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Acute Effects of a Tempo Run on Different Surfaces

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Abstract

Running on harder surfaces is known to increase the chance of overuse injury, but those who race on these surfaces should train on them due to the principle of specificity. The goal of this study was to determine whether a typical running workout on hard versus soft surfaces has different effects on ground reaction forces (GRF). Twenty runners performed a typical 20 minute tempo run, once on asphalt and once on grass. GRF were recorded pre, post and 24 hours after the tempo runs. No significant differences (p>0.02) between pre, post and 24 hour GRF parameters were found for asphalt or grass, separately. Also, no significant differences in the changes in the GRF (after the workout) between asphalt and grass were found. These findings indicate that a single workout on a harder surface does not result in significant changes to GRF compared to on grass. Therefore, single bouts of running on harder surfaces do not appear to be a potential cause for injury. These findings indicate that runners training for races on harder surfaces (e.g. road runners) can perform their primary workouts on these surfaces without increasing chances of injury.

Keywords: *ground reaction force, training, jogging*

Introduction

Running is a popular exercise performed for recreation and competitive purposes. In the United States alone, there was an increase in road race finishers from 5 million in 1990 to over nearly 17 million in 2016 [1]. With such a considerable increase in participation, the occurrence of running-related overuse injuries has become more frequent [2]. Running injuries are most often caused by the chronic loading of ground reaction forces (GRF) on the tissues of the lower extremities [3]. Many factors may affect the nature of the GRF acting on the tissues and include shoe type, running surface, and degree of muscle fatigue.

There is evidence that the cushioning properties of a running surface may influence the onset of injury [4]. Furthermore, individual testimonies from runners indicate that harder surfaces like asphalt and concrete are more injurious than more compliant surfaces such as grass or track material [5]. Dixon et al. (2000) stated that to better understand the association between sports surfaces and injury occurrence, knowledge of the biomechanical effect of surface variation is required. Significant differences in peak pressure, contact area, and contact time between running on natural grass versus on asphalt suggests that running on a more compliant surface may reduce overloads to the musculoskeletal system [6]. On the contrary, force plate measurements revealed no change in GRF parameters when running on different surfaces [7, 8], which has led to the belief that humans subconsciously adjust lower extremity joint angles and muscle activity upon impact, in relation to the stiffness or compliance of the running surface. If humans do in fact experience similar GRF while running on different surfaces, there may be an inter-relation between factors that affect the onset of injury.

Muscles decrease the bending stress on bone, protecting musculoskeletal tissue from impact forces [9]. However, over time, fatigued muscles are less capable of absorbing the shock induced from impact. The GRF is instead transferred to the bone and connective tissue. When considering that humans tend to adjust joint angles and muscle activities in relation to the surface properties, it is possible that different surfaces might therefore induce varying degrees of potential injury to the body [10]. Peak impact forces have typically been found to be maintained at similar levels when running on surfaces with differing mechanical properties [11, 12]. Studies have made a possible connection between joint angle alterations, the resulting moments of force on tendons and ligaments, and the increased susceptibility to injury [7, 8]. However, these findings have not yet been linked to a single typical running workout.

A runner's training regimen includes primary workouts interspersed with recovery runs. If running on harder surfaces leads to greater potential for injuries, training on softer surfaces might be the simple solution. However, for runners who are training to compete in races that are on harder surfaces (e.g. marathon runners), the principle of specificity suggests that training should be performed on these harder surfaces. Perhaps the compromise is to perform primary workouts on hard surfaces and recovery runs on more compliant surfaces. Unfortunately, it is not yet clear whether a single workout on different running surfaces are related to changes in GRF, and therefore potential increases in injury.

The purpose of the present study was to investigate the variation in GRF parameters after a typical running workout on a natural compliant surface (grass) and on a hard surface (asphalt). In this premise, variations within each surface (i.e. from pre to post workout) as well as differences between surfaces can be examined. Differences observed may indicate whether there is, if any, a surface-dependent or independent influence on changes in GRF parameters. It was hypothesized that variations would exist in GRF parameters and would be greater after running on a hard surface, compared to that of the compliant surface. Since changes in GRF parameters have been found to be directly related to injury[13], the outcome from this study may have significant implications for athletes and coaches regarding injury prevention and training techniques.

Materials and Methods

Participants

Twenty participants, 10 male (mean ± standard deviation age 23.3 ± 6.4 years, height 180.0 ± 5.6 cm, weight 69.0 ± 10.6 kg) and 10 female (age 21.8 ± 4.0 years, height 168.2 ± 8.9 cm, weight 63.2 ± 8.1 kg) were recruited for this study. All were free of injury at the time of testing, were members of the varsity track and/or cross-country team, and had a minimum of 5 years of competitive running experience. Participants gave written consent prior to the study in compliance with the university's Institutional Review Board.

