

FOOT STRIKE PATTERN trends in sub-elite half marathon runners

**Dustin Bakkie, Melissa A. Mache, Christine Johnson, Paula Garcia-Krauss,
Keith Kendall, and ChengTu Hsieh**

California State University, Chico, Chico, CA, USA

The purpose of this study was to examine the changes in foot strike patterns throughout a sub elite half-marathon and examine the relationship between foot strike pattern and race performance. Race participants were filmed at mile 2, 5.5 and 12.5. Video was analysed to determine if participants used a forefoot, mid-foot strike or rear foot strike pattern at each camera. Furthermore participants were broken down in performance groups of 50 based off of time taken to reach each camera. At mile 5.5 and 12.5 significant difference in foot strike pattern ($P<.01$) was observed; as well as significant linear relationships between performance groups and strike pattern ($P<.01$). Based on the present findings we hypothesize that when fatigued sub-elite half marathoners default to the most efficient foot strike pattern.

KEY WORDS: foot strike patterns, running, efficiency, sub-elite, half-marathon.

INTRODUCTION: Foot strike patterns in runners have been of interest in recent years because of their potential relationship to running injuries and performance. Though extensive efforts have been aimed at understanding the relationship between the types of foot strike pattern used and running performance, conclusive findings have remained elusive (Chi & Schmitt, 2005 & Dalleau, Belli, Bourdin & Lacour, 1998).

Dalleau and colleagues (1998) found that running efficiency and leg stiffness had positive association and a direct relationship between leg stiffness and stride frequency had also been demonstrated. Furthermore, because a forefoot strike (FFS) during running has been associated with a higher stride frequency when compared to rear foot strike (RFS) pattern at similar running speeds (De Wit, De Clercq, & Aerts, 2000), one might hypothesize that the FFS is more efficient than a RFS. However, a RFS appears to be characteristic of a higher leg stiffness, which suggests that RFS may be more efficient (Bakkie & Hsieh, 2012).

Despite the abundance of foot strike pattern data, minimal research has been conducted examining striking patterns during races. To date only two studies have examined the prevalence of strike types in an actual race, and only one examined how they changed throughout the race (Hasegawa et al., 2007 & Larson et al., 2012). Researchers have previously reported that RFS patterns appear to be the dominant foot strike patterns among elite, and sub-elite marathon runners. Furthermore, the majority of individuals who use a FFS pattern seem to modify their technique to a mid-foot strike (MFS) or RFS as the race progresses (Hasegawa et al., 2007; Larson et al., 2012). Although this evidence is strong, similar research is needed to strengthen our understanding of foot strike patterns and their relationship to running performance. Thus, the purpose of this study was to examine changes in foot strike patterns throughout a sub elite half-marathon race and examine the relationship between foot strike pattern and race performance.

METHODS: In the present study approximately 450 participants were observed running a half-marathon race. The number evaluated varied throughout the race due to obstructions in the camera field of view and runners dropping from the race. Permission to film the race was obtained from race administrators and all policies and procedures for the use of human subjects were followed and approved by the university Institutional Review Board.

Three 60-Hz digital video cameras (Canon zr-960) were each placed at three separate locations along the course; at the 2 mile, the 5.5 mile, and the 12.5 mile marks. All runners who ran past the respective cameras were analyzed, with the exception of those who walked through the field of view. The foot strike pattern of each runner was identified and defined as

RFS, MFS, or FFS. Striking patterns were defined as: 1) RFS was characterized by the heel, or rear one-third of the foot contacting the ground initially followed by center of pressure transfer into toe-off; 2) MFS was characterized by the heel and metatarsal heads landing simultaneously, typically on the lateral edge, and pushing forward into toe-off; and 3) FFS was characterized by the metatarsal heads contacting initially followed by heel contact before toe off.

When identifying striking techniques the strike of the leg closest to the camera in the center of the field of view was analyzed. If this strike was unable to be viewed then the next closest strike was used. Runners were also grouped in performance groups according to the order in which they reached the respective camera (e.g., the first 50 runners to reach camera 1 were grouped together). This provided a general measure of running performance (race position), based on the order in which each runner arrived to the respective cameras. All video was analyzed by the lead researcher only to ensure consistent classification of foot strike patterns. Chi Squared analysis was used to examine the potential differences in the distribution of foot strike patterns between cameras. Additionally, the regression model (curve fit) was used to examine the relationship among performance groups at each camera. Statistical significance was set at $P < 0.05$ for all statistical analyses.

