# JOINT MOBILITY AND FORCE APPLICATION DURING THE THRUST PHASE OF THE FRONT HANDSPRING ON FLOOR EXERCISE

Nelson , NG*, Miklós METZING**

*Slippery Rock University of Pennsylvania, U.S.A
**Hungarian University of Physical Education, Budapest, Hungary

## INTRODUCTION

The front handspring element in gymnastics, though rated as an easy difficulty by the Code of Points (International Gymnastics Federation, 1989). is a fundamental skill that gymnasts must perfect since its technical requirements lend themselves to more difficult elements. Its execution, relying upon ballistic force as well as flexibility, is well presented from a mechanical standpoint (George, 1980; Hay, 1993). This investigation sought to observe the relationship between the flexibility of major joints and the dynamic forces generated during the thrust phase of the movement.

## METHODOLOGY

### Subjects

The subjects were 22 young females belonging to the Butler Gymnastics Club of Butler. Pennsylvania. All had undergone moderate to extensive training in gymnastics and possessed competitive experience at the club level. The subjects, ranging from good to outstanding in ability, were all capable of performing the front handspring element. Five of the subjects were classified at Class 2 level while the remaining seventeen were Class 3.

### Data Collection

Flexibility measures. Prior to the handspring skill, range of motion of the gymnasts' shoulder, hip and trunk joints was obtained by a Sankyo Seiki super-8mm. camera with variable zoom lens set at 8.5 mm. The camera was mounted on a Vivitar Model 904 tripod at a lens height of 101.6 cm (40 in.) and located a perpendicular distance of 6.09 m (20 ft.) to the near edge of the box used for the hip flexibility test. Data were filmed at 18 frames per second using Kodak Ektachrome ASA 160 Type G color movie film. Subsequently, the film was converted to standard VHS-format for digitizing via motion video instnunentation.

Measurement of trunk flexibility called for a front lying prone position with arms locked around a 1.52-meter (5-ft.) length pole. With ankles stabilized, each subject hyperextended the trunk as much as possible and held the position for 2-3 seconds. Range of motion was measured with the shoulder and knee joints as the two extreme points ($P_1$ and $P_2$) and with the hip joint, i.e., greater trochanter, forming the vertex (V). Gripping the pole at shoulder width and with elbows locked, shoulder flexibility was measured as the degree of flexion/hyperflexion that could be attained. The elbow, shoulder, and hip formed $P_1$, V, and $P_2$, respectively. This test was conducted with the subject standing and the upper trunk bent forward at the waist. Measurement of hip flexibility called for the subject to assume a stance simulating the front handspring takeoff position, however with the hands placed on top of a 33-cm. (13 in.) high box rather than on the floor. The objective was to determine range of motion between the support leg and the extended kick leg. The two knee joints and the support hip formed the extreme points ($P_1$, $P_2$) and V, respectively. For this last flexibility parameter, both static and dynamic measurements were conducted.

Force platform. The force measurement system consisted of a Kistler Instrument force platform and charge amplifying unit interfaced to a Honeywell 1858 Visicorder recording unit. The Type 9261A multicomponent measuring system was utilized to record only the horizontal shear forces along the direction of movement (X) and the vertical impact forces. In this study negative and positive horizontal X forces acted to the front and rear of the performer, respectively, while vertically downward forces were registered as positive. Nominal transducer sensitivities for the horizontal X and vertical Z forces were 3.5 pC/N and 7.8 pC/N, respectively. Output voltage range was $\pm$10 V. Charge amp measuring ranges of 1000 pc/10V and 5000 pc/10V were selected for the shear force and normal force, respectively. Force calibrations were conducted in Newtons with the application of known weight to the platform to measure the Z direction and the use of a spring scale to measure horizontally-applied forces. Chart recorder pen deflection sensitvity was 0.5 volts/division at a recording speed of 10.16 cm/sec (4 in./sec).

