SPORTS EQUIPMENT AND REHABILITATION

THE EFFECT OF SELECTED SPORT SURFACES ON VERTICAL LANDING FORCES IN JUMPING

T.S. Al-Hasso and J.A. Sawhill
Washington State University
Pullman, Washington

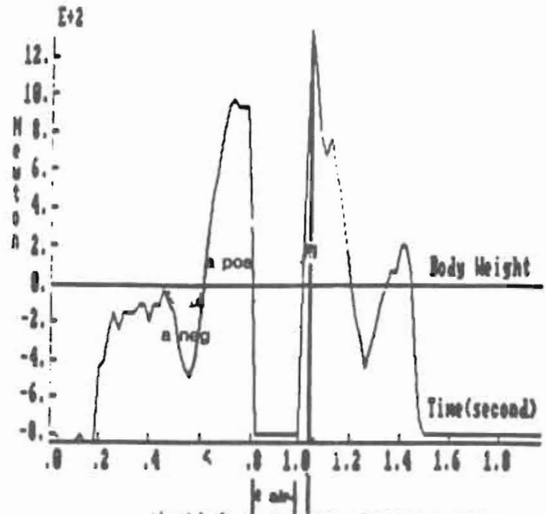
Introduction

The jump for height has received much attention as an important element in many sport activities, but less attention is given to the impact of landing, which may result in injuries due to the large forces involved (Miller, 1976). Therefore, activities that involve landings are potentially more harmful to the joint when there is inefficient absorptive material within the shoes and/or the sport surface.

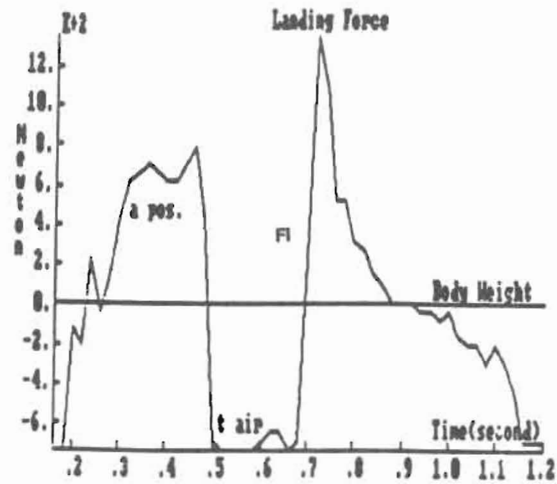
Cavanagh and Lafortune (1980) found that vertical forces, with magnitudes 2.5 times those found in running, were generated when landing from a vertical jump. Nigg, Denoth and Neukomm (1981) reported a force of magnitude 3.5 times the body weight when landing from a vertical jump. Knowing the magnitude of the vertical reaction forces to human beings, when jumping on different sport surfaces, could assist surface manufacturers and shoe designers in producing products that will reduce impact and therefore reduce injuries.

The force-time curve of all landings is characterized by two peaks which indicate the intensity of the forces in landing and the hardness of the sport surface. The attenuation of these two peaks is interpreted as a decrease of the hardness and the absorbing ability of the sport surface (Mizrahi & Susak, 1982).

The purpose of this study was to investigate the effects of landing on different sport surfaces with vertical force. Five dependent variables (see Figure 1) and two independent variables were examined in the study.



Vertical ground reaction force in squat jump



Vertical ground reaction force in countermovement jump

Figure 1. Vertical ground reaction force in jumping

Method

Ten healthy male physical education majors at Washington State University were utilized in the study. Their mean and standard deviation for age, weight and height were; 22.9 years (3.2), 767 Newtons (92.4), and 181 cm (13.8) respectively.

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 jump 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 100 Hz for both squat jumping conditions. The apparatus connection used in the study is illustrated in Figure 2.

