IS JUMPING AND LANDING TECHNIQUE SYMMETRICAL IN FEMALE GYMNASTS?

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The effect of eccentric load (drop height) on lower extremity neuromuscular function and performance was examined in young healthy female gymnasts. Each gymnast (level 4 – 6, n = 15) performed five drop landings and five rebound jumps whilst barefoot from three heights (30, 60, 90 cm) onto two AMTI force platforms (1000 Hz) covered with 6 cm thick carpeted gymnastics mats. Force-time measurements were exported into custom-written software to obtain key measures such as peak force (BW), loading rate (BW/s), and take-off power (Watts/kg). Significant asymmetry was identified in the jumping and landing performance of the gymnasts, however the level of asymmetry observed was not influenced by eccentric load. In conclusion, coaches should aim to achieve safer landing strategies by developing ambidextrous movement in young gymnasts.

KEYWORDS: Gymnastics, Injury, Leg, Kinetics, Symmetry.

INTRODUCTION:

The musculoskeletal control of the lower extremity during the various running, leaping, hopping, jumping and landing skills in gymnastics may have specific performance patterns related to the incidence of lower extremity injury (Bradshaw, Le Rossignol, Lorenzen, & Williams, 2006). The incidence of acute and chronic injuries is a serious problem facing contemporary gymnastics (Sands, 2000). The lower extremity is the most frequently injured site with the ankle joint being especially vulnerable in both landing (48%) and take-off (36%) (Kirialanis, Malliou, Beneka, & Giannakopoulos, 2003). Panzer (1988) revealed that peak vertical ground reaction forces experienced through an individual leg can be as high as 18-times body weight when landing unevenly from double backward somersaults (saltos). Attenuating more force on one leg amplifies the risk to athletes of sustaining chronic overuse injuries and is one of the most common means of injury in other sports or physical activity tasks (Kovacs et al., 1999). This also leaves the contralateral limb weaker and imbalanced, and unable to absorb the high forces associated with the athletic task (Ford, Myer, Smith, & Hewett, 2003).

During competitive and elite level training, gymnasts aim to be able to perform their skills using both their preferred and non preferred limb. Yet it appears logical and natural that once a successful technique has been established, that the preferred leg and hand would be used repeatedly to achieve performance consistency and reliability. Therefore many gymnasts may be exposed to future long term injuries associated with asymmetrical loading patterns. The development of laterality and dominance has been identified as injury precursors in a number of sports, particularly those that produce high impact forces during landings such as basketball or volleyball (Ford, et al., 2003; Sadeghi, Allard, & Duhaime, 1997). Sadeghi (1997) identified that once limb preference is developed, the dominant or preferred limb has been conditioned for mobilization during the movement, while its counterpart acts as a stabilizer. Ford et al (2003) revealed that the dominant leg in female basketballers experienced significantly greater valgus motion at the knee when compared to the non dominant / stabilisation limb. This places the dominant limb at an increased risk for knee injuries such as anterior crucriate ligament strains (Pappas, Sheikhzadeh, Hagins, Nordin, 2007).

Clinical and objective definitions of a functional imbalance are not well established for competitive gymnastics skills. Clinically, most estimate higher risk limbs as those with an asymmetry of more than 10 to 20% (Grace, 1985). Considering this apparent risk to the dominant limb, monitoring levels of power output and loading rates of each individual leg during jumping and landing tasks is a potential tool for identifying “at risk” limbs. Identifying and training to eliminate limb asymmetry in these elite athletes may have a significant impact on the injury rates commonly observed in women's gymnastics. The purpose of current study was to determine the effects of eccentric load, laterality, and dominance on lower extremity asymmetry during jumping and landing tasks in female competitive gymnasts.