Testing was conducted on the ground floor of the fieldhouse complex in an area designed specifically to accommodate force plate studies. The force plate was bolted to the ground so that its top surface was flush with the gymnasium floor. A 2.54 cm. (1 in.) thick sheet of wrestling mat (of resilite material) was affixed over the plate with contact cement. Three 1.52-m. wide by 3.65-m. long (5 ft. by 12 ft.) gymnastics landing mats were used to form a runway; two placed on the approach leading to the force plate and the other on the landing side. The approach was such that the subjects addressed the width of the platform.

A total of three successful trials were recorded for each subject. The trials were performed in consecutive order. A successful trial was deemed as such if hand placement was executed entirely within the force plate's 40 cm. by 60 cm. perimeter and if the skill was performed with the subject landing in upright feet support. In only four instances were trials repeated; twice due to depletion of the film cartridge; once when the recorder was not reset; and once when the subject fell during the approach.

## Data Reduction

Force tracings were charted on thermal recording paper. Those plots were in turn quantitatively analyzed by a digitizer and reproduced on a Hewlett-Packard 7475 plotter. The digitizer system, a Science Accessories Corporation GP7 Mark II, consisted of a 2.55 cm by 7.48 cm (6.5 in. by 19.0 in.) flat panel control unit with input provided via a hand-held stylus. The digitizing surface, a 10.23 cm. by 18.89 cm. (26 in. by 48 in.) wall-mounted plexiglas sheet, allowed for an effective digitizing area of 8.66 cm. wide by 7.48 cm. high (22 in. by 19 in.).

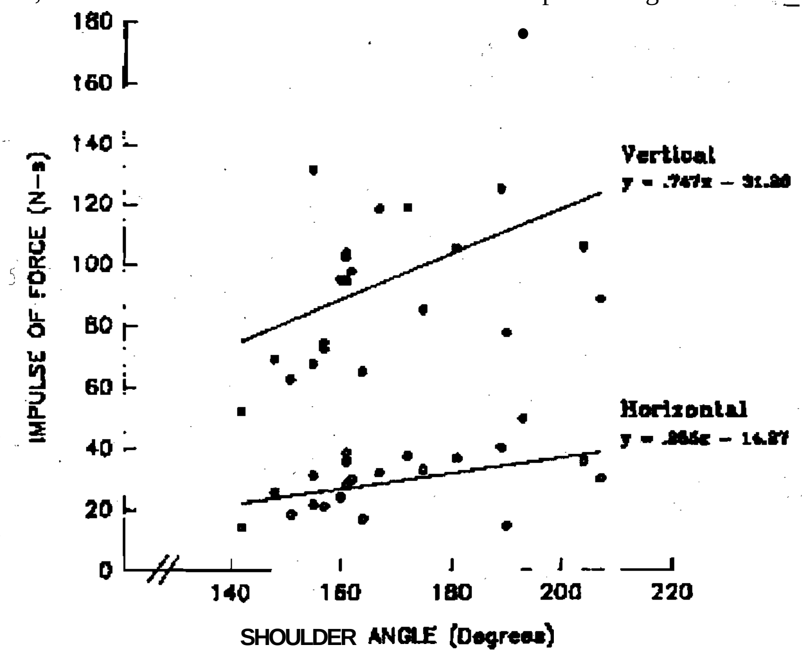
Quantification of force-time data was facilitated by in-house software utilizing the digitizer to integrate the area under the force curve (Ng, 1991). Based on the summation of individual areas of an enclosed irregular area as detailed by Stolk and Ettershank (1987), results were extrapolated from the data points making up each force curve. In addition to impulse of force in the vertical and forward-backward directions, peak vertical force, peak horizontal force, time to reach peak force, and total contact time were determined. Force (in Newtons) was scaled per unit of vertical pen deflection. Time data were determined from Visicorder paper speed.

