IN-SHOE PRESSURE DISTRIBUTION DURING ERGOMETER ROWING IN NOVICE AND EXPERIENCED ROWERS

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INTRODUCTION

Bourne (1928) believed that the effectiveness of an oarsman's effort was dependent upon the use of their feet. In spite of recent advances in technology, foot function during rowing has been minimally investigated. An understanding of foot function could lead to an improvement in foot stretcher design and enhance the process of teaching effective technique. Ernst (1983) explained that one factor in an effective leg drive is the foot stretcher angle. In determining this angle some coaches believe that the athlete's heels should remain in contact with the stretcher at the initiation of the drive (catch) and throughout the entire stroke. However, athletes with poor ankle flexibility have difficulty keeping their heels down at the catch, causing pressure at the catch to be created under the forefoot. On the other hand, many coaches believe that the heels rarely make contact with the foot stretcher. More objective evidence is needed to determine the location of foot pressure during the stroke.

Foot function may change with skill level. Muscle groups used during rowing have been shown to be influenced by experience. Daireaux and Pottier (1982) found that novice rowers generated a greater amount of muscle activity with the upper body than experienced rowers and were less dependent on the lower body in generating force. Peak pressure generation under the forefoot and rearfoot during the stroke may also reflect these differences in skill, although this has not been investigated. Novice rowers may have difficulty balancing their center of mass and may also generate pressure under a smaller portion of the foot. The mediolateral and anteroposterior center of pressure distribution under the feet will reflect the stability and the length of the foot used during force generation.

In order to study effective foot function during the stroke, it is necessary to investigate foot pressure distribution. Therefore, the purpose of this study was to investigate the effect of experience on peak forefoot and rearfoot in-shoe pressure, and mediolateral and anteroposterior center of pressure of the dominant foot during rowing on an inline-pull rowing ergometer

METHODOLOGY

Five novice and five experienced collegiate male and female rowers volunteered to participate in this study (Table 1). Years of participation in rowing for the experienced subjects ranged from 0.7 to 7.0 years ($x=3.8 \pm 3.2$). Foot pressure data collection was accomplished through a pressure sensor (Tekscan) placed inside the shoe of the dominant foot. The sensor featured 960 potential sensing locations over its surface, each capable of 8-bit resolution. It was trimmed to fit the shoe while still maintaining full functionality. Foot dominance was determined by kicking preference. The same model shoe was worn by each subject. Subjects performed a set warm-up on the inline-pull rowing ergometer (Concept II). This was followed by five strokes at a cadence of 32-34 strokes per minute. Subjects were instructed to place maximal pressure on each stroke. During these five strokes in-shoe pressures were collected at a rate of 100 Hz via the Tekscan data collection software. Following a period of adequate rest four additional trials were likewise collected for a total of five trials.

Table 1. Novice and experienced subject mean (sd) values of age, height, mass, and years of rowing experience (N=10).

	Novice	Experienced
Age (years)	28.4 (4.5)	22.2 (2.4)
Height (cm)	171.7 (5.7)	165.0 (14.5)
Mass (kg)	61.5 (3.8)	75.3 (5.4)
Experience (years)	None	3.8 (3.2)

Data analysis was performed on one stroke cycle (drive and recovery) within each trial through custom software. The following dependent variables were measured: forefoot peak pressure, rearfoot peak pressure, ratio of forefoot to rearfoot peak pressure, mediolateral and anteroposterior center of pressure. Forefoot was defined as the front half of the foot and rearfoot as the back half of the foot. Mean values were calculated from the five trials for each variable.The mean values of each variable were statistically evaluated using a one-way ANOVA ($p<0.05$).

RESULTS

The mean values and standard deviations for forefoot and rearfoot peak pressure are presented in Table 2 and in Figure 1. Forefoot peak pressure was significantly higher in the experienced subjects while peak rearfoot pressure was significantly higher in the novice subjects. Experienced rowers had a significantly higher amount of peak pressure in the forefoot when compared to the rearfoot, nearly twice as much, whereas the novice generated similar peak pressures in the forefoot and the rearfoot.