RESULTS: Foot strike pattern demographics are reported in Table 1. Similar to past studies, FFS and MFS data were combined for the statistical analysis. At mile 2 there were no differences in foot strike patterns among performance groups (Figure 1).

Table 1
Foot Strike Patterns at Each Mile Marker

	N	FFS (%)	MFS (%)	RFS (%)
Mile 2	455	2.64	17.58	79.78
Mile 5.5	415	0.72	20.72	78.56
Mile 12.5	433	2.54	26.33	71.13

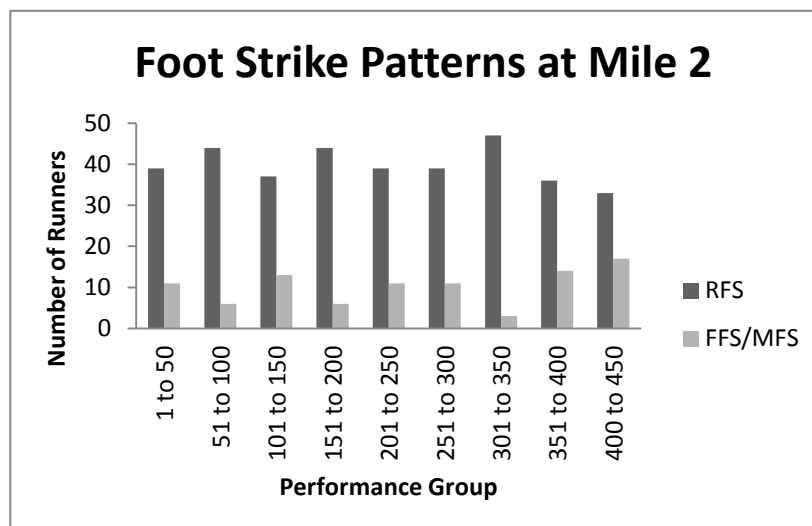


Figure 1: Foot strike patterns among race participants at mile 2.

However, at mile 5.5 and mile 12.5 a statistically significant difference in foot strike pattern distribution was observed (Figure 2, Figure 3, $\chi^2=10.64$, $P < 0.01$). Statistically significant linear relationships among performance groups' striking patterns were also found at mile 5.5 and mile 12.5 ($P < 0.01$).

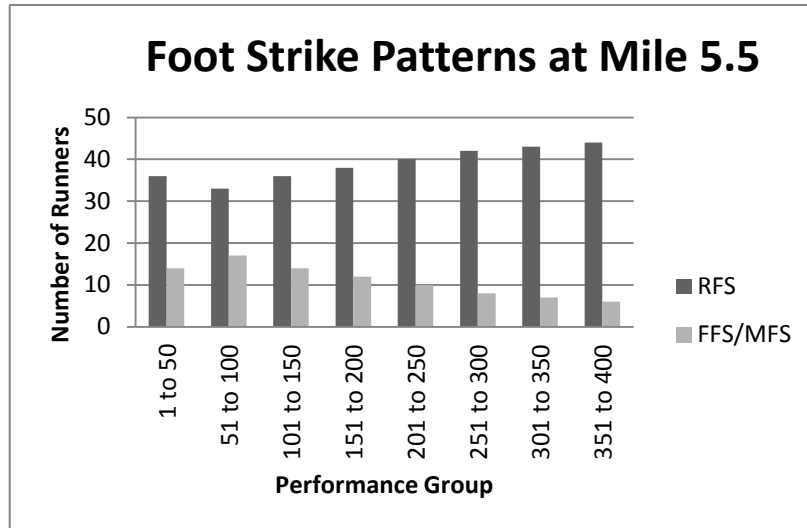


Figure 2: Foot strike patterns among race participants at mile 5.5.

