©Journal of Sports Science and Medicine (2007) **6**, 93-97
http://www.jssm.org

Research article

Strength performance assessment in a simulated men's gymnastics still rings cross

Jennifer K. Dunlavy [1], William A. Sands [1]✉, Jeni R. McNeal [2], Michael H. Stone [3], Sarah L. Smith [1], Monem Jemni [4] and G. Gregory Haff [5]

[1] Sport Science, U.S Olympic Committee, Colorado Springs, CO, USA, [2] Department PEHR, Eastern Washington University, Cheney, WA, USA, [3] Dept KLSS East Tennessee State University, Johnson City, TN, USA, [4] Anglia Ruskin University, Department of Life Sciences, Cambridge, UK, [5] Division of Exercise Physiology, Department of Human Performance and Applied Exercise Science, West Virginia University School of Medicine, Morgantown, WV, USA

Abstract

Athletes in sports such as the gymnastics who perform the still rings cross position are disadvantaged due to a lack of objective and convenient measurement methods. The gymnastics "cross" is a held isometric strength position considered fundamental to all still rings athletes. The purpose of this investigation was to determine if two small force platforms (FPs) placed on supports to simulate a cross position could demonstrate the fidelity necessary to differentiate between athletes who could perform a cross from those who could not. Ten gymnasts (5 USA Gymnastics, Senior National Team, and 5 Age Group Level Gymnasts) agreed to participate. The five Senior National Team athletes were grouped as cross *Performers*; the Age Group Gymnasts could not successfully perform the cross position and were grouped as cross *Non-Performers*. The two small FPs were first tested for reliability and validity and were then used to obtain a force-time record of a simulated cross position. The simulated cross test consisted of standing between two small force platforms placed on top of large solid gymnastics spotting blocks. The gymnasts attempted to perform a cross position by placing their hands at the center of the FPs and pressing downward with sufficient force that they could remove the support of their feet from the floor. Force-time curves (100 Hz) were obtained and analyzed for the sum of peak and mean arm ground reaction forces. The summed arm forces, mean and peak, were compared to body weight to determine how close the gymnasts came to achieving forces equal to body weight and thus the ability to perform the cross. The mean and peak summed arm forces were able to statistically differentiate between athletes who could perform the cross from those who could not ($p < 0.05$). The force-time curves and small FPs showed sufficient fidelity to differentiate between Performer and Non-Performer groups. This experiment showed that small and inexpensive force platforms may serve as useful adjuncts to athlete performance measurement such as the gymnastics still rings cross.

Key words: Portable force platform, field test.

Introduction

Measurement of sport specific performance is vital to determine progress and potential for important skills. Sports like wrestling, gymnastics, boxing, and diving are presumed to rely heavily on strength but lack specific metrics that permit direct or nearly direct measurement of strength-related skill performance. Sports such as track and field, weightlifting, and powerlifting permit more straightforward and objective measurement of skill performance due to their reliance on measured weights, stop watches, and tape measures. One of the primary problems faced by coaches and athletes in those sports which rely on sport movements that are not easily measurable is that progress and potential are often unknown for a relatively long period of athlete preparation (Sands, et al., 2006a; 2006b). Coaches and athletes in gymnastics are largely constrained by judgment from a coach or judge to assess progress. From a tactical standpoint, this problem can be both frustrating and wasteful. Clearly, coaches would like to know how close an athlete might be to a strength-related skill to capitalize on skill selection or abandonment, and gain an ability to predict when the skill might be ready for inclusion in a competitive routine.

