PRESSURE DISTRIBUTION IN INLINE SKATING STRAIGHTS WITH DIFFERENT SPEEDS

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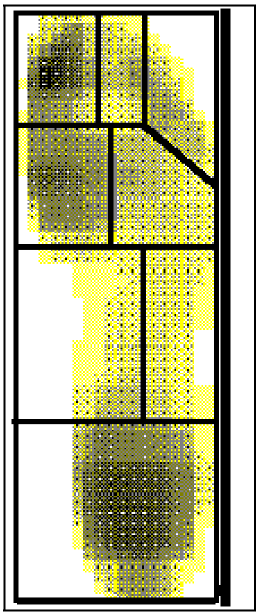
INTRODUCTION: Inline skating (ILS) has been one of the fastest growing sports in recent years. Most of the literature to date has dealt with injuries and physiological responses of ILS (Adams, S. L. et al. 1996; Melanson, E. L. et al. 1996; Rundell, K. W. 1996; Ellis, J. A./ Kierulf, J. C./ Klassen, T. P. 1995; Fedel, F. J. et al. 1995; Wallick, M. E. et al. 1995; Callé, S. C./ Eaton, R.G. 1993; Snyder, A. C. et al. 1993). Recently, some authors have published work that is related to biomechanics and ILS (Mahar et al. 1997; Giacobetti et al. 1997). However, from a kinetic point of view little is known about ILS. The purpose of this study was to measure plantar pressure distribution and stride characteristics for two skating velocities.

Figure 1. Average footprint of one subject with developed mask



METHODS: Thirteen male advanced skaters with shoe size 9 participated in the study. Their mean age, mass and height were 30.3±7 years, 71.9±4.5 kg, 175±5 cm, respectively. Testing took place at an indoor hockey rink and a Pedar Mobile system was used to collect plantar pressure information (50 Hz). A pair of recreational skates fitted with rigid, flat insoles was used to eliminate the influence of the sock liners. In addition, the sensors were zeroed before each trial to exclude the pressure due to lacing and to account for potential drift of the sensors. Data was collected during straight ILS. Nine trials per foot were saved for analysis. Two skating velocities, 18 km/h ± 5% and 24 km/h ± 5%, were examined.

Novel-win software was used to process the data. A mask, based on visual inspection of each trial, was developed. This is represented in Figure 1, overlaid on an average footprint for one subject. Areas defined by the mask were heel (H), medial and lateral midfoot, first and second metatarsal head (FMH), third to fifth metatarsal head, first toe (FT), second and third toe, and fourth and fifth toe. Peak pressure (PP), time to PP (tPP), pressure impulse (PI) and pressure-time curves for these areas were calculated using Novel's 'Groupmask evaluation'. In addition, the force-time curves for the total sensing area were calculated. Finally, the contact time for the total area was extracted. For statistical analysis a repeated measures ANOVA ($p<0.05$) was used.

RESULTS: The total sensing area force-time curves for both speeds demonstrated high similarity with patterns reported for walking (Figure 2). The two velocities produced similarly shaped curves, with the first peak occurring just before 20%, the second peak at approximately 80%, and the minimum at 55% of the total roll-over period (ROP). There were no significant differences for the first peak (688 ± 92 N, 692 ± 108 N) for the slow and fast speeds, respectively. However, differences did exist for the second peak (775 ± 112 N, 907 ± 132 N).

The total force impulses were significantly reduced with increased speed (530 ± 88 N*s and 423 ± 68 N*s for the slow and fast speeds, respectively. There was no difference in the average force between the two speeds (529 ±66N, 537 ±66N).

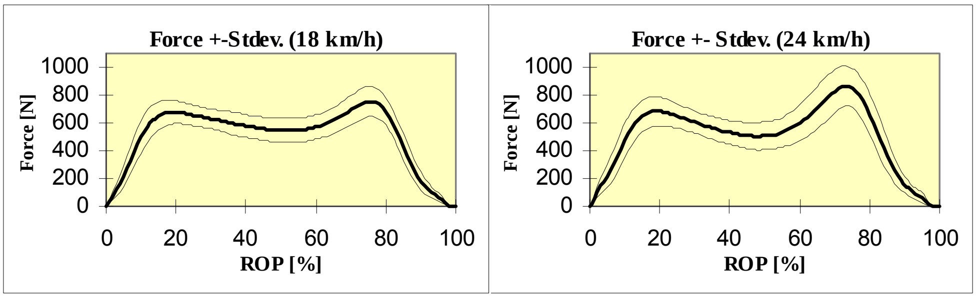


Figure 2. Force-time plots for the total sensing area as a percentage of ROP.

