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THE INFLUENCE OF A 10KM RUNNING TIME TRIAL ON BAREFOOT BIOMECHANICS IN HABITAULLY SHOD RUNNERS

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SUMMARY

Various changes have been noted with running barefoot when compared to running shod. Some of these changes have been suggested to be favourable for injury prevention and performance. The aim of this study was to determine whether these changes persist once an athlete has become fatigued. 15 runners performed 20m overground running trials in both a barefoot and shod condition prior to and after a 10km fatiguing run. The runners ran a 10km run at 2% above their 10km familiarization trial. Fatigue was insured with a rating of perceived exertion of 19. Distinct condition differences were found in ankle sagittal plane kinematics at footstrike and toe-off. Further, initial rate of loading was also found to be different. This was also quantified grossly as 8 runners progressed from a rear footstrike to a midfoot strike and 2 from a midfoot to a forefoot strike. However, changes due to fatigue were found in the knee sagittal plane at footstrike and a decreased vertical ground reaction force. These differences and large variability illustrate that not all runners adjust to different conditions and it appears barefoot running is a skill that is learnt. Complex analysis of gait kinematics and kinetics together with the characterization neuromuscular responses may further elucidate these findings.

INTRODUCTION

Recent evidence has established that barefoot running is associated with reduced impact forces and loading rates compared to shod running [2]. These reduced force variables, which have been found in habitually barefoot runners, may have potential injury prevention benefits. However, a crucial finding is that habitually shod runners who run barefoot (with a rearfoot striking pattern) had marginally higher impact forces than when running in shoes [2,3]. Most significantly, the rate of loading was seven-fold higher when barefoot than in shoes in habitually shod runners. This suggests that while the impact forces and loading rates may decrease with familiarity, there is a period where unfavourable changes occur as a result of barefoot running.

These findings suggest that the observed reductions in impact force and rate of loading that may prevent injury are learned responses. Paradoxically, this first exposure to barefoot running may increase the risk of injury.

There is some evidence of instinctual responses to barefoot running in habitually shod runners, such as a flatter foot placement at touchdown. This implies an actively induced adaptation strategy that enables the impact to be cushioned before landing by reducing peak heel pressure.

Running generally involves sustained physical activity and repetitive cycle which unavoidably subjects the body to various levels of muscular fatigue (inability to maintain a given level of force production). As fatigue develops over the duration of a run, the protective neuromuscular mechanism of the muscle diminishes (muscle aids in the dissipation of mechanical forces acting on the body). Exercising in a fatigued state increases stress, strain and impact forces, particularly on the lower extremity.

It has been hypothesized that these loads accumulate and lead to various overuse problems. Research has shown that fatigue influences the lower extremity mechanics during running, with altered contraction of the muscle on the shank, imbalance in transfer of mechanical energy between eccentric and concentric muscle contractions and slower muscle reaction time. All these factors will affect the resilience of the neuromuscular system in consistently dampening these large forces. Investigating fatigue during exercise therefore provides a pertinent model to explore the body's innate ability to adapt and provide indicators of injury risk. Hence fatigue is an attractive intervention to determine whether barefoot training may influence the resilience of the body to adapt to such stresses.

Accordingly, the aim of the present study is to investigate the differences in kinematic and kinetic response between shod and barefoot gait. Finally, to explore the influence of fatigue on barefoot and shod gait.

METHODS

15 runners (<50 minute 10km running time) volunteered to participate. A 10km familiarization time trial was completed on a treadmill, with encouragement to run the distance in the fastest time possible, whilst being blinded to the speed and time.

The time achieved from the time trial established the participant's 10km running pace used in the subsequent visit. The second visit consisted of biomechanical assessments either side of the fatigue trial. Immediately before and after the fatiguing bout runs, participants performed 20 metre runs at 4.5m/s on a level surface over a force plate, during which kinematic and kinetic measurements were obtained. These trials were performed in the shod and barefoot condition. Six adequate trials were collected from each participant for each condition.

Three-dimensional kinematics and kinetics of the lower limb and external ground reaction forces were recorded using the

Vicon MX motion capture system (Oxford Metrics, UK) synchronised with a floor embedded force plate (AMTI, Watertown, MA). Subsequently, only sagittal plane joint angles of the ankle, knee and hip joints were calculated at ground contact and toe-off. Initial loading rate and vertical ground reaction were also calculated.