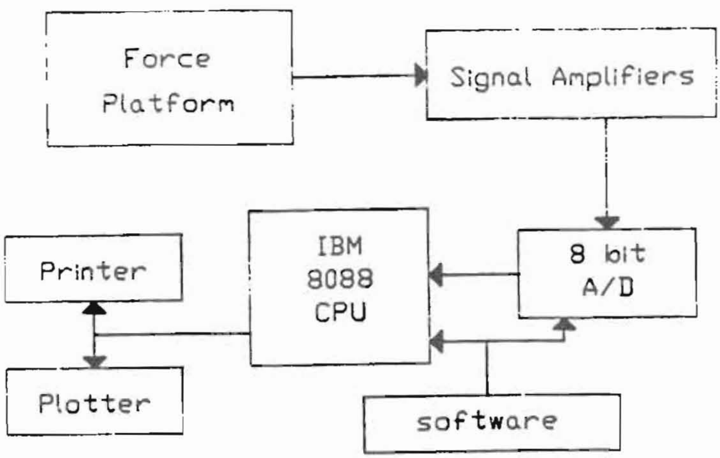


Figure 2. Block diagram of the apparatus connection

Sport surfaces were requested from 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), Supreme Allweather sent two samples (Supreme Track & Supreme Court), Sportec International Inc. sent "Laykold 400" and Vibra-Whirl sent a surface called "Gym-Sol"N". The tenth surface was the force platform which served as the control surface. The sport surfaces were of different thicknesses according to use by the manufacturers.

To execute the squat jump (SJ), each subject started from a line 0.30 meters from the force platform, took one step onto the middle of the force platform and then flexed his knees prior to the jump. In the case of the countermovement jump (CMJ), the subject started from a line two meters behind the force platform and then ran forward to the middle of the force platform for the jump. In both jumping techniques, the take-off was double bare-footed and all subjects were instructed to jump as high as possible. Furthermore, the subjects kept their hands on their waists during the jumps, took-off and landed in the same position, and minimized the flexion and the extension movement of the trunk. Each subject performed three trials of the squat jump and three trials of the countermovement jump on each of the tested surfaces. Therefore, each subject had a total of 60 trials using the squat and countermovement jumps. The experimenter observed each subject in order to avoid unnecessary segmental movements and abnormal take-off and landing positions after leaving the middle of the force platform.

In preparation for each trial, a sport surface was laid out on the force platform in an order according to two Latin Squares. Hyperplot software (Interactive Microware, Inc.) was used to measure some of the tested variables needed to record the vertical portion of the ground reaction force featuring both the squat and countermovement jumps. Dunnett's multiple comparison test was used to identify the means of the variables for the sport surfaces which were significantly different from the control surface. The projected Least Significant Difference (LSD) was used to test and compare the means of the variables from the sport surfaces.

Results and Discussion

The greatest means of the five variables to be discussed are presented in Table 1.

Table 1

Grand Means of the Tested Variables

Surf.		Fl Newtons	a neg N/sec/sec	a pos N/sec/sec	CG Meters	t air second
A	SJ	2715	4.7	15.5	0.520	0.212
	CMJ	2857	---	17.0	0.521	0.212
B	SJ	2750	4.7	15.6	0.506	0.216
	CMJ	2938	---	17.8	0.507	0.205
C	SJ	2699	4.7	15.7	0.514	0.210
	CMJ	2859	---	18.3	0.530	0.217
D	SJ	2559	4.7	15.0	0.522	0.214
	CMJ	2693	---	17.8	0.523	0.204
E	SJ	2800	4.4	15.3	0.520	0.213
	CMJ	2795	---	17.5	0.534	0.211
F	SJ	2582	4.7	15.1	0.519	0.212
	CMJ	2838	---	17.5	0.529	0.212
G	SJ	2592	4.8	15.8	0.506	0.201
	CMJ	2787	---	17.3	0.529	0.216
H	SJ	2713	4.3	14.5	0.527	0.215
	CMJ	2806	---	17.4	0.539	0.219
I	SJ	2723	4.8	15.3	0.526	0.215
	CMJ	2853	---	17.8	0.523	0.212
J	SJ	2661	4.6	16.1	0.524	0.218
	CMJ	2909	---	17.9	0.535	0.219

Fl=landing force; a neg=negative acceleration; a pos=positive acceleration; CG=displacement in center of gravity; t air=time in the air; SJ=squat jump; CMJ=countermovement jump; I=force platform.

No significant differences in landing forces were found, among the tested sport surfaces, for either the SJ or the CMJ. The landing forces following the SJ and CMJ were 2679 Newtons (3.52BW) and 2833 Newtons (3.73BW) respectively. The landing force from the SJ was similar to the landing force reported by Nigg, Denoth and Neukomm (1981). However, the landing force of the CMJ was less than the landing force reported by Valiant and Cavanagh (1985). The barefoot landings on these sport surfaces generated lower landing forces than those produced when individuals wore basketball shoes and landed on the force platform surface. This indicates that the tested sport surfaces absorbed more forces in landing than the basketball shoes.

