BAREFOOT RUNNING PRODUCES CHANGES IN FOOT STRIKE PATTERN AND BILATERAL ASYMMETRIES ONLY AS AN ACUTE EFFECT

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This study analyzed changes and bilateral asymmetries in Foot Strike Pattern (FSP). Twenty-eight 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 3.1 $m \cdot s^{-1}$ (Post 20min Running), and at the end of an 8-week running training protocol (Post 8-week Training). Plantar pressures were obtained to calculate Strike Index (SI). Only condition factor (SHGr/BFGr) resulted in significative effect ($F=52.45$, $p=0.00$, $\eta^2_p=0.67$). The number of subjects with Forefoot Strike (FFS) and Midfoot Strike (MFS) was always higher in BFGr than SHGr. This difference was higher in Post 20min Running, where BFGr outperformed SHGr by 46 percentage points. BFGr doubled the percentage of asymmetric subjects in Post 20min Running (25% in Baseline to 50% in 20min Running) and returned to Baseline's value in Post 8-week Training. The shift of FSP towards MFS or FFS and the increase of asymmetries are immediate adaptations caused by barefoot running. However, a training protocol of 8-weeks does not produce maintenance of these modifications.

KEYWORDS: Foot Strike Pattern, Plantar Pressure, Running, Barefoot, Strike Index

INTRODUCTION: Barefoot Running (BFR) has become an interesting topic of sports sciences, especially among scientists that study how to prevent overuse injuries (Lieberman, 2014; Lieberman et al., 2015). To date, the main potential effect produced by BFR to prevent injuries is to change the Foot Strike Pattern from Rearfoot Strike (RFS) to Midfoot Strike (MFS) or Forefoot Strike (FFS) (Hall et al., 2013). In a recent review (Xu et al., 2021), the main effects of the FFS pattern have been described concluding that FFS produces lower values of Ground Reaction Force variables, higher values of ankle dorsiflexion in First Foot Contact (FFC) and higher knee flexion excursion. Today, changes produced by BFR over the FSP have not been confirmed since there is limited evidence; there are also few randomized control trials that allow knowing the long-term effects (Hollander et al., 2017). Another foot strike pattern aspect that has not been widely studied in BFR is the left and right foot asymmetry. This variable is related to mechanics asymmetries which could be associated with higher injury risk, through a load increase over one of the lower extremities. (Stiffler-Joachim et al., 2021). Just one study (Tenforde et al., 2018) includes this topic, with results indicating that BFR helps make the foot strike more symmetric. Therefore, this study aimed to analyze foot strike patterns in a sample of recreational runners and describe bilateral asymmetries of support produced by an 8-week barefoot running training protocol.

METHODS: Twenty-eight healthy recreational runners without experience of BFR were part of this study (20 ± 1.5 years; 70.9 ± 10.4 kg; 1.7 ± 0.1 m; and 24.1 ± 2.5 $kg \cdot m^{-2}$). They signed the informed consent approved by the institutional ethics committee of the University of Santiago of Chile (Ethic report nº 184/2018). The sample was divided into two groups: Shod Group (SHGr) (n = 12) and Barefoot Group (BFGr) (n = 16). SHGr subjects completed the training protocol with their regular running shoes, and BFGr barefoot. The protocol had three assessment moments: Baseline was the diagnostic assessment; Post 20 min Running was done immediately after the subjects ran twenty minutes over a treadmill at 3.1 $m \cdot s^{-1}$ (acute effect); and Post 8-week Training was done 48 – 72 hours after the subjects completed the running training protocol of eight weeks in the same conditions that another study (Sánchez-Ramírez & Alegre, 2020) (long-time effect). Foot strike pattern was measured by modified Strike Index (SI) (Altman & Davis, 2012) using static and dynamic baropodoscope with 1,600 receiving sensors (Sidas™, model Presscam V4, Voiron, France) in both feet (dominant and

non-dominant). In a traditional way, the foot used to kick a ball was determined as the dominant foot.
Figure 1 shows how SI was obtained. Static footprint (A) was divided by its longitudinal axis (FAx), and using perpendicular lines from points a and b, and the footprint length was identified (FL). To calculate SI, it is necessary to know the first point of occurrence of the Center of Pressure (CoP) by measuring the distance between CoP and b (DCoP) from dynamic footprint. SI can be calculated according to the following equation: SI = ((FL – DCoP)/FL)/100

According to SI values, the FSP can be classified: 0 – 33% = RFS; 34% - 66% = MFS, and 67% - 100% = FFS.