Procedures

Pre and Post Workout Trials

Prior to the pre-workout trials, participants performed 5 minutes of easy jogging on the surface in which the workout was to be performed (i.e. grass or asphalt). Participants were asked to perform three indoor running trials along a 40 m runway, in which subsequent foot strikes landed entirely on each of the two force plates (Bertec, London, England), located near the end of the runway. A high-speed (200 Hz) digital video camera (Basler Vision Technologies, Ahrensburg, Germany) placed in the sagittal plane (right side) recorded participants as they crossed the force-plates. The participants were allowed to wear their own running shoes, so as not to alter their natural gait and running stride. Participants were instructed to run at their specific tempo pace, via Daniel's running formula[14], a pace they had used consistently in a minimum of 4 previous weeks' training (i.e. they were familiar with the pace).

Vertical ground reaction force data upon foot contact with the force plates were collected at 1000Hz. Running speed was determined by digitizing the tip of the foot as the participant ran across both force plates in a single stride. Running speed was calculated by digitizing the distance between the first foot at force plate contact and the second foot at force plate contact, then dividing this distance by the difference in time between each foot strike.

Running Workout Protocols

The two running workouts (in random order) were performed one week apart at approximately the same time of day. The workout on grass was performed on a flat, natural grass loop of approximately 475m. The grass was weekly cut to a height of approximately 3-4 inches and was well established. The workout on asphalt was performed on a loop of road of approximately 465m. The slight differences in loop distances were to ensure the most consistent course on both surfaces (i.e. avoiding pot-holes, dead grass, etc.). Intensities and durations of the running workouts were based on each participant's specific tempo pace based on Daniel's running formula [14]. This intensity level was chosen because it is a typical workout performed by distance runners. The participant's lap times were recorded for each lap during the workout to ensure pace remained consistent.

Participants performed a 10 minute warm-up jog at their own typical warm-up pace, staying exclusively on the surface being tested. A one minute rest was then provided followed by the 20 minute tempo run on either the loop of natural grass or on the loop of asphalt road. Lap times were measured to ensureproper pacing. Immediately following the workout, participants performed post-workout testing.

The participants performed indoor post-workout testing over the force plates, following the same procedure as the pre-workout trials. A second post-workout running trial over the force plates was performed 24 hours later (after a 5 minute warm-up jog on the specific surface of the workout) to determine whether delayed alterations in the dependent measures were present.

Overall, contact time (s), impulse (Ns), and peak vertical force (N) were collected on three instances for each trial: pre-, post-, and 24 hr after the running workout, for both grass and asphalt the independent variable, separately.

Statistical Analysis

Means and standard deviations were calculated for contact time, impulse, and peak vertical force for the three instances recorded for the pre, post and 24 hr after workout, separately. The contact time was determined by subtracting the time at heel-strike from the time at toe-off of the right foot. The impulse was determined by integrating the GRF-time curve during right foot force-plate contact. Both impulse and peak vertical forces were normalized for body weight. Comparisons of the differences in the three measures for each surface, as well as changes in the measures (post minus pre, and 24 hr after workout minus pre) between surfaces were made using separate repeated analysis of variance. A Bonferroni correction was made due to three statistical tests on the same data. Therefore, alpha was set to 0.05/3 = 0.2. Cohen's effect sizes for the three dependent measures were also determined [15].

Results and Discussion

Table 1 shows the means and standard deviations for contact time, impulse, and peak vertical force for the workouts on asphalt and grass, separately. There were no significant differences between pre, post or 24hr on either surface ($p>0.02$) across the three GRF parameters. Likewise, the GRF parameters on the grass surface were similar ($p>0.02$). Although no statistical significance was detected, individual data showed that the impulse was less for 10 of the 12 participants for the post-workout than for the pre-workout. Furthermore, the peak vertical force was less for the post-workout than for the pre-workout in 8 of the 12 participants. The standard deviations were similar throughout the trials for each surface, indicating consistency in the variability of each parameter.

Table 1. *Means ± standard deviation for contact time (CT), impulse (I), and peak vertical force (VF). GRF parameters were normalized for body weight. No significant differences (p>0.02) were found between the pre- and post- running or the pre- and 24 hr- post running GRF parameters.*

	Asphalt			Grass		
	Pre	Post	24-hr	Pre	Post	24-hr
CT (s)	0.18 ± 0.03	0.18 ± 0.03	0.19 ± 0.02	0.19 ± 0.03	0.18 ± 0.03	0.18 ± 0.03
I (Ns)	0.67 ± 0.07	0.66 ± 0.07	0.68 ± 0.05	0.66 ± 0.08	0.65 ± 0.07	0.65 ± 0.08
PVF (N)	5.55 ± 0.53	5.44 ± 0.58	5.53 ± 0.58	5.42 ± 0.55	5.42 ± 0.53	5.60 ± 0.39

The means and standard deviations of the differences between the pre- and post- and the pre- and 24 hr-post GRF parameters for the two surfaces are shown in Table 2. The differences between GRF parameters for asphalt and for grass were similar ($p>0.02$), except for peak vertical force differences for post minus pre-trial values between asphalt versus grass ($p<0.02$). Although no statistical significance was found, the peak vertical force difference between post and pre-workout values for the asphalt (-0.11 ± 0.02 N) was 15 times less than that for grass (-2.4 x 103 ± 0.11 N). Furthermore, the post-pre standard deviation of the peak vertical force was 5 times greater for grass than for asphalt. The 24 hr-pre standard deviation in the peak vertical force was also twice as great for grass as for asphalt.

