A KINETIC AND KINEMATIC COMPARISON OF SKILLED VERSUS UNSKILLED STANDING BACK HANDSPRING PERFORMANCES IN YOUNG GYMNASTS

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INTRODUCTION

Wrist injuries comprise approximately 25% of all general athletic injuries (Howse, 1994). In sports such as gymnastics, where the upper extremity is used for weight bearing, the incidence for wrist injury increases dramatically. Mandelbaum, Bartolozzi, Davis, Terlings & Bragonier (1989) reported that 87.5% of male gymnasts and 55% of female gymnasts have experienced wrist pain at some point in their careers.

Forces in many gymnastic maneuvers must be transferred throughout the wrist and arm which can have a compromising effect on the wrist joint and other related structures. As training time increases the wrist is subjected to these forces at more frequent intervals and also more often during one training session. Mandelbaum et al. (I 989) showed a direct correlation between hours spent in practice and the incidence of wrist pain. When the wrist is subjected to stresses, injury to the wrist becomes almost inevitable. As the number of participants in organized gymnastics increases and the younger ages at which they enter the sport, these statistics become even more alarming (Roy, Cain & Singer, 1985).

Ground reaction forces (GRF) of the foot have been studied in several sports and activities such as running, basketball, netball, gymnastics, track and field, and aerobics. In some instances the GRF generated during the activity have been related to the incidence of injury in the sport (Dufek & Bates, 1991). However, very few studies have looked at GRF of the hand and its relation to injury. Koh, Grabiner & Weiker (1992) studied GRF of the hand in relation to the amount of elbow varus/valgus movements that occurred during the execution of a roundoff back handspring. They concluded that the combination of forces in the back handspring may be a contributor to lateral compression injuries to the elbow joint and that larger amounts of elbow flexion may protect the elbow from large valgus moments that occur during the back handspring.

The purpose of this study was to kinetically and kinematically compare skilled and unskilled standing back handspring performances in young gymnasts. More specifically, force-time variables such as peak vertical

GRF, time to peak (TP), time of hand contact (THC), and kinematic variables such as linear velocities of the shoulder, elbow, wrist, hip, knee, ankle, and vertical displacement of the shoulder during hand contact were correlated with the kinetic variables.

METHODS

Nineteen United States Gymnastics Federation (USGF) female competitive gymnasts, ages 7-12, volunteered to participate in this study. Nine of the subjects were classified as level 5 gymnasts while ten were classified as level 8. For the purposes of this study, the level 5 gymnasts were classified as unskilled while the level 8 gymnasts were classified as skilled. In reality, all subjects were "skilled" at the back handspring. However, the subjects in the level 8 group had greater overall refined skill levels. All subjects and parents of the subjects signed consent forms prior to participation.

The subjects went through a general warm-up prior to participation. Each subject performed several practice trials of a standing back handspring to establish proper starting position. Proper position was established when the subjects left hand was totally within the perimeter of the force plate. A previous study (Koh et al., 1992) determined that GRF were the same whether only the right hand or the left hand was used to obtain GRF. Once proper positioning was established each subject performed three trials of the back handspring while being videotaped (I 20 Hz) and force data collected on a Kistler forceplate (540 Hz).

Independent samples t-tests with the alpha level set at $p < .05$ were used to compare all kinetic and kinematic data between the two groups.

RESULTS

The force-time variables of the unskilled and skilled subjects are summarized in Table 1.

Table 1.

Force-time Data and t-test Means and (Standard Deviations) Between Unskilled and Skilled Gymnasts

Variable	Unskilled	Skilled	t
GRF (BW)	3.34 (0.47)	2.78 (0.51)	0.115"
Time to Peak (s)	0.025 (0.006)	0.034 (0.004)	.0003
Time Hand Contact (s)	0.399 (0.1 10)	0.297 (0.038)	.1519

Note. Significant at $p < .05$

The peak velocity and displacement data and t-test results are found in Table 2.

Statistical results showed that there was a significant difference in the means of the skilled and unskilled groups for GRF and TP. Peak GRF was found to be higher in the unskilled group over the skilled group. Conversely, TP values were found to be higher in the skilled group. No significant differences were noted in the comparison of THC for the two groups.