During the 10km fatigue trial, the first and the final 200 meters were run barefoot. The 9.6 km in between were performed in the participant's own shoes. Running on the treadmill was interrupted for a brief period to allow for participants to put on and take off their shoes after the first and before the last 200 metres. High-speed video footage (Casio EXFilm 210 fps) was recorded during the treadmill runs in order to determine footstrike. Forefoot strike patterns were classified visually by analysing the high-speed data [1].
Rating of perceived exertion (RPE) was recorded at the end of every kilometre. The run bouts were run at 2% faster than the participant's 10km familiarisation pace to ensure that a sufficient level of fatigue was reached during the trial. The objective was to complete the 10km trial with a maximal RPE.
Data are reported as means ± SD and differences between time and condition were analysed with a repeated measured ANOVA. A Tukeys Post-hoc analysis was applied where significant.

RESULTS AND DISCUSSION

Differences between shod and barefoot conditions were only found in ankle plantar-dorsiflexion ($p<0.05$) (Figure 1). Interestingly, this difference was also present at toe-off where in the barefoot condition runners were 5 degrees more plantarflexed. These findings suggest that differences in barefoot gait persist through out stance phase and that runners land and push-off with greater plantarflexion.

Further, condition differences were found in rate of loading (Figure 1). When trained shod runners run barefoot loading rates were 30 bodyweights per second higher. Interestingly, no changes as a result of fatigue were found. This finding further questions whether the ability to run barefoot and the benefits from its supposed favourable changes need be learnt. Although, changes in ankle plantarflexion appear to be the lack of elevated heel from the shoe rather than a barefoot adaptation [2].

Changes as a result of fatigue were greater knee flexion at ground contact (Figure 1). When running barefoot runners experience 1.5^o increase whereas in the shoes a 2.5^o increase

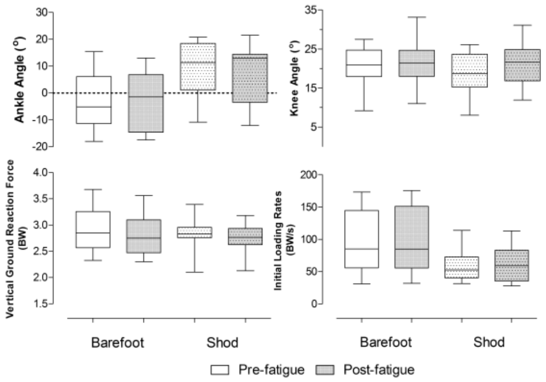

Figure 1. Sagittal plane ankle and knee angles at ground contact, vertical ground reaction force and initial loading rate.

was found. Ground reaction forces were also found to decrease 0,1 bodyweight as a result of fatigue. It appears that the body is able to attenuate ground contact forces even in a fatigue state and that leg stiffness is higher in the barefoot condition [3].

Condition differences in footstrike were found, 2 midfoot strikers when shod changed to a forefoot strike and 4 out of the 8 rearfoot strikers adapted to a midfoot strike. However, changes as a result of fatigue were no different. This acute fatigue may not have been sufficient to experience changes as previously observed [1].

Further investigation into these differences may provide further information on the influence of cushioning on kinematic changes and it's potential influence on injury. Also the investigation of difference in initial loading rates and peak vertical ground reaction forces may reveal the physiological capabilities of the body to deal with forces experienced during stance.

CONCLUSIONS

Known differences between barefoot and shod conditions were reported such as greater plantarflexion at ground contact and higher loading rates when barefoot. At toe-off runners were more plantarflexed. Similarly, greater knee flexion and vertical ground reaction force were found as a result of fatigue.
Further research should include greater sample size, groupings of different footstrike types and runners of different abilities, complex data reduction techniques and multivariate analysis over the entire gait cycle.

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Table 1. Descriptive Characteristics of the runners

n	15
Age	28 ± 4
Body mass	73,5 ± 9,8
Height	1.80 ± 0.07
10km time trial time	42.95 ± 3.56