THE INFLUENCE OF SIZE ON PERFORMANCE IN WOMEN'S GYMNASTICS

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Thirty-seven female gymnasts, aged initially between 10 and 12 years, completed a mixed longitudinal study over 3.3 years to investigate the effect of size on gymnastic performance. Subjects were tested at four-monthly intervals on a battery of measures including structural growth, strength and gymnastic performance. The size of these gymnasts at 150 months had a varying effect on performance. Performances of front and back rotations, as well as the twisting jump were significantly, but inversely related to the height and mass of the gymnast. The twisting jump was positively influenced by a high ratio of strength to body mass. Gymnasts with large bodies also took longer to perform the v-sit action, thus indicating poorer performance. A theoretical model was developed to demonstrate the effect of size on the ability to perform generic gymnastic skills.

KEY WORDS: gymnastics, body size, strength, children, biomechanics.

INTRODUCTION: Participation by young people in selected sports such as swimming, gymnastics and figure skating is highlighted by the decreasing age of participants at the international level (Malina et al., 1982). Women gymnasts have always been the smallest of Olympic participants (Medved, 1966), being lighter, stronger when normalised for body mass, leaner and more flexible than all others (Montpetit, 1976). In contrast to the trend in many other sports, elite gymnasts are shorter and younger in comparison to past champions (Bernink et al., 1983). The purpose of this study was to evaluate the relationship between physical size and the performance of simple gymnastic motor skills and from these relationships develop a model outlining factors that contribute to performance.

METHODS: A total of 37 female gymnasts aged 10 to 12 years, who trained more than 15 hours per week, attended an initial testing session, where a number of anthropometric (height; mass; skinfolds and moment of inertia), strength (leg, trunk and arm) and gymnastic ability (forward and backward saultos; v-sit time; twist displacement and jump height) tests were administered. Tests were repeated using an identical protocol at four-monthly intervals over 3.3 years (Richards et al., 1999). Interpolated anthropometric and strength data at the age of 150 months were related to gymnastic performance using Pearson correlations, and a performance model was developed that explained how factors influenced performance on the generic gymnastic skills.

RESULTS AND DISCUSSION: The relationship between measures of gymnastic ability and variables that describe the size of the gymnast at 150 months are shown in Table 1. Performances of front and back rotations as well as the twisting jump were significantly, but inversely related to the height and mass of the gymnast. With the exception of front rotation velocity, these relationships were also reflected in the whole-body moment of inertia of the gymnast. That is, once airborne, the smaller gymnast has less resistance to rotation. The larger gymnasts were able to produce greater power and angular momentum at take off, which would appear due to greater size and leg strength compared with the small performers. However, this ability to generate higher levels of angular momentum does not appear to counter the disadvantage imposed by increases in whole-body moment of inertia for the performance of rotational movements. Similarly, the larger gymnast may be able to produce greater power on take-off, but due to a larger body mass, cannot significantly improve the time of flight in a vertical jump. There are clear differences in the factors that influence the front versus back rotations. While the possession of a small body seems absolutely critical in back rotation performance (significant, negative correlations for height, mass, moment of inertia and absolute leg strength), this was not the case for the front rotation. The latter skill appeared less affected by body size. This may be related to the high ratio of strength to body mass being used more effectively in the forward rotation.

Table 1 Pearson correlation coefficients for performance and physical capacity variables at age = 150 months (n=37).

	Performance Variables							
Physical Capacity	Fr V	Fr L	Br V	Br L	TWIST	V-SIT	J HT	PWR
Height	-0.349 *	0.816 *	-0.534 *	0.742 *	-0.420 *	0.467 *	-0.053	0.596 *
Body mass	-0.316 *	0.715 *	-0.485 *	0.729 *	-0.413 *	0.254	-0.104	0.689 *
Iyy	-0.172	0.891 *	-0.498 *	0.845 *	-0.342 *	0.375 *	-0.074	0.605 *
Sum 8 skinfolds	-0.345 *	0.152	-0.299 *	0.130	-0.253	0.135	-0.106	0.331 *
Leg strength	-0.100	0.715 *	-0.412 *	0.678 *	-0.162	0.154	-0.180	0.453 *
Leg strength / mass	0.339 *	0.158	0.011	0.116	0.372 *	-0.134	-0.115	-0.186

* Significant at $p<0.05$

Fr V & Br V = Maximum angular velocity of the trunk segment during the front and back rotations respectively
Fr L & Br L = Maximum angular momentum of the whole-body during the front and back rotations respectively
TWIST = Amount of longitudinal rotation during the twisting jump
J HT = Maximum height attained during a modified vertical jump
PWR = Maximum power recorded at take-off for the vertical jump
Iyy = Whole-body moment of inertia about the principal transverse axis

Similarly, the twisting jump was positively influenced by a high ratio of strength to body mass. This may have assisted the gymnast to increase flight time in order to counter any negative effects of body size. In addition, it could be argued that rotation about the longitudinal axis is least affected by high moment of inertia values. The v-sit action was positively correlated with the gymnast's height and whole-body moment of inertia. This meant that gymnasts with large bodies took longer to perform the v-sit action. These data support the findings of many studies (eg Bale & Goodway, 1987; Salmela, 1979) in which young female gymnasts typically possess shorter and lighter bodies than other athletes.