Significant differences were found between the two groups on peak linear velocities of the elbow, wrist, hip, and ankle variables. No significant differences were found in the peak linear velocities of the shoulder and knee between the groups. Likewise, there was a significant differences in the vertical shoulder displacement between the two groups. The displacement was larger in the unskilled group.

Table 2.

Peak Velocity and Displacement Data and t-test Means and (Standard Deviations)

Variable	Unskilled	Skilled	t
Shoulder (m/s)	2.500 (0.214)	2.631 (0.282)	0.1364
Elbow (m/s)	5.809 (0.519)	6,239 (0.234)	0.0150*
Wrist (d s)	9.187 (0.769)	9,737 (0.521)	0.0413*
MP (M/S)	2.649 (0.203)	3.199 (0.281)	0.0001*
Knee (d s)	4.090 (0.485)	4.196 (0.187)	0.2652
Ankle (m/s)	7.452 (0.641)	8.276 (0.382)	0.0015*
Shoulder displacement (m)	0.056 (0.028)	0.031 (0.014)	0.0100*

Note. Significant at $p \le .05$

When the Pearson product-moment correlations were run between the kinetic and kinematic variables, several significant relationships were found between the kinematic variables and GRF, TP, and THC. There was a significant correlation between the peak velocity of the hip and GRF ($r = 0.7375$), velocity of the hip and TP ($r = 0.6540$), and velocity of the hip and THC ($r = 0.5362$). Peak velocity of the ankle and THC ($r = 0.4792$) and vertical displacement of the shoulder and THC ($r = 0.7742$ were the other significant relationships.

DISCUSSION

A summary of the results suggests that there are fundamental differences in the skilled and unskilled performances of standing back handsprings of young gymnasts. The most notable differences in force-time variables were in GRF and TP. Significant differences were also noted in the peak linear

velocities of the elbow, wrist, hip and ankle, and the vertical shoulder displacement.

Peak GRF and TP for the unskilled and skilled groups are interesting when looked at together. Ground reaction forces for the skilled are smaller and the time it took to reach that peak was longer. This result showed that the skilled gymnast was able to keep the GRF at lower peaks and was also able to attenuate that force over a longer period of time. The less skilled gymnast was not able to achieve this to the same degree and possibly could be at higher risk for injury.

Another kinematic variable that showed a significant difference was the vertical shoulder displacement during hand contact. The unskilled group showed almost twice the amount of shoulder displacement as 'the skilled group. This result was not in agreement with Gluck's (I 982) observation that skilled and therefore stronger gymnasts can benefit from the sinking of the shoulder. Coming out of the dip greatly aids in the performance of skills where a catapulting type action is necessary for the proper execution of the skill. A weaker, and therefore less skilled, gymnast is not able to benefit from the catapulting action of the dipping shoulder and therefore proper execution of the skill is nearly impossible. The unskilled subjects in this study actually had greater vertical displacements. This may be explained by the fact that they used the dip as a protective mechanism when rotating backward. They were then unable to catapult themselves upward either due to a lack of strength or a lack of skill.

Significant differences were also noted in the peak velocities of the hip, ankle, shoulder, and wrist. These results corresponded with George's (1980) assumption that the greater the realized horizontal velocity before take-off (hip velocity), the greater will be the resulting quantity of rotary motion (wrist and ankle velocities) at take-off.

In this study, the linear velocity of the hip was related to GRF, TP, and THC. Perhaps the most interesting finding is the relationship between hip velocity and GRF. Peak hip velocity accounts for approximately 55% of the total GRF.

It can be concluded that there are differences between skilled and unskilled standing back handspring performances. More specifically, there are differences in GRF, TP, and elbow, wrist, hip, and ankle linear velocities between groups. The speed at which the gymnast performs the maneuver has a bearing on the amount of force, the time to peak force and the time of hand contact. In general, the more powerful the performance of the handspring, the less force the gymnast has to deal with.

The implications for coaches and teachers are in the training techniques. Training techniques can be implemented to increase muscle strength and power in the muscles involved with the extension of the hip and knee joints (quadriceps, gluteal muscles), thereby reducing the intensity of GRF that the gymnast must tolerate. The strength of the shoulder girdle musculature is also of paramount importance to the gymnast. Techniques for strengthening the shoulder girdle should also be a part of the gymnastic training curriculum. The decrease in GRF that the gymnast has to deal with over an entire career may possible relate to fewer and less frequent injuries of the wrist and therefore, less time missed because of injury.

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