ACUTE EFFECTS OF SURFACE TYPE ON BIOMECHANICAL PARAMETERS OF RUNNING

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The purpose of this study was to examine whether an acute bout of exercise on a compliant versus non-compliant surface could reveal biomechanical indicators of injury. Twelve college-aged seasoned cross-country runners performed two bouts of 20 minute runs, one on grass and one on asphalt, one week apart. Changes (pre vs. post) measures in contact time (s), impulse (Ns) and peak vertical force (N) showed no significant differences based on surface type. The results show that an acute bout of exercise on either surface will not be different in terms of potential for injury. However, the chronic effects of running on different surfaces should be examined using fatigue levels to determine if constant surface type affects the chance of injuries.

KEY WORDS: acute, ground reaction force, injury.

INTRODUCTION: Running is an activity that with increased frequency and intensity can lead to injuries. These injuries are a result of ground reaction forces (GRF) that can reach 2.5 times an individual's body weight, combined with an average of 1000-1200 steps taken for every mile run (Tillman et al., 2002). Both internal and external factors can be altered to aid in reducing the influence of GRF on the muscloskeletal system, in turn reducing the chance of injuries.

Internally, muscle fatigue is one of the primary factors that influence the nature of the GRF during running. Fatigued dorsiflexor and invertors of the foot resulted in a significantly greater loading rate of the peak impact forces (Christina et al., 2001). Furthermore, fatigue reduces stride rate that is directly associated with an increase amplitude of the heel-strike shock wave (Verbitsky et al., 1998). These and other studies (Dickinson et al., 1985) have suggested that running while fatigued results in the passive tissues (bone, tendons, and ligaments) absorbing the relatively large and repetitive GRF instead of the active muscle tissues, increasing the risk of injuries.

External factors can be altered to help absorb the GRF and potentially reduce the chance of injuries. When running on compliant surfaces such as grass, a significantly greater foot contact time and a great surface area contact were found compared to a non-compliant surface (Tessutti et al., 2008). Conversely, Tillman et al. (2002) found no significant difference in peak force, contact time or impulse while running on grass compared to concrete, which may be a direct result of altered gait patterns dependent on surface hardness (Ferris et al., 1999).

What is not yet known is whether there is a combined effect of the internal and external factors on biomechanical running parameters and how this might influence the chance of injuries. Specifically, the span of the study focuses on the external factor of surface characteristics and the subsequent effects on running mechanics and the potential for injuries. The goal of this study was to examine the effects an acute bout of running (at a typical level of fatigue experience by runners) on a compliant versus non-compliant surface on the changes in several running parameters. It was expected that a significantly greater change in the parameters would be found after a running on the non-compliant surface.

METHODS: Seven males and five females were recruited from a Division II college cross-country running team. Prior to inclusion, each participant signed a consent form approved by the Institutional Review Board where the testing took place. Pre-workout, participants were asked to run at the workout pace (described below) along a runway that included two (Bertec™) force plates that record the right and left foot GRF, respectively. A four camera motion-capture system (SIMI™) was synchronized with the force plates and was used to determine the speed of the runners. A total of three successful trials were performed.

Immediately following the pre-workout testing, participants performed a 10 minute warm-up jog staying exclusively on the surface being tested (i.e. either grass or asphalt). After a 2 minute rest period, participants ran for 20 minutes at 85% maximum heart rate. Heart rate, time, and rate of perceived exertion (using the Borg scale) were measured each lap of a 470 meter loop to ensure the pace was consistent and at the determined level.
Within 10 minutes of completing the workout, runners repeated the same procedures as the pre-workout. This post-testing was performed as quickly as possible to ensure the acute adaptation remained. Following a one week rest, participants then performed the same testing procedures but on the other surface than the first testing session. The order of surface was randomized such that approximately half the participants ran on grass the first session and the other on asphalt.
Contact time (s), impulse (Ns), peak impact force (N), and peak vertical force (N) were determined for the pre and post workout testing in each session (grass vs. asphalt) for each foot; the right and left foot data were combined. However, after analyzing the force vs. time curves from the force-plates, most of these runners did not possess a peak impact force. For this reason, peak impact force was not included in the study. Impulse and peak vertical force were normalized to body weight. In addition, the running speed of the participant while crossing the force-plates was determined from the motion-capture system. The running speed for the pre and post trials of both sessions (grass vs. asphalt) were examined and the four (one from each combination) that were closest in running speeds were used in subsequent analysis. This selection was to ensure that differences in the biomechanical measures were not a result of variations in running speed.
Changes between pre to post workout for the three measures were then calculated. To determine whether there was a significant difference in the changes of the measures between grass and asphalt, three repeated-measures t-tests were used. To compensate for multiple t-tests, alpha was set to 0.05/3 = 0.17. In addition, a repeated measures t-test was used to determine whether the mean (of all participants) averaged (of each loop) running speed was significantly different between the surfaces; alpha was set at 0.05.