Static and dynamic flexibility measurements were determined by the Peak Performance Technologies, Inc. 2D motion measurement system consisting of a video controller board and a frame grabber board. The boards were incorporated into a 386-25MHz AT-compatible computer and interfaced to a Panasonic AG7350 video cassette recorder and a Panasonic BTH1350 color video monitor with composite and RGB inputs. Proprietary Peak5 software was used to digitize the marked segmental endpoints to determine the shoulder, hip, and trunk angles.

## RESULTS AND DISCUSSION

Inspection of dynamometric data showed relatively light to moderate plate impact forces and impulses. Peak vertical forces at impact (**Mean** = 709.31 N) were, on average, about 1.8 times bodyweight and vertical impulse tended to be low (Mean = 94.88 **N-sec**). Peak horizontal **blocking** force on hand contact and horizontal impulse averaged 71.56 N and 28.91 **N-sec,** respectively. Average hand contact time at takeoff was 0.30 seconds.. A significant relationship was established for vertical impulse and contact time ($r = 0.45$, $p < .05$). Relationship between vertical and horizontal impulses was highly significant ($r = 0.87$, $p < .05$).

Analyses sought to establish association between each the vertical impulse and the horizontal impulse and each of the independent variables (shoulder angle, trunk angle. static hip angle, and dynamic hip angle). Except for the shoulder joint, variation in normal and shear impulses could not be explained by variation in joint angle. Figure 1 shows the linear regression of vertical impulse and horizontal impulse on shoulder joint flexibility fitted to data. The amount of linear variation in vertical impulse accounted for by variation of shoulder angle was determined and a significant relationship between impulse and flexibility was observed ($F = 5.83$, $p < 0.01$). For horizontal impulse and shoulder flexibility similar results were found ($F = 6.45$, $p < 0.01$). Standard error for sampled mean of impulse at mean joint angle proved low: 1.66 N-sec for the horizontal and 5.17 N-sec for the vertical. The findings strongly suggest that variation of impulse of force could be explained because of variation in shoulder joint flexibiltiy. This finding **appears** to be consistent with proper handspring technique which emphasizes contraction of the shoulder musculature to maintain shoulder flexion and shoulder girdle elevation at impact (George, 1980). The angle between the shoulders and upper body should be eliminated (**Kaneko,** 1977). Such a straight-arm-over-the-headposition evokes stronger **horizontal** and vertical impulses as a result of the desired "**blocking**" effect. Impact positions involving less degree of shoulder flexion, that is, with the shoulders moving too far forward with respect to the hands, are less aesthetic and result in excessive dissipation of ground **reaction** forces.



Finally, determination of relationship between performance and both dynamometric data and joint flexibility measures was carried out. Trials were evaluated beforehand and independent of other analyses with ratings on a 0-5 scale, including .5 unit increments, assigned to each subject's overall performance. Pearson correlation coefficients werecalculated between rating and each of the flexibility parameters, time of contact, and impulse of force. A test of significance using the distribution of *t* was applied to test the null hypotheses that the values of *r* were equal to zero. Non-significant relationships were found to exist between performance score and degree of shoulder, trunk, and hip flexibility. Only the associations between rating and horizontal impulse ($r = .50$, $p < 0.05$) and rating and platform contact time ($r = -.47$, $p < 0.05$) were significant, i.e., the assignment of higher ratings coincided with handsprings that exhibited greater forward blocking and livelier rebound.

## CONCLUSIONS

1. Variation of normal and shear impulses of force during the thrust phase could be explained by variation in shoulder joint range of motion. The greater the degree of shoulder flexion, the greater the tendency for higher impulses. Both are desirable; shoulder flexion for aesthetic appearance, and impulse for 'spring' momentum.
2. Higher performance ratings were associated with shorter handspring contact times.
3. A low relationship between performance and flexibility (shoulder, trunk, hip) does not minimize the importance of joint flexibility for successful handspring execution, but rather, suggests that ballistic actions might play a more significant role.

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