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Research Article

Analysing Foot Strikes in Different Running Related Movements in Performance Optimisation in a Handy and Less Expensive Way

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Abstract

The objective of this study was the optimisation of speed performance by lowering fatigue index with the determination of suitable foot strike patterns. The effect of foot-strike patterns on the running economy is evaluated as highly prevalent in recent studies on runners, but no study has reported its effect on multi-sprint sports. Three-dimensional motion analysis laboratories need high-cost instrumentation and programs whereas, two-dimensional low-cost technologies like Kinovea are valid, reliable and handy. Twenty-six male athletes of multi-sprint sports between the age group of 18 - 25 years took part in the study. Running-based anaerobic sprint test (RAST) was performed by the participants. To determine the foot strike patterns, a camera was fixed in the sagittal plane during RAST and Kinovea was used for analysis. The study has shown that most participants (50%) followed the rear-foot strike (RFS) pattern during RAST. Significant differences in maximum and average power output in RAST were found among the fore-foot strike (FFS) and mid-foot strike (MFS) runners with the RFS runners in Mann - Whitney test ($p < 0.05$). In the continual six sprints of the RAST, the consistency of power outputs was FFS < MFS < RFS. Significant differences were found in fatigue index (FI) and anaerobic capacity (AC) of the MFS and FFS with RFS participants in Kruskal-Wallis test among the FFS, MFS and RFS participants ($p < 0.05$). This study has observed a significantly low fatigue rate among RFS compared to FFS. However, further studies are required to optimise sprinting in multi-sprint sports on different shod and surface conditions, along with more match specific conditions. Due to 2D and less expensive, handy analysis technique the study can be improved in a more match-realistic condition.

Keywords: *Running-Based Anaerobic Sprint Test (RAST); Rear-Foot Strike (RFS); Fore-Foot Strike (FFS); Mid-Foot Strike (MFS)*

Introduction

The optimization of multi-sprint sports performances is often researched from the physiological and anthropometric perspectives directly. In multi-sprint sports like football, basketball, volleyball where biomechanics and kinesiology play a significant role in performances are not studied from the combined viewpoint of biomechanics and Kinesiology characteristics. The effect of foot-strike patterns on the running economy and injury rates is evaluated as highly prevalent in recent studies [3,11-15]. Studies have concluded the dependency of sports performances on the foot strike patterns, primarily in running events. Studies have reported the effects of foot strike patterns during treadmill running, mid-distance and long-distance races [16-19], but no study has reported its effect on multi-sprint sports. Performances in multi-sprint sports may depend on the running economy as football, basketball, volleyball with the pass, hit, kick, throwing the ball, reaching the ball, and moving with the ball is vital for optimal performance.

The following classification of foot strike patterns is familiar: fore-foot strike (FFS) where at the foot landing ball of the foot lands before the landing of the heel of the foot (toe-heel-toe run), mid-foot strike (MFS) is described as the simultaneous landing of heel and ball of the foot, and rear-foot strike (RFS) also known as heel strike is when the heel lands before the ball of the foot while (heel-to-toe run) [12,13]. An alternative foot strike pattern classification is the determination of foot strike index by evaluating centre of pressure (COP) at landing relative to the maximum shoe length, with an FFS ≥ 67%, 66% ≥ MFS ≥ 34% and RFS ≤ 33%, an arbitrary index concerning foot anatomy [10,13].

The force generated per unit of activation (the force generation ability) at peak active force has been higher in the medial and lateral gastrocnemius during FFS than in RFS. However, no significant difference in force generation ability of the soleus between the FFS and RFS has been reported. The shifting of the peak active force was found earlier in the FFS gait cycle than RFS gait cycle [25].

Several researchers have investigated the effects of fatigue on the kinematics of the running gait, but none of them has explicitly commented on the effects of fatigue on the foot strike patterns in the multi-sprint sports.

