INJURY PREDICTION IN FEMALE GYMNASTS

Valerie A. STEELE, MSc, MGSP, DipTP* and J. A. WHITE, PhD**

*District Physiotherapist, St. Luke's Hospital, Little Horton Lane, Bradford, BD5 0NA, Yorks.
**Reader in Human Sciences, West London Institute of Higher Education, Borough Road, Isleworth, TW7 5DU, Middlesex

ABSTRACT

In order to identify injury-proneness in female competitive gymnasts, 20 measures of flexibility, hypermobility, spinal posture and anthropometry were performed on 40 competitive gymnasts and injury scores were derived from the severity and extent of previous gymnastic injury and inherent hypermobility traits. Results were compared between contrasting groups of "low" and "high" injury gymnasts respectively (both N = 10). Nine variables demonstrated significant differences between the "low" and "high" injury risk status groups namely, weight ($p < 0.001$), height ($p < 0.001$), age ($p < 0.001$), mesomorphy ($p < 0.01$), Quetelet Index ($p < 0.01$), shoulder flexion ($p < 0.05$) and lumbar extension ($p < 0.05$), standing lumbar curvature and total peripheral flexibility score (both $p \leq 0.05$).

Multiple regression analysis was applied to determine the relative contribution of these variables to the estimation of injury-proneness as evidenced by previous history of injury and hypermobility traits. Using 9 independent variables, multiple regression yielded a multiple correlation coefficient (R) = 0.840, accounting for over 70% of the observed variance ($R^2 = 0.706$) in injury scores among the total group of gymnasts. However, a subset of five variables, (weight, mesomorphy, standing lumbar curvature, age and height) yielded a multiple correlation coefficient (R) = 0.834 accounting for almost 70% of the observed variance ($R^2 = 0.696$). This was not significantly different from the larger subset.

Using injury classification system of "low", "medium", and "high" risk categories, comparisons were made between predicted and observed injury scores in the respective risk categories. In "high" risk and "low" risk gymnasts, injury scores could be classified correctly with 70% and 79% accuracy respectively, so that relative risk status could be determined from simple physical tests which may be employed by practitioners in the field.

Key words: Injury, Prediction, Female gymnasts.

INTRODUCTION

Female Olympic-style gymnastics has become increasingly popular in the United Kingdom during the past 10-15 years, not least because of spectacular displays on television (Read, 1981). The British Amateur Gymnastics Association estimate that 4 million people now participate in gymnastics in this country in 10,000 gymnastic clubs; at least 75% of the gymnasts are female. Sperryn (1980) has suggested that the popularisation of female gymnastics has encouraged many girls with inappropriate physiques to participate in the sport and suffer resultant injury. Snook (1979), Garrick and Requa (1980) and Lowry and LeVeau (1982) have observed that lower limb injuries were particularly common in gymnasts, with ankle sprain the most prevalent lesion.

Micheli (1979) has commented on the 'current epidemic' of back injuries amongst American female gymnasts. Jackson et al (1976) have reported that the incidence of spondylolysis and spondylolisthesis amongst female gymnasts is four times higher than in female age-matched non-gymnasts. Goldberg (1980) has indicated that the weight bearing function of the arms during gymnastic activities may contribute to the higher incidence of injury that has been reported in relation to the upper limbs (Snook, 1979).

In an injury survey reported by Steele and White (1983, 1985), an injury rate of 1.1 per gymnast was recorded amongst 130 female competitive Olympic-style gymnasts over a 2 year period. Over one third of the gymnasts were not injured, the remainder sustained 1.7 injuries per gymnast. An association between age and rate of injury was noted in the study, as well as a link between the type of activity and injury. Almost 80% of reported injuries resulted in a break in training which varied according to severity of the injury. However, there was no significant relationship between injury rate and menarche.

In view of the findings of the survey, a further investigation was carried out to examine whether high injury risk status gymnasts could be identified using simple physical tests which could be undertaken in the training gymnasium without too much disruption of training.

METHODS

Following test, retest procedures, to establish reliability of the measures selected, a battery of physical tests of hypermobility, peripheral joint flexibility, spinal posture and lumbar extension and anthropometry were performed on 40 female gymnasts whose ages were between 10-21 years. The gymnasts were competitive members of local gymnastic clubs and the zone squad of the North of England.

MEASURES

Hypermobility was assessed using the method of Carter and Wilkinson (1964) modified by Beighton and Horan (1969). Peripheral flexibility was determined using a Leighton flexometer (Leighton, 1955) where possible using the starting positions and motions as described by the American Academy of Orthopaedic Surgeons (1965), however some positions were modified because the instrument is gravity dependent. Peripheral joint movements which were measured included: shoulder flexion with elevation and abduction with elevation, elbow and wrist flexion, hip flexion with knee extension, flexion with knee flexion and abduction, knee flexion, and ankle dorsiflexion with knee flexion/extension. In addition a total peripheral flexibility score was obtained by the summation of all peripheral joint flexibility scores. Thoracic and lumbar curvatures in standing and lumbar extension in prone, were measured using a Loebl hydrogoniometer (Loebl, 1968). Height (cm) and weight (kg) were used to derive the Quetelet index (Keys et al, 1972). Endomorphy, mesomorphy and ectomorphy were determined using the modified somatotype method of Heath and Carter (1967).