Gymnastics, in particular, suffers from this problem when trying to acquire and perfect difficult strength skills on the still rings. Most of these skills are relatively slow moving or held (i.e., isometric), occur in extraordinary postures, and require months or years of development. The still rings cross (also called an "iron cross," and hereafter simply a "cross") is a difficult skill, requiring shoulder joint stability and astonishing levels of strength in shoulder adduction (Rozin, 1974). There are several means of practicing this particular skill in a modified manner through the use of pulleys, elastic tubing, a partner, or modified apparatus (Bernasconi, et al., 2004; Hesson, 1985; Rozin, 1974). However, none of these training methods is easy to measure. While drills, practiced on a regular basis are the means to improve the athlete's proficiency at the cross and other skills, the qualitative observation of the drills may not serve as an accurate means of assessing progress (Bernasconi et al., 2004; Hesson, 1985; Rozin, 1974; Sands et al., 2006a; Sands and McNeal, 2006). Most of the skills involved in still rings performance involve equaling or overcoming body weight (Cheetham and Mizoguchi, 1987; Hay, 1993; Hesson, 1985). If a means could be developed to simulate still rings strength skills, such as the cross, sport scientists may be able to serve the gymnastics coach and athlete by providing regular feedback regarding progress or lack of progress.

The purpose of this investigation was to determine if two small force platforms (FPs) placed on supports could demonstrate the fidelity necessary to differentiate between athletes who could perform a simulated cross from those who could not and could indicate among the

Received: 10 November 2006 / Accepted: 22 December 2006 / Published (online): 01 March 2007

non-performers how close they might be to performing the desired skill. It was hypothesized that the summed force records of the two FPs would be sufficiently precise to differentiate between cross performers and non-performers.

Methods

Approach to the Problem

Through the use of two portable FPs, two groups of athletes (performers and non-performers), attempted a simulated still rings cross position. The two small FPs were first tested for reliability and validity; having met these criteria, they were then used to measure the vertical forces applied by the gymnasts in a simulated cross. The force-time records were then compared to body weight to determine how closely the gymnasts came to achieving forces equal to body weight and thus the ability to perform the cross.

Subjects

Ten male gymnasts (n = 5 age group level gymnasts and n = 5 Senior US National Team members) volunteered to participate in this study. Appropriate informed consent in writing was obtained in compliance with U.S. Olympic Committee requirements. The characteristics of the athletes are shown in Table 1. All of the senior gymnasts had competed with a cross in the past (Performers); all of the age group gymnasts were unable to perform the skill on the still rings but were at varying levels approaching competence (Non-Perfomers). Data were collected during the first portion of a joint training session at the U.S. Olympic Training Center in Colorado Springs, CO.

Table 1. Subject characteristics

	Age (yrs)	Height (m)	Mass (kg)
Performers	23.8 (1.3)	1.59 (.02)	66.6 (3.5)
Non-Performers	14.0 (1.0)	1.60 (.04)	55.3 (8.6)

Instrumentation

The force platforms (Pasco Scientific, Inc. Roseville, CA, USA, PS-2141) were new to our laboratory and were thus tested for reliability and validity via three methods (Cheetham and Mizoguchi, 1987; Hay, 1993; Hesson, 1985; Major, et al., 1998). The FPs measured 4.5 x 35 x 35 cm and had a mass of 4.0 kg. Both FPs were connected via a short cable to a data logger (GLX, Pasco Scientific, Inc. Roseville, CA, USA, PS-2002).

The first method of calibration/validation assessed the linearity of the force values from the FP. Eleven static weight values, ranging from 244.5 N to 2449.0 N, were placed in the center of the FP. The force output values collected from the FP were correlated to the actual weight values from the previously weighed weight plates used as the calibrated resistances. The correlations for both plates were sufficiently high to indicate linearity of response (both FPs r values = 0.999, both standard errors of estimate <1.5 N).

The second method of FP validation determined whether areas of the surface of the FP suffered from regional dependencies. This test consisted of placing a wooden block (8.5 cm x 9.0 cm x 1.7 cm) in nine randomly ordered positions on the surface of the FP. The nine positions included each corner, the center of each edge, and the center of the FP. At each position, a 243.7 N (24.84 kg) weight plate was placed on top of the wooden block. Fifty raw samples were recorded at 100 Hz at each position. The data were then analyzed using two Oneway Analyses of Variance (ANOVA) assessing regional differences by selected positions on the FP. The ANOVAs and post hoc Tukey HSD procedures revealed that there were statistically significant differences between all regions of FP1 and all regions except one pair in FP2 (FP1, $F(8,377) = 8975.2$, $p < 0.001$; FP2, $F(8,377) = 15492.6$, $p < 0.001$). However, in spite of the statistical differences, the means of each region ranged from 241.2 to 244.5 N on FP1 and 239.6 to 245.3 N on FP2. Moreover, the coefficients of variation ranged from 0.00030 to 0.00042 for FP1 and 0.00032 to 0.00049 for FP2. Thus, the absolute differences between regions, although statistically different, showed low variability and were small in absolute terms (i.e., approximately three to six Newtons).