THEORETICAL MODEL: A theoretical model outlining factors that contribute to the performance of fundamental activities in gymnastics was developed from these data. These simple movement skills were selected because they necessitated the production of maximum rotational velocity, yet would not be greatly influenced by skill level. The ability to produce angular velocity and angular momentum of body segments is directly proportional to the production of a torque about the segment's axis of rotation, and inversely proportional to the moment of inertia of the segment. The same may be stated for the production of whole-body angular velocity and angular momentum. Jensen (1981) emphasised the significance to performance of increases in mass and moment of inertia during growth, and their influence on the resultant muscle torques required to maintain performance. That is, any increases in body size must be matched by gains in the development of eccentric thrust and angular momentum if performance is not to suffer.

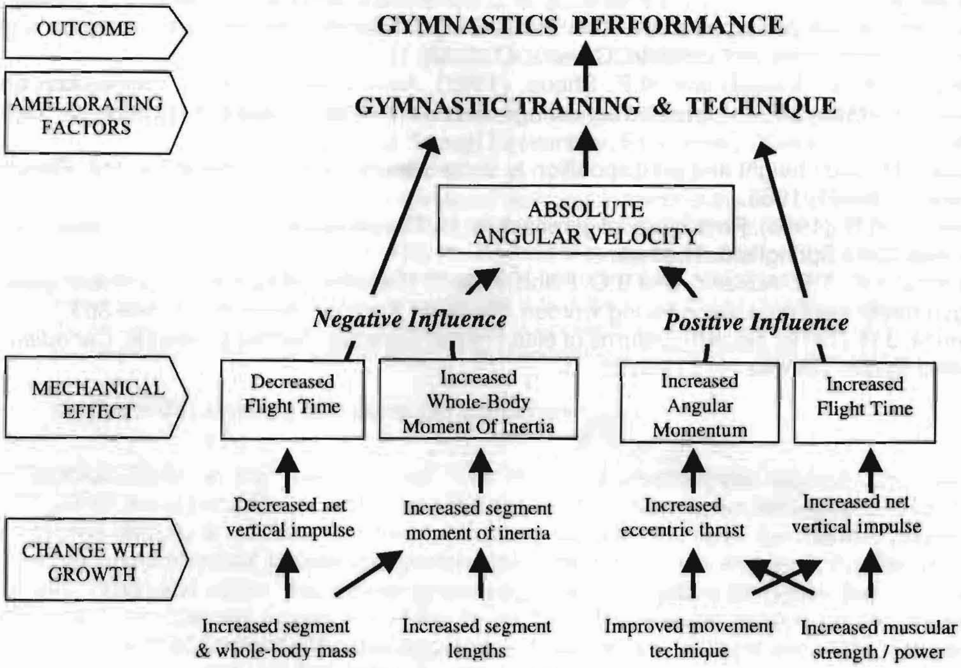

Figure 1 Gymnastic performance model.

It can be seen in Figure 1 that growth changes and their related mechanical effects have been divided into those that have a negative or positive influence on the performance outcome. Negative influences include those factors that contribute to increasing whole-body moment of inertia and thereby, reduce absolute angular velocity during the performance of rotational skills. Increases in body mass also have the potential to reduce flight time during which the gymnast may rotate, and this will have a direct negative effect on performance. Hence, when a gymnast experiences a growth spurt in height, an increase in muscle mass without a concomitant increase in strength, or an increase in her level of adipose tissue, these factors conspire to inhibit performance.

CONCLUSION: The results of this study indicate that gymnasts with the potential to produce high levels of performance on front and back rotations, a twisting jump and a V-sit action at the age of 150 months (or 12.5 years) are smaller in height, mass and sum of skinfolds. Larger gymnasts may be able to produce more power in the lower extremity and greater amounts of angular momentum during the rotations, but these factors were presumably offset by their greater inertia and/or poorer technique, as this advantage was not transferred into better performances. Absolute levels of lower limb strength play an important role in producing leg power but appear to be contraindicated for performance of gymnastic skills at this age, particularly with respect to back rotations. When strength levels were normalised for body mass, however, those gymnasts with high strength/mass ratios also produced better performances in the front rotation and the twisting jump. This relationship was not noted for the back rotation. One may surmise that the successful performance of the back rotation relies more heavily on correct technique and minimising whole body moment of inertia, than on the development of thrust at take-off.

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