
399   phase, as well as a decrease of the plantar pressure peak in both phases. Also, an increase in the
400   duration of the total foot contact and in the flat foot phase is observed, which may be related to an
401   acquired strategy to attenuate the impacts of the reaction forces of the ground.
402

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Determination of the amount of training of the experimental protocol over the 8 weeks and 24 training sessions.

	Week 1			Week 2			Week 3			Week 4		
Session Nº	1	2	3	4	5	6	7	8	9	10	11	12
Minutes	5	7	5	8	10	8	15	10	10	20	10	15

	Week 5			Week 6			Week 7			Week 8		
Session N°	13	14	15	16	17	18	19	20	21	22	23	24
Minutes	25	15	25	30	25	30	35	30	35	35	40	35

1 Table 1. Determination of the amount of training of the experimental protocol over the 8 weeks
2 and 24 training sessions.

Characterization variables of the two groups obtained in Baseline.

	SHOD GROUP	BAREFOOT GROUP	p
Age (years)	20.50 ± 1.45	19.56 ± 1.41	0.10
Weight (kg)	1.72 ± 0.06	1.71 ± 0.08	0.12
Height (m)	74.49 ± 10.72	68.18 ± 9.99	0.61
BMI (kg·m⁻²)	25.06 ± 2.55	23.33 ± 2.35	0.07

1   Table 2. Characterization variables of the two groups obtained in Baseline.

Results obtained by both groups in each of the evaluation times.

[a] Significant differences between groups

[b] Significant differences between evaluation times

	SHOD GROUP			BAREFOOT GROUP		
	Baseline	**Post-20-Minutes Running**	**Post-8-Week Training**	**Baseline**	**Post-20-Minutes Running**	**Post-8-Week Training**
Duration of TFC (ms)	218 ±39[a]	221 ±38[a]	228 ±29	168 ±36[ab]	160 ±41[ab]	221 ±40[b]
Moment in which FFP occurs (%)	48.3 ±6.2	48.8 ±7.1	42.8 ±6.7	46.8 ±10.9	48.3 ±7.4	43.0 ±7.5
Maximum surface of TFC (cm2)	104.6 ±26.0[ab]	109.8 ±28.2[a]	118.6 ±25.7[b]	73.6 ±18.5[ab]	83.8 ±24.7[ab]	111.6 ±19.8[b]
Surface of FFP (cm2)	82.9 ±19.8[a]	81.6 ±22.1[a]	87.9 ±18.7	54.8 ±9.7[ab]	60.8 ±14.6[ab]	83.8 ±15.9[b]
Peak Pressure of the TFC (kg·cm-2)	2.0 ±0.6	2.2 ±0.7	2.1 ±0.4	2.4 ±0.4[b]	2.1 ±0.5	1.9 ±0.3[b]
Peak pressure of FFP (kg·cm-2)	1.8 ±0.6	1.7 ±0.6	1.6 ±0.5	2.7 ±0.5[b]	1.8 ±0.5[b]	1.4 ±0.3[b]

2 Table 3. Results obtained by both groups in each of the evaluation times.

3 [a] Significant differences between groups

4 [b] Significant differences between evaluation times

Distribution of strike pattern in both groups in the three assessment moments.

	SHOD GROUP		BAREFOOT GROUP	
	n	%	n	%
Baseline				
Hindfoot	9	75.0	6	37.5
Midfoot	1	8.3	3	18.8
Forefoot	2	16.7	7	43.8
Post-20-min Running				
Hindfoot	10	83.3	6	37.5
Midfoot	0	0.0	5	31.3
Forefoot	2	16.7	5	31.3
Post-8-week Training				
Hindfoot	8	66.7	10	62.5
Midfoot	1	8.3	0	0.0
Forefoot	3	25.0	6	37.5

1   Table 4. Distribution of strike pattern in both groups in the three assessment moments.

Figure 1

Temporal scheme of the evaluation and training protocol.

Plant. P° Eval: Plantar pressure evaluation.
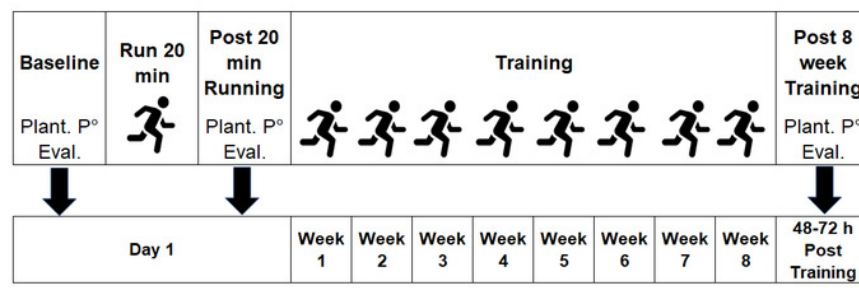
Figure 2

Graphs of the differences detected at each of the evaluation times compared to the measurements registered in Baseline, expressed as percent.

(a) Duration of total foot contact. (b) Moment at which the flat foot phase occurs. (c) Maximum surface of total foot contact. (d) Surface of flat foot phase. (e) Peak pressure of total foot contact. (f) Peak pressure of flat foot phase.