The third method consisted of placing the portable FP on top of a larger (90 cm x 60 cm x 16 cm) calibrated Kistler (Kistler Instruments Corp, Amherst, NY, USA) FP mounted in the laboratory floor. Simultaneous force data were collected from both FPs at a sampling rate of 1000 Hz during three separate static jumps. Vertical ground reaction forces from the Kistler FP were analyzed using Peak Motus software (Peak Performance Technologies, Inc., Centennial, CO, USA, Version 9.1) and compared to data from the portable FPs. Force-time curves were then overlaid and correlated to determine the strength of a linear relationship between the two types of plates. The correlations over the three trials for both FPs ranged from r = 0.994 to r = 0.999, with standard errors of estimate ranging from 6.6 to 61.5 N).

The results from the three calibration tests showed that the FPs were valid and reasonably linear; therefore the data obtained when testing the athletes were presumed to be accurate in representing ground reaction forces and when comparing one set of forces from one FP to the other.

Simulated cross testing procedures

Athletes were positioned standing between two solid gymnastics spotting blocks (60 x 60 x 120 cm). The two FPs were placed on top of each block with a single piece of 1.27 cm (0.5") plywood between the mat and the FP to create a flat surface. The distance between the two mats was adjusted to accommodate differing arm lengths of the gymnasts. A small wooden block (12.5 cm x 9 cm x 3.5 cm) was placed on the center of each FP to eliminate assistance from the gymnasts' forearms due to contact with support of the forearms on the FP. Each athlete attempted to press downward onto the FP in the simulated cross position and elevate himself off the floor, holding for three or more seconds. Two trials were performed by each athlete. A completed cross was one in which the athlete was able to lift himself off the ground while keeping the arms parallel to the ground, abducted at shoulder height (Figure 1). Sampling was performed from both FPs at 100 Hz and stored in the data logger.

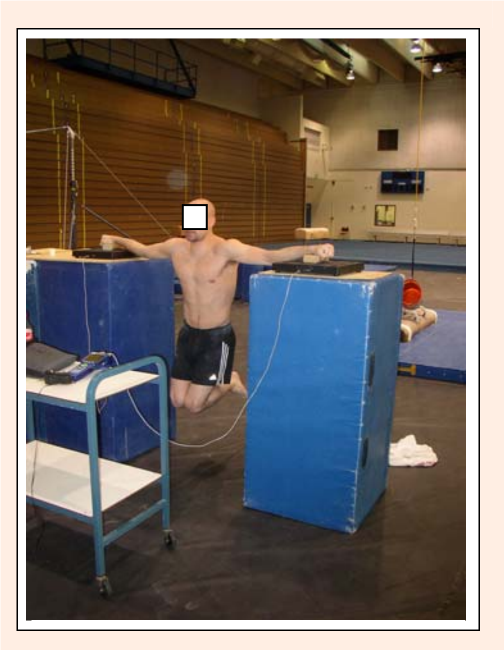

Figure 1. Simulated cross test.