RESULTS: There were no significant differences in the average running speed during the workout sessions between grass (5.15 ± 1.29 m/s) versus asphalt (5.13 ± 1.18 m/s); $t(11) = 0.44$, $p = 0.67$. Furthermore, the largest difference in running speeds within an individual across the four testing sessions, measure while crossing the force plates (pre vs. post x grass vs. asphalt) was 0.11 m/s. The average Borg scale reading across all participants was relatively consistent for both testing sessions (16.3 ± 0.4 vs. 16.4 ± 0.4) for the asphalt vs. grass, respectively.

The average contact time after a workout on asphalt did not change, while after the grass session, it slightly decreased (Table 1). Impulse remained nearly the same with minimal changes from pre to post workout for both running surfaces. There was a decrease in the peak vertical force after the running workout on asphalt (-0.11 ± 0.02 N) but no change for the grass session on this variable. Among these three biomechanical measures, no significant differences ($p > 0.17$) in the changes in the pre-workout and post-workout measures between the asphalt and grass groups were found.

Table 1
Means (SD) of changes (post-pre workout) in biomechanical measures of running, n=12.

	Asphalt		Grass	
	Pre	**Post**	**Pre**	**Post**
Contact time (s)	0.18 (0.03)	0.18 (0.03)	0.19 (0.03)	0.18 (0.03)
Impulse (Ns)	0.67 (0.07)	0.66 (0.07)	0.66 (0.08)	0.65 (0.07)
Peak vertical force (N)	5.55 (0.53)	5.44 (0.58)	5.42 (0.55)	5.42 (0.53)

DISCUSSION: Previous studies have found that separately, fatigue and non-compliant surfaces are potential causes for running injuries. This study combined both factors to determine if an acute workout (at a more typical level of fatigue experienced by runners) on different surfaces would cause potential changes in biomechanical running measures, thus leading to a possible cause of injury. The results revealed no significant differences among the temporal and kinetic GRF parameters between the two running surfaces, suggesting that an acute bout of running on either surface has minimal effect on running patterns, and therefore does not show signs of potential injury.

The methodology used in the present study to include fatigue as a possible component of running injuries differed from past. The magnitude of fatigue was likely less than other studies, but more analogous to what would be experienced in a typical running program. Although fatigue cannot be directly measured, the runners in this grouped performed a 20 minute run at an Borg level of 16, which equates to between a 'hard' and 'very hard' session. Other studies have used treadmill running as the fatiguing protocol (Dickinson et al., 1985; Verbitsky et al., 1998) or fatiguing exercises on localized muscle groups, such as the ankle dorsiflexors and plantarflexors (Christina et al., 2001). This difference in protocols could be a primary reason why the results of the present study were in discordance with past research, in which previous studies did find significant differences in the pre- and post- fatigue GRF parameters. Referring back to the training principle of specificity, which states that an activity should closely simulate the primary sport in order to improve performance, the body may more efficiently adapt to an actual running workout than to a fatiguing protocol that targets very specific muscle groups. In other words, the significant differences found in these previous studies may have been a result of fatiguing muscles in a manner that is not typical of what would be experienced during typical outdoor running (i.e. fatiguing a single muscle and running on a treadmill).

Examining the running surface as a potential cause for injury, this study used grass and asphalt. However, to ensure consistent GRF testing, all measures were performed on a force plate, rather than on the surface on which the workout was performed. Perhaps if the treadmill was fit with a grass and asphalt surface, respectively, the outcomes might have been different. Also, grass varies in properties due to the thickness of grass, the hardness of the soil underneath, and the outcome of this study may have been different on various grass surfaces. Still, care was given to ensure the grass surface was consistent along the loop where the testing took place.

The design of this study was used as a preliminary examination of interaction between running fatigue and surface type. No significant differences in the changes in pre versus post-workout training on biomechanical measures of running across two different surfaces were found. Several factors may explain this outcome. First, the participants in this study were experienced college cross-country runners who have trained extensively on both surfaces. Furthermore, a 20 minute run at 85% of maximum heart rate is equivalent to a 'tempo-run' that would fatigue the runners to a level below full exhaustion. In addition, Kamibayashi and associates (2006) examined how neuromuscular control affects muscle preactivation and stretch reflexes when landing on different surfaces. It is thought that muscle preactivation prepares the lower limb for impact absorption upon landing, and that the stretch reflex is the lower limb's response to proprioceptive information gathered by the central nervous system. Therefore, the body appears to alter gait patterns, such as leg stiffness, (Ferris et al., 1999; Dixon et al., 2000) to minimize impact forces on the body while running on non-compliant surfaces.

CONCLUSION: This study examined the combined effects of fatigue and running surface type as a potential cause of running injuries. This initial examination focused on the acute effects of a typical training session, rather than a full fatiguing regiment. No significant differences between the surface types on the biomechanical measures of running were found. This suggests that the principle of specificity can apply to running programs. Specifically, during a cross-country season, the primary workout sessions can be performed on grass, while during the track and field or road running season, these sessions can be performed on non-compliant surfaces, without any acute affects towards injury. Future studies should examine chronic effects of running surface, and include fatiguing approaches and levels characteristic of a typical running program.

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