METHOD:

Fifteen 9 – 14 year old, level 4 to 6 female artistic gymnasts (height = 1.46, + 8.3 m; mass = 38.8 + 7.4 kg), who were injury free at the time of testing participated in the study. An ISAK Level 2 Anthropometrist measured each gymnast's height, weight, bone lengths, and q-angles. The knees of the gymnasts were also examined by a NATA certified athletic trainer to eliminate or identify any structural or functional abnormalities. Further the handedness and footedness of each gymnast was assessed through a questionnaire and video observations of the gymnast's lead foot during the various jumping and landing tests. All participants, whilst barefoot, executed drop landing and rebound jumps from three heights (5 trials per task and height; 30, 60, 90 cm) onto two AMTI force platforms, covered with 6cm thick gymnastics mats. The force/time curves for each leg were exported from the AMTI BioAnalysis software into a custom-written program to identify the peak ground reaction forces (BW), loading rates (BW/s), leg stiffness (kN/m), and take-off peak power (Watts/kg). Each gymnast's data was pooled according to the highest and lowest values (regardless of which leg this occurred) in order to eliminate negative values within the results and therefore assess movement symmetry. These values created from the individual limb were used to test for statistical significance (differences) between the limbs. The Symmetry Index (SI=(XR – XL) / (0.5 x (XR + XL))) was then used to calculate each gymnast's functional symmetry during landing (Zifchock & Davis, 2005). Functional symmetry refers to the percentage difference between lower limb forces during jumping and landing skills.
A repeated measures, 3x3x2 way mixed design ANOVA (alpha = 0.05) was used to analyse the ground reaction forces of the gymnasts across three age groups (9-10, 11-12, 13-14years old) with a) each subject's left and right leg data (pooled according to 'high' and 'low' leg data) and b) the height of drop jumps (30, 60 and 90 cm). A 3x1 way ANOVA was then used to determine if asymmetry increased with height. Finally a Spearman's rank order correlation was used to analyse the relationship between laterality and dominance. All statistical procedures were performed using SPSS for Windows.

RESULTS AND DISCUSSION:

Statistical asymmetry was established in the overall ground reaction forces for the jumping and landing tasks ($F(1,14) = 20.25$, $p<0.01$). On average over the three heights (30, 60 and 90cm) the 'high' leg experienced forces of 3.46 ± 0.71BW, significantly higher than the 'low' leg (2.69 ± 0.77BW).
The symmetry index (SI) was calculated for each height, with the averages for each individual displayed in Table 1. Only two out of the fifteen gymnasts tested had functionally symmetrical results (less than 10% difference between limbs; Grace, 1985), with an average of 18.14% asymmetry. Asymmetry in ground reaction forces (BW) experienced by the current sample of gymnasts was identified both statistically and functionally according to the criteria established in the methods. The symmetry index (Zifchock & Davis, 2005) indicated that thirteen of the gymnasts had an average asymmetry in loading patterns across the three heights of over 10%. Six of these gymnasts had greater than 20% asymmetry, however a staggering 73% of asymmetry was revealed for one gymnast during the landing trials. Considering the previously outlined clinical values of asymmetry specified by Grace (1985), the majority of the sample are therefore at risk of sustaining (or may soon emerge with) long term chronic overuse injuries. Considering the extreme accuracy and precision required to perform at an elite level, in combination with the long training hours and highly repetitive nature of each element, it is perhaps not surprising that significant functional asymmetry is present, even in this sample of non-elite, but competitive gymnasts. This asymmetry was also present when testing for dominance and laterality (Table 2). Significant limb dominance,

tested through power output during rebound jump take off, was present in all fifteen gymnasts (10 out of the 15 gymnasts were left leg dominant). No significant relationship was found between laterality (footedness/leading leg) and dominance (greatest propulsive power output).

Table 1 - Percentage peak force asymmetry between participants' right and left leg data during drop landings. Negative values indicate that the left leg produced the higher GRF value.

Gymnast	Mean (%)	SD
SP	-13.90	32.741
ED	36.601	24.411
IL	18.039	16.865
GW	36.601	24.411
JM	10.336	22.694
TM	12.103	14.793
EM	25.037	15.359
ER	-15.64	21.262
FR	15.223	11.833
KM	-0.457	8.6938
ML	26.648	23.738
RS	10.655	2.0649
TD	72.997	25.829
ES	1.415	9.5149
VA	36.368	52.746
Average	18.135	
SD	20.464	

Table 2 - Means and standard deviations for dominant and non-dominant rebound data for participants' peak power (Watts/kg) on their dominant and non Dominant leg. Leading and dominant leg preference was also recorded.