It was also found that similar areas of high pressure existed between the two velocities (H, FMH and FT). PP, tPP and PI for these areas are presented in Table 1. Non-statistically significant differences of 4%, 7% and 0% were found for the H, the FMH and the FT, respectively. The tPP was significantly longer at the FMH and FT at the slower speed. The pressure impulses for the three areas and the contact time were significantly reduced for the faster speed. The impulse under the big toe (FT) was reduced by approximately 40%.

Table 1. PP, tPP, PI for three areas and contact time for the total sensing area.

Km/h	Peak pressure [N/cm^2]			Time of PP [ms]			Impulse [(N/cm^2)*s]			Contact Time (ms)
	H	FMH	FT	H	FMH *	FT *	H *	FMH *	FT *	total*
24	27±8	28±10	32±9	234±111	622±90	618±105	12±4	10±4	9±5	791±106
18	26±7	26±8	32±8	247±93	760±97	784±80	14±4	13±6	14±7	1003±114

*significant differences between the speeds ($p<0.05$)

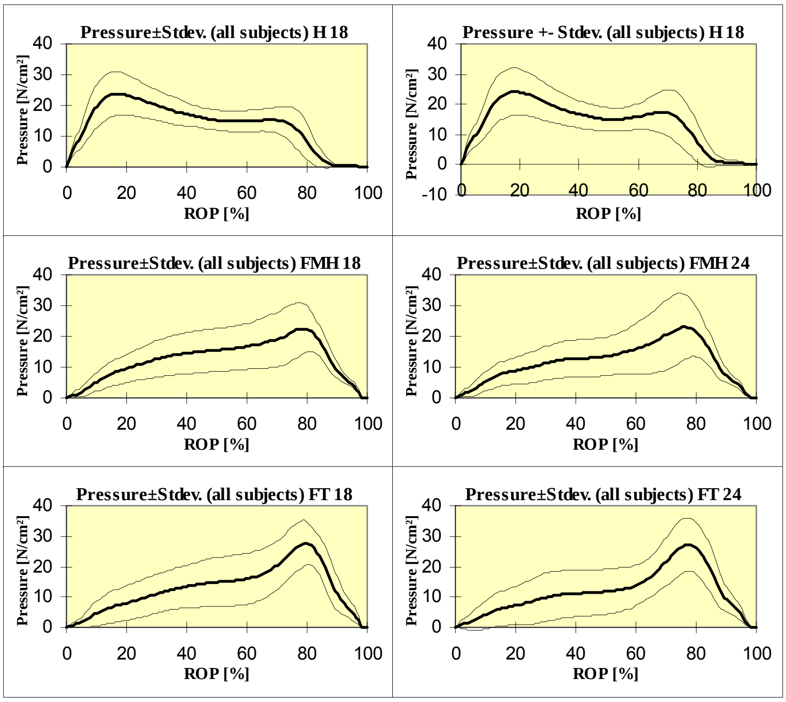


Figure 3. Pressure-time plots for H, FMH and FT as a percentage of roll-over period (ROP).

The characteristics of the force-time curves (Figure 2) are reflected in the pressure-time plots for H, FMH and FT (Figure 3). For all three areas the shape of the curves was similar between the two speeds. The H curves reached their first peak at approximately 20%, their second maximum around 70%, and the minimum between the two peaks at around 55% of ROP. Curves for the FMH and the FT increased to a maximum at approximately 80% of ROP. Except for the heel region, which is associated with the impact of the skate with the ground, these peaks were reached earlier at the faster skating speed (Table 1).

