THE EFFECT OF SELECTED SPORT SURFACES ON GROUND REACTION FORCES IN WALKING AND RUNNING

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Introduction

During physical activity, the human body exerts force against its environment. Previous research indicates that the body is exposed to magnitudes of force equaling 2 to 3 times body weight in running (Bates, 1985 & Dickinson, Cook & Leinhardt, 1985) and 1.1 to 1.3 times body weight in walking (Cavanagh, 1980). The magnitude and duration of these forces are a potential source of physical injury. Most biomechanical research in locomotion has examined the role of footwear. However, there is not enough information on the absorption capacity of shoes to determine their safety limit and the ground reaction force is relatively unaffected by footwear changes (Clarke, Frederick & Hamill, 1984).

Reduction of injuries related to sport and recreational activities has been a major concern of researchers and manufacturers (Nigg, Denoth & Karr, 1984). They realize that some instances of pain and injury could be avoided by changing surface materials and altering surface construction. The optimal sport surface would produce an environment that reduces stress on the legs. This would limit the potential for athletic injuries and help improve performance.

The purpose of this study was to investigate the effects of different sport surfaces upon vertical ground reaction forces, energy loss and absorption for walking and running. Eight variables (see Figure 1) were examined to find the differences in vertical reaction forces, energy loss and absorption among the surfaces.

Methods

Ten, healthy, male physical education majors at Washington

State University volunteered for the study. The subjects' age, height and weight were recorded and described in Table 1.

TABLE 1. Subject characteristics

	Age (Years)	Height (cm)	Weight (Newtons)
M	22.9	181	767
SD	3.2	13.8	92.4

Note n= 10

The force platform used in this study was a modified version of Cooper's design, constructed to measure the three orthogonal ground reaction force components through the amplified deflections of strain gauges bonded to cantilever armatures. The force platform was fitted into a wooden runway specially constructed so that the approach area for the walk and run was similar to that of competitive situations. The force platform was interfaced via Lab Tender analog to a digital converter (Scientific Solution, Inc. #020028) and to an IBM PC/XT microcomputer. The sampling rates used for recording the vertical and anterior-posterior forces were 42 Hz and 100 Hz for walking and running respectively.

Two brake switch mats (Carol Stream, Illinois) were placed 8 meters apart on each side of the force plate and were connected by a chronoscope (Dekan Timer) to record and control the velocity of the walk or run. Figure 2 shows the arrangement of the test apparatus.

Sport surfaces were requested from thirty manufacturers in the United States and five corporations responded by sending sample(s) of their products. Three sport surfaces were provided by Robbin Inc. (Durathon), two were provided by Mondo Corporation (Sportflex & Super-X), and Supreme Allweather sent two samples (Supreme Track & Supreme Court). Sportec International Inc. sent the surface "Laykold 400" and Vibra-Whirl sent a sample of "Gym-Sol"N". The sport surfaces were of different thicknesses as provided by the manufacturers. The tenth surface was the force platform which served as the control surface.

Subjects were required to walk and run barefooted form a starting line 6.3 meters from the force platform. They were instructed to walk at a speed between 1.3 and 1.5 meters/second and to run at a speed of 3.5 to 4 meters/second. Each subject was asked to perform three trials of walking and three trials of running on each tested surface. Each subject had a total of 60 trials of walking and running. The experimenter observed each subject in order to avoid abnormal footfalls and stride alteration in striking the middle of the force platform.

Prior to each set, a sport surface was laid out on the force platform in the order of two Latin Squares. Hyperplot software (Interactive Microware, Inc.) was used to smooth the vertical and anterior-posterior portions of the ground reaction force during walking and running and to extract the dependent variables. Dunnett's multiple comparison test was used to identify the mean of the variables for the sport surfaces which were significantly different form the control surface. The projected Least Significant Difference (LSD) was used to compare the means of the variables of the sport surfaces.