Finally, an injury score was devised which categorised injuries in terms of severity whereby high numerical ratings were assigned to most serious injuries and low numerical ratings were assigned to least serious injuries asccording to the classification in Table I with scores also attributed to symptoms associated with hypermobility as described by Beighton et al (1973).

TABLE I

Classification of injuries in conjunction with the derived injury score.

Category		Score
1.	Head injury, fracture/dislocation of major point.	20
2.	Fracture into a joint, dislocation, ligament rupture, muscle rupture.	15
3.	Fracture of a major bone, mild head injury, joint effusion; back, neck over-use injuries (recurrent absence from training in excess of 6 weeks)	10
4.	As above (3) with training absence 3-6 weeks	8
5.	Fracture of small bone, over-use joint injury, ligament sprain, joint, limb and back pain, hypermobility, recurrent tendon injury — over-use, persistent pain. (Absence from training 1-3 weeks).	5
6.	Muscle strain, poor wound healing. (Modified training 3-6 weeks).	3
7.	Muscle contusion, ease of bruising (absence from training less than 1 week).	2
8.	Modified training less than 1 week.	1

RESULTS

From a total of forty gymnasts included in the study, the results of the ten gymnasts with the lowest injury scores were compared with ten gymnasts with the highest injury score using the Student's 't' test to determine whether there were differences between two contrasting levels of injury status on selected anthropometric, flexibility and spinal curvature measures.

It can be observed from Table II that there were significant differences between the two groups on the following measures; age ($p < 0.001$), weight ($p < 0.001$), Quetelet index ($p < 0.01$), lumbar extension (p 0.05) and shoulder flexion ($p < 0.05$). Furthermore, lumbar curvature and total peripheral flexibility also demonstrated differences between the two groups close to the 0.05 level, and were therefore included in the subsequent analyses. These nine measures which showed significant differences between the high and the low injury risk status gymnasts were subjected to further analysis in an attempt to develop a prediction equation which might enable a small battery of variables to be identified which could be used by coaches and physical educationists to isolate high injury risk status girls in terms of gymnastic participation.

A stepwise multiple regression technique was used on the measures obtained on all 40 gymnasts to eliminate those variables which made the least significant contribution to the estimation of injury (as evidenced by previous history of injury and hypermobility traits).

A PDP11 computer was used with an RSTS/E II statistical package for statistical analyses of data. The Stat II programme selects independent variables in the order of decreasing magnitude of their contribution to the total amount of variance observed in the dependent variable, namely the derived injury score. When all nine independent variables were included in the multiple regression, the following values were obtained for injury prediction: variance (R^2) = 0.706, multiple correlation coefficient (R) = 0.840 and standard error of estimate = 11.56. The regression equation for the prediction of injury score from the subset of nine varibles was given by

TABLE II

Comparison of gymnasts with 'low' and 'high' injury status (both N = 10) on selected anthropometric, flexibility and spinal curvature measures.

Item	Low Injury Mean ± S.E.		High Injury Mean ± S.E.	
Anthropometry				
Endomorphy	2.4	0.24	2.9	0.28
Mesomorphy	2.6	0.18	1.8	0.19*
Ectomorphy	2.9	0.37	2.8	0.28
Ponderal Index	13.0	0.13	12.9	0.11
Quetelet Index	17.7	0.54	19.7	0.68*
Height (cm)	135.2	1.62	153.4	2.65**
Weight (kg)	31.8	1.14	46.9	3.02**
Age (years)	10.8	0.33	14.6	0.83**
Injury score	7.3	1.32	51.2	4.98**
Flexibility (degrees)				
Carter Wilkinson score	5.5	0.45	5.7	0.70
Shoulder flexion	253.8	3.13	240.1	4.91†
Shoulder abduction	208.1	3.04	201.8	4.41
Elbow flexion	167.5	3.22	161.9	3.37
Wrist flexion	158.9	5.05	152.4	4.17
Hip flexion, knee extended	129.5	4.47	129.5	4.87
Hip flexion, knee flexed	133.4	7.44	127.6	4.35
Hip abduction	151.8	4.55	140.7	5.26
Knee flexion	152.6	2.44	150.7	1.86
Ankle dorsiflexion, knee flexed	82.5	2.83	79.9	4.54
Ankle dorsiflexion, knee extended	71.8	2.80	73.6	3.62
Total peripheral flexibility	1509.2	15.43	1458.2	24.13
Spinal Curvature (degrees)				
Thoracic posture	24.1	2.84	26.8	3.65
Lumbar posture	18.4	2.77	28.6	4.79
Back extension — lumbar	46.7	2.94	59.8	4.32†

Levels of significance † $p < 0.05$ * $p < 0.01$ ** $p < 0.001$

(R_9) Injury score = 52.150 + (0.970) Weight − (11.566) Mesomorphy + (0.238) Standing Lumbar Curvature + (1.508) Age − (0.339) Height − (0.0339) Total Flexibility Score + (1.866) Quetelet Index − (0.033) Lumbar Extension − (0.011) Shoulder Flexion.