Table 2. *Means ± standard deviation of the differences in contact time (s), impulse (Ns), and peak vertical force (N). GRF parameters were normalized for body weight. No significant differences (p>0.02) were found.*

	Post-Pre		24 hr-Pre	
	Asphalt	Grass	Asphalt	Grass
Contact time (s x 10^{-3})	0.14 ± 8.92	-1.60 ± 7.37	-3.79 ± 0.01	-1.75 ± 0.01
Impulse (Ns x 10^{-3})	-0.01 ± 0.03	-0.01 ± 0.02	-2.01 ± 0.03	-3.69 ± 0.04
Peak vertical force (N)	-0.11 ± 0.02	-2.4 x 10^{-3}± 0.11	-0.01 ± 0.10	0.02 ± 0.21

The purpose of this study was to compare variations in GRF parameters after workouts performed on two separate running surfaces. To examine how surface type may affect GRF parameters in distance running, the pre-workout values were compared to the post- and the 24 hr post workout values, for asphalt and grass separately. The focus of this study was to focus on the acute effects on running on different surfaces after a traditional workout. Therefore, the running muscles were fatigued to a degree that runners would typically experience.

On the contrary to the findings of this study, past research [16, 17, 9, 18] did find significant acute changes in GRF parameters after muscles were fatigued. These differences are likely attributed to the protocol of the present study, which required participants to perform an actual outdoor running workout that would typically be included in an athlete's training regimen. Other studies have used treadmill running as a fatiguing protocol[18, 9] or fatiguing exercises on localized muscle groups, such as the ankle dorsiflexors and plantarflexors[16, 17]. The principle of specificity suggests that the body tends to adapt more efficiently to what it is accustomed; in this case an actual outdoor running workout compared to a protocol that targets specific muscle groups or one that involves pre-set, uniform, and 'different than typical' conditions as is the case for an indoor treadmill run. As such, the significant difference in GRF parameters found by previous studies may be due to the principle of specificity rather and/or full fatigue rather than alterations caused by a typical workout that runners would experience.

To observe the potential influence of running surface on changes in GRF parameters, differences between pre-workout and both the post-workout and the 24 hr-post workout values were compared between asphalt and grass. The fact that no significant differences were found (p>0.02) suggests that the body changes its kinematics and kinetics to maintain consistent GRF parameters regardless of the surface type on which a tempo running workout is performed. Past studies [7, 8, 4, 5], postulate that humans subconsciously adjust lower extremity joint angles and muscle activity upon impact according to the stiffness or compliance of the running surface. Authors from these studies have suggested that running on more compliant surfaces results in an increased leg stiffness and consequently straighter limb posture whereas running on harder surfaces results in reduced leg stiffness and consequently a more flexed limb posture. In order to compensate for higher ground reaction forces experienced on harder surfaces, kinematic variances may be a result of greater muscle forces and joint moments [5], and could therefore potentially result in a greater risk of over-use injury. However, these findings were not seen in the present study, and is likely due to the differences in the protocol of the studies.

A trend in the data that warrants investigation is the greater degree of variation in the post-pre and in the 24 hr-pre differences in the peak vertical force for grass. The standard deviation for the post-pre difference in peak vertical force was five times greater for grass than for asphalt. In addition, the standard deviation for the 24 hr-pre difference in peak vertical force was twice as great for grass as for asphalt. The participants in this study were more accustomed to running on harder surfaces (i.e. road running) at the time of the study, and may be considered a limitation of the study. The greater variability in peak force, directly related to muscle activation for the more compliant surface seen in this study may suggest that peak vertical force can be perturbed when running on a surface to which they are unaccustomed. This notion is weakly supported by the data and further research is required before more concrete conclusions can be drawn.

Mechanical test results of past research would suggest that the GRF parameters exhibited by runners would vary significantly between surfaces with different mechanical characteristics [7]. However, combined results from the present study, from joint angle and leg stiffness studies, and from EMG muscle pre-activation studies support presumption that the body alters lower extremity joint angles and muscle activation to compensate for changes in surface type.

Conclusions

No short-term alterations in GRF were found in this study, suggesting that runners training for races on hard surfaces can perform their main workouts on these surfaces with minimal to no increase in potential injury compared to running on a softer surface (i.e. grass). Performing main workouts on harder surfaces allows the body to adapt to those specific conditions and prepare it better to race on that surface-type (principle of specificity). Although no short-term effects in GRF parameters were found, coaches and athletes should be aware that running on harder surfaces is known to generate greater muscle activation, which is known to lead to quicker fatigue and eventual injury. Running on more compliant surfaces seems to generate less muscle activation and may be a better choice for recovery runs.

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