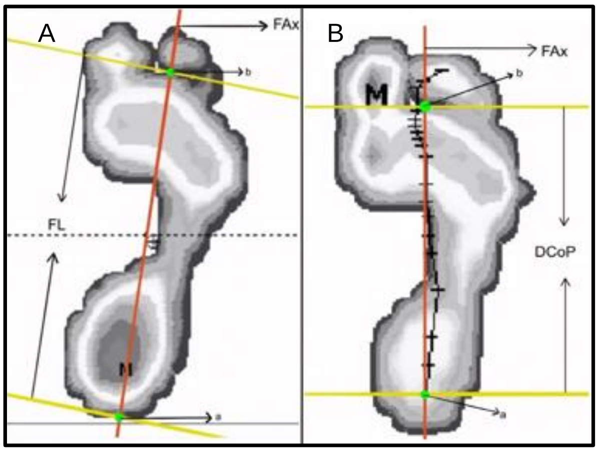

Figure 1. Obtaining measurements to calculate Strike Index from static (A) and dynamic (B) baropodoscopy.

A 3 x 2 variance analysis of repeated measures (ANOVA) was made to establish effects and interactions that the Time factor produces on each one of the variables (Baseline/Post-20-min Running/Post-8-week Training), as well as the effects and interactions that the factor Condition of use of sports shoes produces (SHGr/BFGr). A post hoc analysis with Bonferroni correction was performed. Statistical significance was determined as $p \leq 0.05$. Finally, frequency analysis of the classification of the three types of FSP was performed. The analyses were made using the statistical SPSS (V23.0; IBM Inc., Chicago, IL, USA) analysis software.

RESULTS: Subjects of both groups began the intervention without differences between characterization variables. In Baseline, there were not significative differences between dominant and non-dominant foot in Strike Index (p = 0.73 in SHGr, p = 0.70 in BFGr). For the SI variable, just Condition factor (SHGr/BFGr) resulted in significative effect (F = 52.45, p = 0.00, η^2_p = 0.67; statistic power = 1.00) but post-hoc analysis did not find significant differences between pairs. Partial square eta value explains 66.9% of the variance. Table 1 resumes SI values.

Table 1. Strike Index values (%) obtained in the Shod Group and Barefoot Group, in dominant (DF) and non-dominant foot (NDF), and in the three assessment moments.

	Shod Group n = 12		Barefoot Group n = 16	
	DF	**NDF**	**DF**	**NDF**
Baseline (%)	12.9 (7.5- 49.61)	12.9 (5.3 - 52)	64.4 (14 – 86.1)	60.7 (14.9 –85.9)
Post 20min Running (%)	10.9 (8.5 -33.2)	12.3 (6.9 –36.2)	56.2 (9.6 –69.9)	48.2 (15.8 - 81)
Post 8-week Training (%)	12.8 (10.5 -68.5)	15 (9 – 52.8)	17.5 (8.8 –73.4)	21 (8.6 – 77.2)

Changes produced by the intervention protocol according to SI classification are shown in Figure 2. It is possible to observe that the percentage of RFS in SHGr undergoes an increase in acute effect and then returns to initial values after the training protocol. In all assessment moments, SHGr showed higher frequencies of RFS than BFGr. On the contrary, RFS in BFGr just increased the percentage after 8-weeks barefoot running training. The percentages of FFS and MFS were consistently higher in BFGr than SHGr. This difference was most evident immediately after running 20 minutes on the treadmill, where BFGr outperformed SHGr by 46 percentage points. In summary, SHGr only experienced an increase of RFS frequencies in acute effect. On the other hand, BFGr experienced a rise of MFS and FFS frequencies in acute effect and experienced an increase of RFS in chronic effect.