Analysing the foot-strike patterns during such movements using motion analysis is expensive to install as well as not available in various sports training centres. The system used in the study is very inexpensive and can be performed in the ground based realistic set up also. The objective of this study was the optimisation of performance by lowering fatigue index and increasing speed in multi-sprint sports with the determination of suitable foot strike patterns. Two-dimensional video analysis to understand sports-specific movements from movement dynamics from a particular plane of motion among the coaches. Several studies have reported utilising two-dimensional video capturing in the analysis of running actions from the sagittal plane view [29,32]. To analyse foot strike patterns at different speeds on treadmill running, studies have captured sagittal plane videos and analysed the foot strike patterns with the slower version of the videos [17]. Fixing the video camera at an 8 km point of competitive distance running and analysing the foot strike pattern by capturing the video and extracting five non-consecutive photographs during the ground contact stage of different foot strike patterns has been analysed [12].

The study of the kinematics of human movements is required for objectifying the movements. Determining quantifiable data or comparing three-dimensional motion analysis is one of the rigorous and validated systems that provide very accurate data. These three-dimensional motion analysis laboratories need high-cost instrumentation and programs and having technical difficulties in set-up. Two-dimensional low-cost technologies Kinovea are valid and reliable are being used for motion analysis such as gait [30,31,39].

Methodology

Twenty-six male athletes of multi-sprint sports between the age group of 18 - 25 years who were free from injury took part in the study. Running-based anaerobic sprint test (RAST) was performed by the participants who post-checking their oxygen saturation and pulse rate (beats per minute) with a warm-up session. The RAST parameters: maximum, minimum and average power outputs, fatigue index and anaerobic capacity were estimated. To determine the foot strike patterns, a camera was fixed in the sagittal plane during RAST and using Kinovea, from the definition of Lieberman, the foot strike patterns (fore-foot, mid-foot and rear-foot) were extracted.

Kinovea is a free, portable and easy-to-use, two-dimensional motion analysis software under the GPLv2 license; it was created in 2009 via the non-profit collaboration of several programmers, researchers, coaches, and athletes worldwide. The frame by frame analysis of coordinates, distances, angles, and spatial-temporal parameters from a recorded video can be performed by Kinovea [30,40].

Figure 1: *Examples of fore-foot, mid-foot and rear-foot strike pattern while performing RAST, 5 frames (Left to right, non-consecutive, every other frame). From top to bottom: Fore-foot strike (right foot in frame), Mid-foot strike (right foot in frame), and Rear-foot strike (left foot in frame).*

Results and Discussion

The study has shown that most participants (50%) followed the rear-foot strike pattern during RAST. Significant differences in maximum and average power output in RAST were found among the fore-foot strike (FFS) and mid-foot strike (MFS) runners with the rear-foot strike (RFS) runners in Mann-Whitney test ($p < 0.05$). In the continual six sprints of the running-based anaerobic sprint test (RAST), the consistency of power outputs was FFS < MFS < RFS. This study has observed a significantly low fatigue rate among RFS compared to FFS.