Statistical analyses

Athletes were grouped for analysis purposes based on whether or not they were able to perform a cross on the rings in competition (Performer versus Non-Performer). For each athlete, the single arm forces as measured by the portable FPs were combined to create a summed force trial. A mean value was determined by visual inspection of the force-time curve and identification of one second of relatively stable (by visual inspection of the force-time curve) force production at or near the peak force value. A peak force value was determined by extracting the highest force value during the period of relatively stable force production. Stable force production was considered to be a period of at least one second. The summed arm forces were also compared to body weight through simple subtraction (i.e., the mean of the summed arm forces was subtracted from body weight, and the peak of the summed arm forces was subtracted from body weight). Stability/reliability of the trials data was determined using an intraclass correlation coefficient and a t-test to assess a statistical difference between trials. Reliability analyses of trials data were performed using the methods outlined by Hopkins (a new view of statistics, Internet Society for Sport Science, http://www.sportsci.org/resource/stats/). The mean of the trials data was then used for further analyses (Henry, 1967; Kroll, 1967). Differences between the two groups were assessed using an independent t-test. Statistical significance was set at $p < 0.05$ due to the exploratory nature of this investigation (Huberty and Morris, 1989). Effect size estimates were calculated (Cohen, 1988).

Results

The trials data showed high stability/reliability (intraclass correlation mean of summed arm forces 0.99, and mean of peak arm forces 0.99). No statistically significant difference between trials for either variable was observed, $p > 0.05$. Table 2 shows the means and statistical difference probabilities between the Performer and Non-Performer groups on mean summed arm forces and peak summed arm forces. Figure 2 shows an example of the force-time data obtained. Small discrepancies between left and right arms were noted, but statistical differences between individual arm forces were not observed (all $P > 0.05$). Effect size estimates range from 1.73 to 3.04, all indicating a large effect (Cohen, 1988).

Discussion

The data obtained from this study showed that through the use of two portable FPs, stable/reliable data on the gymnastics cross could be obtained. The results also indicated that the FPs could provide information of sufficient fidelity to distinguish between athletes who could perform the cross from those who could not. In spite of a computer-based literature search on “cross” and “still rings,” only a few studies could be located. None of the studies dealt with the measurement of forces exerted by the athlete in the cross position. One needs to go back to 1985 to find a lay article on learning a cross, but with no indication of how to measure progress (Hesson, 1985).

As shown in Figure 2, the data available from this type of analysis can permit the scientist and coach to assess both cross potential and arm adduction strength symmetry. The current near epidemic of shoulder injuries among America’s best male gymnasts (personal communication, Dennis McIntyre, USA Gymnastics, Men’s Program Director) amplifies the need for shoulder strength and strength symmetry assessment (Cerulli, et al., 1998; Mitchell, 1988). Attempts at reducing upper extremity stresses have been applied. For example, the “herdos” is a device designed for use in teaching the cross by reducing some of the stress on the elbows of the gymnast by moving the force application nearer to the elbow along the forearm. Elbow problems due to the cross are relatively common (Caine et al., 1996; Mitchell, 1988). While the herdos does simulate the cross, it also places a higher emphasis on the teres major muscle than

Table 2. Simulated Cross Test results.

Variables	Group	Mean (±SD)	p
Mean – Sum of Mean Arm Forces	Performers	654.7 (35.4)	.007
	Non-Performers	306.0 (201.4)	
Mean – Sum of Peak Arm Forces	Performers	676.0 (41.5)	.005
	Non-Performers	330.3 (213.5)	
Mean – Sum of Mean Arm Forces Minus BW	Performers	-4.0 (5.8)	.019
	Non-Performers	-232.5 (134.4)	
Mean – Sum of Peak Arm Forces Minus BW	Performers	29.3 (10.3)	.007
	Non-Performers	-208.1 (146.2	

Abbreviation: BW = body weight.