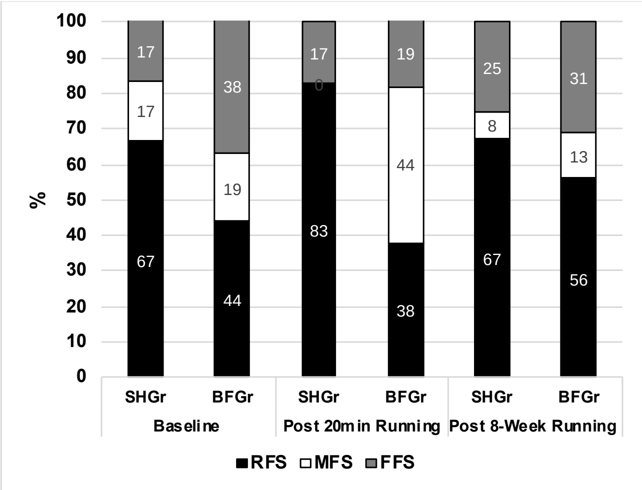

Figure 2. Foot Strike Pattern distribution in each group, in each assessment moment. SHGr: Shod Group, BFGr: Barefoot Group, FFS: Forefoot Strike, RFS: Rearfoot Strike; MFS: Midfoot Strike

In this research, SI of both feet was studied to obtain symmetry data between dominant and non-dominant foot strike pattern. BFGr doubled the percentage of asymmetric subjects in Post 20min Running from 4 to 8 subjects (25% in Baseline to 50% in 20min Running) and returned to Baseline's value in Post 8-week Training. SHGr only increased the percentage of asymmetric subjects in Post 8-week Training, increasing the number of subjects threefold from 1 to 3 subjects (8.3% in Baseline and Post 20min Running to 25% in Post 8-week Training).

DISCUSSION: This study aimed to analyze changes in foot strike pattern in a sample of recreational runners and to describe bilateral asymmetries of support produced by an 8-week Barefoot Running training protocol. It was possible to establish that FSP changed toward FFS or MFS by barefoot condition, a result that coincides with several studies with cross-sectional design (Becker et al., 2014; Bonacci et al., 2013; Lai et al., 2020; Lieberman et al., 2010; Squadrone & Gallozzi, 2009) which can be a logical biomechanical strategy in order to cushion the impacts over the heel. However, FSP changed toward RFS after 8-weeks barefoot running training, which is the opposite of results of an 8-weeks longitudinal study accomplished over a treadmill with lower training volume (Hollander et al., 2019), and another one of twelve weeks duration with progressive volume performed over a grass surface (Latorre-Román et al., 2015). Both studies classified FSP with a capture motion system from the sagittal plane. Following these results, two studies stated a higher incidence rate of subjects with FFS in a habitually barefoot population (Lieberman, 2014; Lieberman et al., 2015). Possibly, some morphological adaptation allows the subjects to resist the impacts and to make unnecessary a forefoot strike pattern, which could be an interesting topic to study in the future. The results obtained can be partially explained because BFGr began the intervention with more subjects with FFS or MFS than SHGr, which could have influenced RFS tendency after 8-weeks Training which may not be the only factor involved. Evidence exists that other factors such as running speed, athletic level, or load-training variables can influence the type of FSP (Hatala et al., 2013). There is evidence to support the fact that giving precise verbal instructions seems to be more effective in modifying FSP towards FFS (Shih et al., 2019). The asymmetry analysis has been little studied. This study showed a substantial increase in the number of BFGr subjects with asymmetric FSP in acute effect, which is an opposite result that reported another study that analyzed kinetic variables of plantar support (Tenforde et al., 2018). It is possible that the starting conditions of the subjects interfered with these results because this study did not consider other aspects of the postural or balance asymmetry. It proposes to deepen this research line to know the effects that BFR produces over this variable in different parts of the runner's body. Moreover, it is proposed to consider the injury prevalence in future experimental research, because there is an interesting link between asymmetry and injury incidence in this population.

CONCLUSION: The shift of foot strike pattern towards MFS or FFS and the increase of asymmetries are immediate adaptations caused by running barefoot for 20 min on a treadmill. However, a training protocol of 8-weeks does not produce maintenance of these modifications. Therefore, it is necessary to study the interaction of other factors that may influence this phenomenon, such as surface, running speed, and the individual capacity of the subjects to respond to training.

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