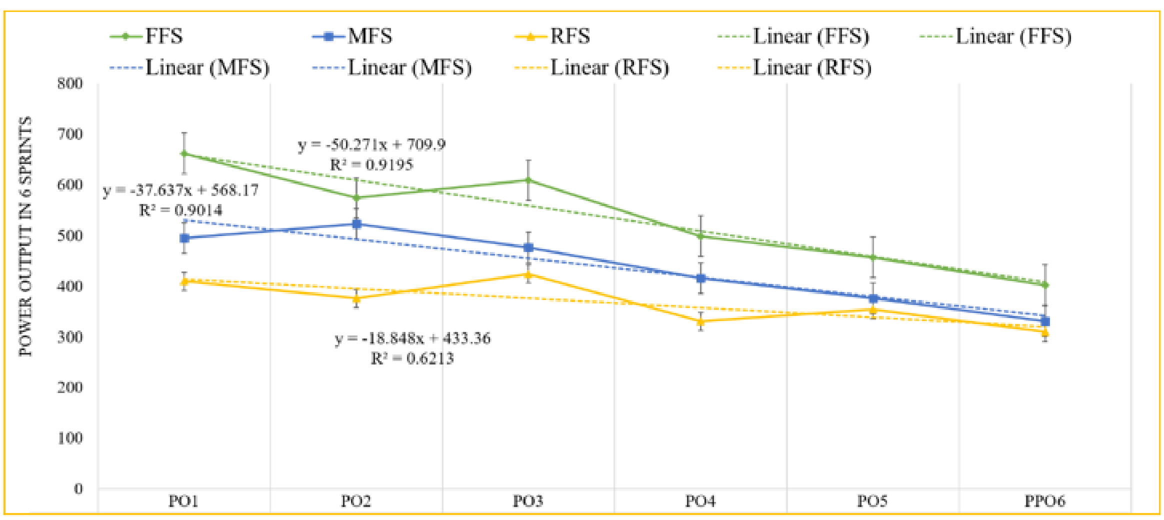

Figure 2: *Graphical representation of the power outputs of RAST among the participants with FFS, MFS and RFS.*

Studies have suggested that FFS places a heavier eccentric load on the ankle joint and the calf muscles while running, resulting in higher FI (fatigue index) and along with these studies, we can speculate that fatigue in the lower leg may cause these FFS runners to shift their running gait late in the matches, leading to an inconsistent performance [11,18]. The reduction in swing phase time and FI of an FFS participant can be highly beneficial in speed-time performances. As the FI and AC (anaerobic capacity) have shown a higher positive correlation, the downfall of the performance with time during a match occurs. If there is an association of an increased AC with decreased FI with foot strike patterns, a conclusion on the optimized foot strike pattern for multi-sprint sports performances for further studies on the influence of aerobic metabolism in different foot strike patterns might be drawn.

Previous studies reported that RFS is the most commonly used foot strike pattern among recreational and distant runners; above 90% of the participants were running in rear-foot in the studies [12,14]. In this study, we have discovered that volleyball, football and cricket players were present in the study, who are into running and fitness, reports a majority of heel-strike runners (50%) but not as high as the previous studies (> 90%), which may imply a probability that such multi-sprints and dynamics sports are playing a role in the control of foot strike while running. Moreover, the running foot strike patterns are of 6 short distance sprinting (35 meters each, 10-second recovery), which is more related to the multi-sprint sports [56].

The benefits of shorter ground contact time were not in use as the higher swing time led to a non-significant difference in time consumption of FFS, MFS and RFS. FFS runners can sprint faster compared to RFS runners. The average power output executed by elite soccer players is closer to that of the FFS participants in the study, which implies a requirement to improve RFS and MFS.

Conclusion

This study concludes a higher tendency of the dependency of the kinesiology on the sprinting strategy in optimizing multi-sprint sports performances. However, further studies are required to optimise sprinting in multi-sprint sports on different shod and surface conditions, along with more match specific conditions. As RAST variables might be affected by the floor surface and the footwear condition in soccer, the study can be improved in a more match-realistic condition. The comparative study of the sprint, agility, aerobic capacity and anaerobic power among the soccer players playing in different positions (defenders, midfielder and forwards) has reported significant differences in the 30m-Sprint Test and Illinois Test not in Yo-Yo and RAST test. Investigations of foot strike patterns in different positions of multi-sprint sports and other agility and sprint tests may conclude the optimisation of sports performance based on foot strike patterns. So, the evaluation of kinanthropometric and physiological needs according to playing positions is needed. Study on the foot strike patterns and agility may also help to optimise the sporting performances. More studies on foot strike patterns among the multi-sprints and dynamics sports players are required to establish that such multi-sprints and dynamics sports play a role in the control of foot strike while running.

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