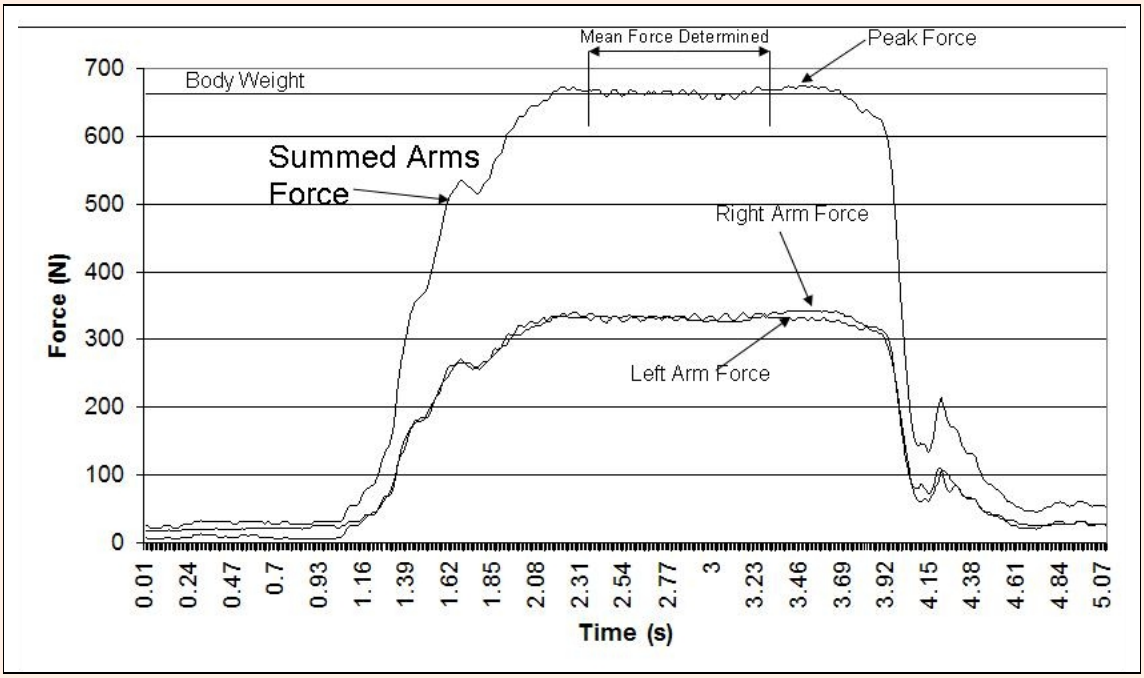

Figure 2. Example data simulated Cross Test.

performing the actual cross (Bernasconi et al., 2004). Therefore, the muscles being trained for the cross are not necessarily emphasized to the same extent when using simulated apparatus as they would be for the actual cross performance.

Future research using this simulated cross approach should also include an electromyographic analysis. Moreover, future investigations should include longitudinal assessment of the progress of the gymnast in learning to determine if the force-time data from a simulated cross using portable FPs can predict when the gymnast will be able to summon the strength and skill to perform a real cross on the still rings for the first time.

Conclusion

Skill simulators, especially those that also provide measurement, can be useful to coaches and athletes in training and assessment of progress. The small portable force platforms described here appear to be useful for determining the progress of a gymnastics still rings cross.

References

Bernasconi, S., Tordi, N., Parratte, B., Rouillon, J.D. and Monnier, G. (2004) Surface electromyography of nine shoulder muscles in two iron cross conditions in gymnastics. *Journal of Sports Medicine and Physical Fitness* **44,** 240-245.

Caine, C.G., Caine, D.J. and Lindner, K.J. (1996) The epidemiologic approach to sports injuries. In: *Epidemiology of sports injuries*. Eds: Caine, D.J., Caine, C.G. and Lindner, K.J. Human Kinetics, Champaign, IL. 1-13.

Cerulli, G., Caraffa, A., Ragusa, F. and Pannacci, M. (1998) A biomechanical study of shoulder pain in elite gymnasts. *ISBS'98 XVI International Symposium on Biomechanics in Sports. University of Konstanz, Konstanz, Germany.* Eds: Riehle, H.J. and Vieten, M.M. 308-310.

Cheetham, P.J. and Mizoguchi, H. (1987) The gymnast on rings - a study of forces. *SOMA* **2,** 30-35.

Cohen, J. (1988) *Statistical power analysis for the behavioral sciences*. Lawrence Erlbaum Associates, Hillsdale, NJ.

Hay, J.G. (1993) *The biomechanics of sports techniques*. Prentice Hall, Englewood Cliffs, NJ.