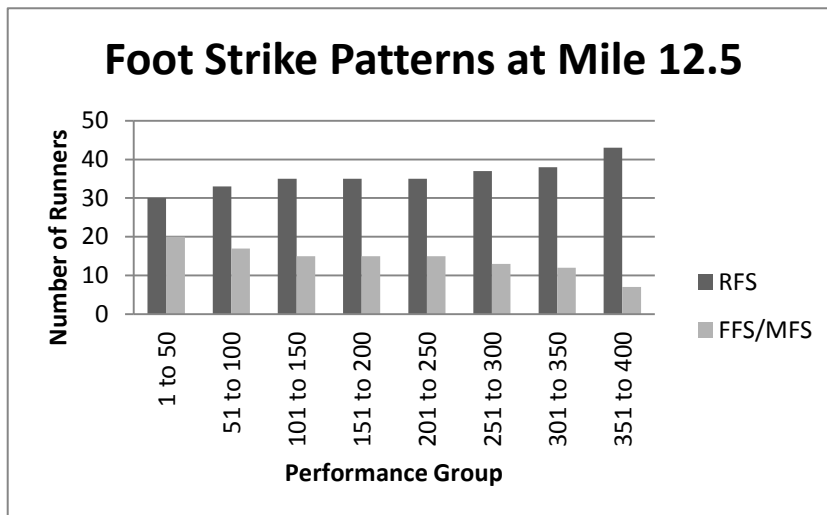


Figure 3: Foot strike patterns among race participants at mile 12.5.

DISCUSSION: Similar to Hasegawa et al. (2007) and Larson et al. (2012), FFS was the least prevalent strike pattern observed in the present population. Beyond FFS the results of this study are very similar to the Hasegawa et al. (2007) results; roughly 70% of runners were observed exhibiting a RFS. Although, Hasegawa et al. (2007) examined elite runner's striking trends and sub-elite runners were examined in the present study, the two populations exhibited remarkably similar trends. Though the results of this study were similar to Hasegawa et al. (2007) they were somewhat different than those reported by Larson et al. (2012); who reported 3.6% and 94.4% of the sub-elite runners were MFS and RFS, respectively. It is difficult to say why this difference in results may have occurred; however it may come down to the definition of 'sub-elite' or different video analyses procedures. However, it should be noted that the methods used in this study were modeled after those used by Hasegawa et al. (2007) and Larson et al. (2012).

With regards to changes in striking pattern throughout a race there is further discrepancy between the results of this study and the results of Larson et al. (2012). Larson et al. (2012) reported a general trend of FFS and MFS runners moving to RFS as the race progressed. The authors suggest that this trend may be related to fatigue, suggesting, that the runner can

no longer support the added loading around the ankle associated with a FFS or MFS strike. In the current study the race population showed a tendency to move towards a FFS or MFS by the end of the race (Table 1). This trend may be explained by research supporting the theory that a FFS or MFS may be more efficient (Dalleau et al., 1998 & De Wit et al., 2000). On the other hand, the increased percentage of FFS/MFS could also be due to drop out from RFS group.

The most that can be determined from this data is that as fatigue accumulated subjects modified their foot strike pattern. The modification in foot strike pattern may be a natural occurrence that allows the runner to fall into a foot strike pattern that is most efficient. Furthermore the trends at mile 5.5 and mile 12.5 suggest that the higher performing runners are more likely to exhibit a FFS or MFS; although the majority will display a RFS.

The present study is not without limitations. One potential limitation is that the subject's speed at the time of foot strike was not measured which would explain the striking pattern; as foot strike pattern may be linked to current running speed. However, it is believed that using the overall performance of the runner (i.e., their position in the race at each of the respective cameras) a good general indicator of overall performance was determined. It should also be noted that within the overall population of the runners studied there were not only half marathoners, but also full marathon runners, and runners competing as members of a relay team (switching out at the 6.5 mile mark). However, we are confident that with the camera placement used, the only camera to observe any runners while they were non-fatigued was camera 1 at the 2 mile mark. Lastly, it was difficult to match up the runners from camera to camera which limited the accuracy of predicting striking pattern change throughout the race.

CONCLUSIONS: Based on the present evidence it appears that sub-elite runners modify their foot strike pattern throughout a half-marathon. This finding seems to suggest that as fatigue accumulates throughout the race runners' default to the most efficient foot strike pattern. The data also suggests that FFS and MFS may be more prevalent among higher performing runners. Further research is needed to examine if strike efficiency and selection of strike pattern may in fact fall along a speed continuum; rather than a single discrete striking pattern for a specific person regardless of running speed.

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