Gymnast	Dominant Leg	Laterality (Leading Leg)	Peak Power (Watts/kg) Dominant Leg	Peak Power (Watts/kg) Non Dominant Leg
SP	Right	Left	34.71	32.75
ED	Right	Left	34.96	29.70
IL	Right	Right	34.23	32.61
GW	Left	Right	34.79	32.68
JM	Right	Right	34.71	32.60
TM	Left	Right	35.73	32.55
EM	Left	Right	34.63	32.69
ER	Left	Right	34.59	32.75
FR	Left	Right	35.04	33.73
KM	Left	Right	35.27	32.27
ML	Left	Right	35.04	32.87
RS	Left	Right	35.86	32.82
TD	Right	Right	32.61	32.57
ES	Left	Right	34.45	32.57
VA	Left	Left	35.58	32.51
Average	n/a	n/a	34.81	32.51
SD	n/a	n/a	0.77	0.84

Unexpectedly, the ground reaction force asymmetry observed decreased with landing height (eccentric load) (30cm: 0.76 BW, 28.04%, $p<0.01$; 60cm: 0.84 BW, 24.21%, $p<0.01$; 90cm: 0.70 BW, 16.75%, $p<0.01$). One possible explanation for this trend could be the heights selected for testing. The gymnasts may have deemed the lower 30 and 60cm heights as not challenging or sufficient enough to make an effort to apply the correct landing technique. Alternatively, or in addition, the gymnasts may not have been able to coordinate the synchronous double-footed landing from smaller heights due to the limited time in the air.

CONCLUSION:

Lower extremity movement patterns when controlling the excursion of the centre of mass during the various jumping and landing tasks, commonly employed in gymnastics, leads to clear asymmetrical loading patterns. In order to minimize the effect of the asymmetrical loading patterns, coaches should try to develop some degree of bilateral movement in the training of young gymnasts or, alternatively, include conditioning strategies that counteract these patterns. However the level of eccentric loading (drop height) was not a negative precursor for limb asymmetry. In fact, some degree of eccentric loading appeared beneficial in reducing the effect of asymmetry. Further research that includes a broader range of drop heights should examine whether this trend in the reduction in asymmetrical loading patterns with increased drop height continues for heights greater than 90 cm. These studies should also include a larger sample size in order to more rigorously test the relationship between laterality and dominance.

REFERENCES:

Bradshaw, E. J., Le Rossignol, P., Williams, M., & Lorenzen, C. (2006). Novel insights on lower limb musculoskeletal health and performance in pre-adolescent and adolescent gymnasts. In; Schwameder, H., Strutzenberger, G., Fastenbauer, V., Lindinger, S., Muller, E. (Eds). *XXIV International Symposium on Biomechanics in Sports Proceedings*, University of Salzburg, Salzburg, 14-18 July, 413-417.

Ford, K. R., Myer, G. D., Smith, R. L., & , & Hewett, T. E. (2003). Valgus knee motion during landing in high school female and male basketball players. *Medicine & Science in Sports & Exercise,* **35**(10), 1745-1750.

Grace, T. G. (1985). Muscle imbalance and extremity injury. A perplexing relationship. *Journal of Sports Medicine,* **2**, 77.

Kirialanis, P., Malliou, P., Beneka, A., & Giannakopoulos, K. (2003). Occurrence of acute lower limb injuries in artistic gymnasts in relation to event and exercise phase. *British Journal of Sports Medicine,* **37**(2), 137-139.

Kovacs, I., Tihanyi, J., DeVita, P., Racz, L., Barrier, J., & Hortobagyi, T. (1999). Foot placement modifies kinematics and kinetics during drop jumping. *Medicine and Science in Sports and Exercise,* **31**, 708-716.

Panzer, V. P., Wood, G. A., Bates, T. B., &, & Mason, B. R. (1988). Lower extremity loads in landings of elite gymnasts. In: De Groot, G., Hollander, A.P., Huijing, P.A., Van Ingen Schenau, G.J. (Eds). *Biomechanics XI*, Free University Press, Amsterdam, The Netherlands, 701-704.

Sadeghi, H., Allard, P., & Duhaime, M. (1997). Functional gait asymmetry in able-bodied subjects. *Human Movement Science,* **16**, 243 - 258.

Sands, W. A. (2000). Injury Prevention in Womens Gymnastics. *Sports Medicine,* **30**(5), 359 - 373.

Zifchock, R., &, & Davis, I. (2005). Kinetic asymmetry in female runners with and without retrospective tibial stress fractures. *Medicine & Science in Sports & Exercise*, **37**(5), S346.