CONCLUSIONS: A step at high speed differed from one at low speed in a significantly increased push-off peak and significantly decreased contact time. However, the average force between speeds did not differ. This suggested that contact time may have been the determining factor in reducing the force-time integral at higher speed. Thus, it would appear that skating velocity is regulated by an increased stride frequency. De-Boer/ Nilsen (1989) and De-Koning et al. (1987) reported results for ice speed skaters. Both found no increase in push-off force but a decrease in contact time and concluded that stride frequency was the dominant factor responsible for velocity regulation. Differences in push-off peak force between speeds for ILS and no differences for ice speed skating could be explained by the use of professional and Olympic speed skaters versus advanced skaters in ILS or by differences in the technique used by inline skaters versus speed skaters. The different measuring techniques used in these studies could also account for the force discrepancy.

In straight ILS the heel and the medial structures of the forefoot were exposed to higher pressures. The reported PPs were comparable to those reported during walking but lower than running. In addition, the force-time curves were similar in shape to the characteristic vertical ground reaction force-time curves for walking. The physiological and perceptual responses to supramaximal and maximal ILS have been found to be similar to those attained during treadmill running (Wallick, M. E. et al. 1995). ILS also demonstrated considerably less impact than running (Mahar et al. 1997). These results suggest that ILS may be used as a training method with comparable physiological demands to running, but without subjecting the athlete to excess musculo-skeletal loading from footstrike. However, additional work is needed to quantify the high frequency vibration experienced during ILS and assess its effects on the locomotor system. Finally, when considering ILS as an exercise modality, the risk of traumatic injury due to falls must be considered.

REFERENCES:

Adams, S. L., Wyte, C. D., Paradise, M. S., DelCastillo, J. (1996). A Prospective Study of In-Line Skating: Observational Series and Survey of Active In-Line Skaters: Injuries, Protective Equipment, and Training. *Academic Emergency Medicine* **3**(4), 304-311.

Callé, S. C., Eaton, R.G. (1993). Wheels-In-Line Roller Skating Injuries. *J. Trauma*, **35**(6), 946-951.

De-Boer, R. W., Nilsen, K. L. (1989). Work Per Stroke and Stroke Frequency Regulation in Olympic Speed Skating. *International Journal of Sport Biomechanics* **5**(2), 135-150.

Ellis, J. A., Kierulf, J. C., Klassen, T. P. (1995). Injuries Associated with In-Line Skating from the Canadian Hospitals Injury Reporting and Prevention Program Database. *Can. J. Public. Health* **86**(2), 133-136.

Fedel, F. J., Keteyian, S. J., Brawner, C. A., Marks, C. R., Hakim, M. J., Kataoka, T. (1995). Cardiorespiratory Responses during Exercise in Competitive In-Line Skaters. *Medicine and Science in Sports and Exercise* **27**(5), 682-687.

Giacobetti, F. B., Sharkey, P. F., Bos-Giacobetti, M. A., Hume, E. L., Taras, J. S. (1997). Biomechanical Analysis of the Effectiveness of In-Line Skating Wrist Guards for Preventing Wrist Fractures. *The American Journal of Sports Medicine* **25**(2), 223-225.

Mahar, A. T., Derrick, T. R., Hamill, J., Caldwell, G. E. (1997). Impact Shock and Attenuation during In-Line Skating. *Medicine and Science in Sports and Exercise* **29** (8), 1069-1075.

Melanson, E. L., Freedson, P. S., Webb, R., Jungbluth, S., Kozlowski, N. (1996). Exercise Responses to Running and In Line Skating at Self Selected Paces. *Medicine and Science in Sports and Exercise* **28**(2), 247-250.

Rundell, K. W. (1996). Compromised Oxygen Uptake in Speed Skaters during Treadmill In Line Skating. *Medicine and Science in Sports and Exercise* **28**(1), 120-127.

Snyder, A. C., O'Hagan, K. P., Clifford, P. S., Hoffman, M. D., Foster, C. (1993). Exercise Responses to In-Line Skating: Comparisons to Running and Cycling. *International Journal of Sports Medicine* **14**(1), 38-42.

Wallick, M. E., Porcari, J. P., Wallick, S. B., Berg, K. M., Brice, G. A., Arimond, G. R. (1995). Physiological Responses to In-Line Skating Compared to Treadmill Running. *Medicine and Science in Sports and Exercise* **27**(2), 242-248.