Results and Discussions

The greatest means of the eight variables to be discussed are presented in Table 2.

Table 2

Grand Means of the Tested Variables

Surf.		Ep Joule	Ek Joule	Etot Joule	Ib N.s	Ip N.s	CT Second	FXCT N.s	MF Newtons
A	W	89	304	305	92	81	0.297	183	937
	R	149	593	361	94	674	0.592	744	2088
B	W	90	211	308	91	84	0.309	185	971
	R	149	599	775	94	654	0.583	743	2203
C	W	92	214	313	97	91	0.298	182	916
	R	145	560	726	90	678	0.587	731	2091
D	W	92	211	321	95	85	0.298	181	974
	R	142	543	732	104	655	0.583	730	2124
E	W	91	214	321	93	86	0.296	179	963
	R	153	638	796	99	681	0.590	757	2159
F	W	89	206	308	92	84	0.298	183	939
	R	147	571	743	99	682	0.585	727	2077
G	W	88	205	302	93	84	0.291	181	905
	R	143	540	699	92	672	0.585	737	2143
H	W	92	215	323	90	88	0.301	187	954
	R	132	479	654	115	624	0.591	701	2014
I	W	90	209	314	92	83	0.304	185	954
	R	133	472	635	96	641	0.572	714	2149
J	W	92	215	333	92	88	0.306	184	924
	R	145	557	726	95	667	0.590	723	2102

Ep=Potential Energy;Ek=Kinetic Energy; Etot=Total Energy; Ib=Braking Impulse; Ip=Propulsive Impulse;CT=Contact Time; FXCT=Pound Second Integration;MF=Maximum Force; Surface I=bare plate; W=Walking; R=Running.

Walking and running on the tested sport surfaces caused an energy loss of 1.5% and 6.2% of the total mechanical energies expended. This indicates that the surfaces have similar physical compositions and that the physical differences in their thicknesses were not large enough to cause higher energy loss. Moreover, both walking and running barefooted on these surfaces were found to be inefficient because of inequivalent transformation of energy sources and small braking impulses in running (99 N/s) relative to the propulsive impulses (659 N/s). Running on H and on J surfaces suggested they could improve performance.

The contact times during walking and running were longer than those reported in the footwear literature (0.36 second in walking & 0.59 second in running) which reflects better shock absorbing abilities in these surfaces. Longer contact times in walking and running may suggest that locomotion on these surfaces offers more mechanical safety by extending the reaction forces over longer durations.

The work done by the foot (Pound Second Integration) when running on surfaces E and A was found to be significantly higher than the work done by the foot when running on surfaces H and I. This may indicate that running on the surfaces E and A is safer than running on H and on I surfaces.

The normalized maximum forces during walking and running were 1.25 times body weight (944 Newtons) and 2.77 times body weight (2115 Newtons) respectively. Moreover, Dunnett's test showed that running generated significantly lower maximum forces than those generated during running on the force platform surface. The least Significant Difference (LSD) demonstrates that running on surface H results in significantly lower maximum forces than those generated during running on D, E and G surfaces. This finding suggests that surface H has a higher absorbing ability during running compared to the bare force platform and other tested sport surfaces and contributes more to safety during performance.

Conclusions

Due to the observed differences between sport surfaces and the force platform, it can be concluded that sport surfaces affect the performance of locomotor activities and potentially the safety of those activities. The beneficial effects of the surfaces increased as the velocity of the activity increased. However, further studies are needed to test these surfaces during other activities; such as, changing direction and running and stopping.

This study indicates that the tested sport surfaces vary in regard to their effect upon performance. some of the sport surfaces offered more safety while others acted to improve performance. The surfaces that improved performance were also found to be more dangerous. It is recommended that this study be repeated using more sport surfaces. Furthermore, additional studies are needed to test the interaction between shoes and the sport surfaces to determine which combination offers better protection from injury while improving performance.

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