Henry, F.M. (1967) "Best" versus "Average" individual scores. *The Research Quarterly* **38,** 317-320.

Hesson, J. (1985) How to learn an Iron Cross (shoulder joint adduction). *International Gymnast* **October,** 40-41.

Huberty, C.J. and Morris, J.D. (1989) Multivariate analysis versus multiple univariate analyses. *Psychological Bulletin* **105,** 302-308.

Kroll, W. (1967) Reliability theory and research decision in selection of a criterion score. *The Research Quarterly* **38,** 412-419.

Major, J.A., Sands, W.A., McNeal, J.R., Paine, D.D. and Kipp, R. (1998) Design, construction, and validation of a portable one-dimensional force platform. *Journal of Strength and Conditioning Research* **12,** 37-41.

Mitchell, W. (1988) The upper extremity in gymnastics. *Forum* **5(12),** 1-2.

Rozin, E.U. (1974) The influence of anthropometric parameters on successful learning in gymnastics. *Yessis Review of Soviet Physical Education and Sports* **9,** 16-21.

Sands, W.A., Dunlavy, J.K., Smith, S.L., Stone, M.H. and McNeal, J.R. (2006a) Understanding and training the Maltese. *Technique* **26(5),** 6-9.

Sands, W.A. and McNeal, J.R. (2006) The inverted cross: a case study with training implications. *Technique* **26(2),** 22-23.

Sands, W.A., Stone, M.H., McNeal, J.R., Smith, S.L., Jemni, M., Dunlavy, J.K., Mizushima, K. and Haff, G.G. (2006b) *XXIV International Symposium on Biomechanics in Sports.* International Society for Biomechanics in Sports, Salzburg, Austria. 404-407.

AUTHORS BIOGRAPHY

Jennifer K. DUNLAVY
Employment
Sport Science, US Olympic Committee, Colorado Springs, CO, USA
Degree
Ms
Research interests
Determining more efficient means of assessing training status and progression.
E-mail: jkdunlavy@hotmail.com

William A. SANDS
Employment
Director of the Athlete Recovery Center, Sport Biomechanist, and Senior Physiologist at the US Olympic Committee.
Degree
PhD
Research interests
Gymnastics, biomechanics, physiology
E-mail: bill.sands@usoc.org

Jeni R. McNEAL
Employment
Associate Professor in Kinesiology at Eastern Washington University. The vice-chair of research for the U.S. Elite Coaches Association for Women's Gymnastics and a member of the Performance Enhancement Team for U.S. Diving.
Degree
PhD
Research interests
Performance aspects of acrobatic sports.
E-mail: jeni_mcneal@hotmail.com

Michael H. STONE
Employment
the exercise and Sports Science Laboratory Director at East Tennessee State University.
Degree
PhD
Research interests
Adaptations to strength/power training.
E-mail: stonem@etsu.edu

Sarah L. SMITH
Employment
Sport Biomechanist at the United States Olympic Committee.
Degree
PhD
Research interests
Sports biomechanics.
E-mail: sarah.smith@usoc.org

Monem JEMNI
Employment
Lecturer, Anglia Ruskin University, Sport Science Department, Cambridge, UK
Degree
PhD
Research interests
Gymnastics.
E-mail: m.jemni@anglia.ac.uk

G. Gregory HAFF
Employment
Assistant professor in the Division of Exercise Physiology in the Department of Human Performance and Applied Exercise Physiology at the West Virginia School of Medicine in Morgantown, West Virginia.
Degrees
PhD, CSCS*D
Research interests
Exercise physiology.
E-mail: ghaff@hsc.wvu.edu

Key points

- Gymnastics skills often suffer from the inability to determine a useful field metric.
- Small portable force platforms were assessed for validity, reliability and the measurement of a simulated gymnastics still rings cross..
- The force platforms and measurement procedures were shown to identify and classify those who can do a still rings cross from those who cannot.

✉ **William A. Sands, PhD**
Head – Sport Biomechanics and Engineering, United States Olympic Committee, Sport Science, 1 Olympic Plaza, Colorado Springs, CO 80909-5760, USA