Table 2. Mean (sd) values for peak forefoot and rearfoot in-shoe pressures.

	Novice	Experienced
Peak Forefoot Pressure (kPa)	162.22 * (67.42)	222.78 * (64.90)
Peak Rearfoot Pressure (kPa)	181.81 * (42.21)	121.54 * (21.45)
Peak Forefoot/Rearfoot Pressure Ratio	0.88 * (0.23)	1.95 * (0.88)

*p<0.05

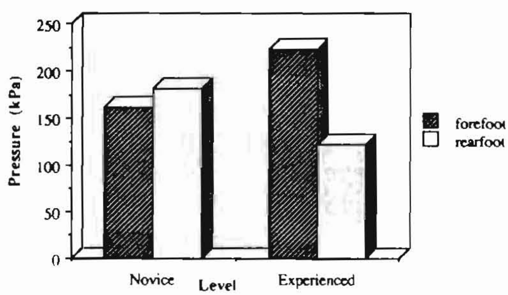

Figure 1. Mean values for forefoot and rearfoot peak in-shoe pressure.

Mediolateral, anteroposterior, and total center of pressure (COP) mean values and standard deviations are found in Table 3. There were no significant differences found in the COP variables; although the anteroposterior center of pressure was greater in the experienced subjects high deviations between subjects precluded finding significant differences.

Table 3. Mean (standard deviation) values for the anteroposterior, mediolateral, and total center of pressure (COP).

	Novice	Experienced
Mediolateral COP (cm)	9.69 (6.88)	10.00 (4.03)
Anteroposterior COP (cm)	34.50 (10.55)	38.52 (11.49)
Total COP (cm)	37.87 (13.37)	41.14 (12.34)

DISCUSSION

Peak forefoot pressure was similarly located for all subjects, near the head of the first metatarsal. This peak occurred at the initiation of the drive phase (catch). It was evident that little heel pressure was applied at the catch.

The lower peak forefoot pressure observed in the novice rowers was likely due to a less effective use of the lower body in force application. This would agree with the findings of Daireaux and Pottier (1982), novice rowers were less dependent on the lower body in generating force. The higher peak rearfoot pressure found in the novice rowers was most likely due to a decrease in control of the body at the end of the drive (finish) and during the recovery.

The higher proportion of forefoot to rearfoot pressure in the experienced subjects (~2:1 versus ~1:1) suggested that to create force effectively rowers need to generate the majority of the foot pressure in the forefoot. This ratio may also be evidence of quick and effective power application at the catch characteristic of experienced rowers.

Mediolateral and anteroposterior center of pressure was essentially unchanged between skill levels. The inexperienced rowers did not seem to be less stable during the stroke, although it may prove fruitful to limit the investigation of pressure distribution to the catch in order to determine differences in balance which may be a crucial difference in technique. There was a trend toward increased anteroposterior center of pressure in the experienced rowers, however between subject variances were high and precluded finding differences. A higher degree of experience may allow for an increased anteroposterior portion of the foot to be used in generating pressure.

CONCLUSIONS

Peak foot pressure was generally located close to the head of the first metatarsal and occurred near the catch across subjects. It was evident that pressure was not applied under the rearfoot at the catch. In creating in-shoe pressure during the rowing stroke, foot function was modified with experience. Higher peak forefoot pressure and lower peak rearfoot pressure were evident as rowers gained in experience with the more experienced rowers generating almost twice as much pressure in the forefoot as in the rearfoot.

Coaches and athletes may want to integrate these findings to improve the teaching and development of correct technique, thus maximizing boat speed and performance. Further studies should incorporate force development and foot function and investigate the differences in foot pressure distribution during sculling versus sweep rowing, and traditional versus pivoting foot stretchers.

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