By dropping variables from this equation, it was possible to obtain a subset of five variables (namely, weight, mesomorphy, lumbar curve in standing, age and height) with the following values for injury prediction: variance (R^2) = 0.696, multiple correlation coefficient (R) = 0.834, and standard error of estimate = 11.04.

The regression equation for the prediction of injury score from the subset of five variables was given by

(R_5) Injury Score = 49.656 + (1.661) Weight − (10.111) Mesomorphy + (0.254) Standing Lumbar Curvature + (1.663) Age − (0.646) Height

These results were not significantly different from the set of nine variables and there was no significant change in the standard error or estimate. Furthermore, since there were significant positive relationships between injury score and weight ($p < 0.05$), lumbar curve ($p < 0.05$) and age ($p < 0.001$), as well as significant negative relationships between injury score and mesomorphy ($p < 0.05$) and height ($p < 0.05$) this indicated a direct relationship existed between injury score and weight, lumbar curve and age, whereas an inverse relationship existed between injury score and muscularity and height. It therefore appeared that these five measures might be used to identify injury-prone gymnasts.

Finally, an attempt was made to compare the risk status of the gymnasts with an appropriate injury scale which categorised the injury risk status of gymnasts as low, medium or high in relation to injury scores derived from previous history of injuries. It was then possible to determine how well the estimated injury score, predicted from the regression equation, classified the observed injury score values in the forty gymnasts within the three categories of risk identified.

It can be observed from Table III that there were no significant differences between mean observed and predicted injury scores in both the low and medium injury risk categories. However, in the high risk category the predicted score significantly overestimated the observed score. Further analysis revealed that 14 predicted scores (35%) were misclassified with respect to the categories of observed scores. Ten predicted high risk scores were found in comparison with seven in the observed scores, therefore 70% of the predictions were correct, however, 3 erroneous scores fell into the medium risk category in the observed scores.

TABLE III

Risk Category	Low		Medium		High	
Injury score	0-15		20-35		40+	
Observed score	11.2		27.5		58.0	
(Mean + S.E.)	±1.1		±1.9		±5.7	
		n.s.		n.s.	•	$p < 0.01$
Predicted score	12.2		25.1		47.8	
(Mean + S.E.)	±0.9		±1.6		±3.1	
% correct classification ('predicted' vs 'observed')	79%		55%		70%	

Eleven (27.5%) estimated medium risk scores were found, six of which were misclassified in comparison with the observed injury scores, therefore, 54.5% of the predictions were incorrect. Nineteen low risk scores were found, four of which (21%) were misclassified in comparison with the observed injury scores, therefore, 79% of the predictions were correct. Of the erroneous low scores, none fell into the high risk category. Some of the scores that were misclassified were on the borderline between the high and medium or medium and low risk category numerical bands.

From these results it appears that high or low injury risk status gymnasts can be predicted more accurately than those with medium risk status, however, of the incorrect classifications in the predictions concerning medium risk gymnasts only one observed high risk score was miscategorised. Thus error in prediction was largely confined to low to medium categories and vice versa.

DISCUSSION

It appears that high and low injury risk status gymnasts can be predicted reasonably accurately using a simple set of five variables. The inclusion of lumbar lordosis in the battery of tests supports the contentions of Micheli (1979) and Goldberg (1980) that hyperlordosis in gymnasts predisposes towards back injury. It also appears that girls with relatively poor musculature and of comparatively short stature are particularly prone to injury, especially if they are relatively heavy. Older gymnasts, perhaps not surprisingly, because of prolonged exposure to risk appear more injury prone than younger competitors.

The lack of relationship between extreme flexibility or hypermobility and injury was unexpected because other workers have demonstrated such an association (Bird, 1979; Beighton et al, 1973) and the injury score was biased towards a positive finding. The results of this study indicate that high risk status gymnasts can be identified with reasonable confidence (70%) and it is suggested that a reduction in unnecessary gymnastic injury in young females may be brought about by the implementation of the findings of this study which suggest that:

1. Injury proneness is related to the anthropometric characteristics of young females.
2. Previous history of injury and hypermobility contribute to injury risk status.
3. A simple set of relatively unsophisticated measures including age, height, weight, muscularity and lumbar curvature, can be used to identify individuals who are at risk.
4. Low, medium or high risk category status can be predicted relatively simply and accurately for the purpose of classification of individuals.
5. Based on the assessment above, advice could be given to individuals concerning the nature and degree of involvement in various forms of gymnastics in order to minimise the risk of injury from exposure to the rigours of the ever-increasing physical demands of such a competitive sport.

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