A negative acceleration of 4.64 g during the SJ was identified; however, a negative acceleration during the CMJ could not be recorded because of the small sampling rate. Jumping on the tested sport surfaces shows a smaller negative acceleration which indicates that these surfaces help the muscles to stabilize the joints by decreasing the initial forces placed upon the joint by the muscles. The small value of negative acceleration also indicates that these sport surfaces have a higher absorbing ability which acts to decrease the magnitude of the maximum force produced during SJ (Bates, 1985 & Denoth, 1986).

The positive acceleration was observed to be larger than the negative acceleration during the two jumping techniques. Positive accelerations of 15.39 g and 17.63 g were found in SJ and CMJ respectively. The larger positive acceleration as compared to the negative acceleration, indicates that jumping on these surfaces offered more muscle reaction to stabilize the joints and reflects the safety when jumping on these surfaces (Lees, 1981).

No significant difference was observed among the sport surfaces during maximum negative and positive acceleration in either the SJ or the CMJ. This shows that these sport surfaces help the muscles to accomplish nearly the same stabilizing effect on the joints during the jump and that they possess nearly the same absorbing ability (Bates, 1985; Denoth, 1986; and Lees, 1981).

A significant difference was observed in the height of the C of G (CG) during the CMJ on the sport surfaces. However, no significant difference was observed in the height of the CG for squat jump. Dunnett's multiple comparison test showed a significantly higher rise in the center of gravity for the CMJ on surface H than the rise of the CG during the CMJ on surface I. The LSD shows that surfaces H and I differ significantly in the elevation of the CG from the surfaces of D, A, and B. LSD also shows a significant difference between J and B.

The average displacement of the CG was 0.52 meters for the SJ and o.57 meters for the CMJ. This indicates that these surfaces helped to increase the displacement of the center of gravity in jumping.

Significant differences were found among the sport surfaces regarding the amount of time in the air (t air) during the CMJ, but no significant difference could be found regarding t for the SJ. Dunnett's multiple comparison test showed no significant differences with reference to time in the air when jumping on I or the rest of the sport surfaces. However, the LSD test showed that the H, J, C, G, and F surfaces were significantly different from the B and D surfaces. The findings from this study indicates that the sport surfaces have a significant effect on jumping ability, but that their effects were not different from the I surface. Some of the tested sport surfaces had greater effects than others.

Conclusions

The differences found among the tested sport surfaces suggested that they differed in their effect on performance. It is suggested, however, that this study be duplicated using additional sport surfaces. Further, studies are also needed to test the interaction between shoes and the sport surface to determine which combination offers the best protection from injury while also helping to improve performance.

References

Al-Hasso, T.S. (1987). The effect of selected sport surfaces on vertical force in walking, running and jumping. Doctoral dissertation, Washington State University, Pullman, Washington.

Bates, B.T.; L. R. Osternig, J. A. Sawhill & J. Hamill (1985). Identification of critical variables describing ground reaction forces during running. In Hideji Matsui and Kando Kabayshi (Eds.). *Biomechanics* VIII-B. Champaign, Illinois: Human Kinetic Publishers.

Cavanagh, Peter R. & Mario A. Lafortune (1980). Ground reaction forces in distance running. *Journal of Biomechanics*, 13, 397-406.

Denoth, Jachen (1986). Load on locomotor system and modeling. In Benno M. Nigg Biomechanics of Running Shoes. Champaign, Illinois, Human Kinetic Publishers.

Lees, A. (1981). Methods of impact absorption when landing from a jump. *Engineering in Medicine*, 10 (4), 207-211.

Miller, D. and R. C. Nelson (1976). Biomechanics of sport: A research approach, Philadelphia: Lea and Febiger

Mizrahi, J. & Z. Susak (1982). Analysis of parameter affecting impact attenuation during loading in human vertical free fall, *Engineering in Medicine*, 11 (3), 141-147.

Nigg, B. M., J. Denoth, & P.A. Neukomm (1981). Quantifying the load on the human body: problems and some possible solutions. In A. Morecki, K. Fidelus, K. Kedzior, & A. Wit (Eds). *Biomechanics* VII-B (pp. 89-99). University Park

Press, Baltimore.
Valiant, G.A., & P.R. Cavanagh (1985). A study of landing from a jump: application for design of basketball shoe, In David A.
Winter, Robert W. Norman, Richard P. Wells, Keith C. Hayes, & Aftab Patla (Eds.). *Biomechanics* IX-B. Champaign, Illinois: Human Kinetic Publishers.