INFLUENCE OF A SUSPENDED AID ON WRIST LOADING PATTERN DURING CIRCLES ON POMMEL HORSE

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The aim of this study was to investigate the influence of a suspended aid on the reaction forces during a basic skill on pommel horse. Twenty gymnasts performed three sets of 10 circles with and without a suspended aid on a pommel horse under which two force plates were set. The results confirmed that the suspended aid could reduce the magnitude of the pommel reaction forces during circles while maintaining the general loading pattern. The average force, peak force, and impact force were all reduced by the use of the aid. A suspended aid may be useful for all levels of gymnasts who would like to practice pommel horse exercises with reduced wrist loading for a purpose such as a progression for learning a new skill, control of training volume or rehabilitation.

KEY WORDS: gymnastics, body weight support, force, wrist injuries, training aid.

INTRODUCTION: Repetitive stress from the pommel horse routines seems most related to wrist overuse injuries in men's artistic gymnastics (Gabel, 1998). Although many risk factors are involved with overuse injuries, biomechanical risk factors can be associated with reaction forces from the pommel horse (pommel reaction forces) as an analogy to ground reaction forces for running injuries.

The pommel reaction forces during "circles," one of the most basic skills on pommel horse (Figure 1 top), have been documented in multiple studies (Fujihara et al., 2009; Markolf et al., 1990). According to these studies, the loads on the wrists are comparable with those on the ankles during walking whereas the durability is not comparable in terms of their anatomical structures.

One of the most common training aids, a suspended aid, might provide gymnasts with an opportunity to practice pommel horse exercises with less stress on their wrists. With this type of aid, a gymnast's feet are suspended from above so that his legs are supported (Figure 1 bottom). A suspended aid is most commonly used for introducing circles to a beginner, but it might be useful to reduce the wrist loading because it does not push down but rather pulls up on a gymnast.

The aim of this study was to examine the influence of using a suspended aid particularly on the pommel reaction forces during circles. The main question was how much loads might be reduced in the upper extremities and how the wrist-loading patterns might be affected by the use of an aid.

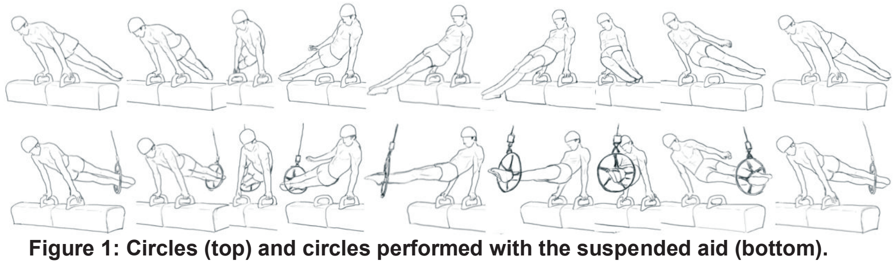

Figure 1: Circles (top) and circles performed with the suspended aid (bottom).

METHODS: Data collection: A no-leg pommel horse was cut in half, and each half was fixed to a force plate (AMTI, OR6-6-4000). A suspended aid was constructed with a rotator twisting belt. The inside of the ring frame was arranged so that it fitted to the various sizes of the gymnasts' legs (Figure 2). The cable suspending the aid was attached to a swivel on a beam running 4.1 m above the surface of the pommel horse.

Twenty gymnasts performed three sets of 10 circles on the pommel horse in two conditions: with and without the suspended aid. They had 9.9 ± 3.5 years of experience in competitive gymnastics, trained 20.3 ± 3.4 hours per week at the time of data collection, and were capable of performing 20 consecutive circles on a pommel horse. Either condition was randomly assigned for the first three sets of 10 circles, and then the gymnasts performed another three sets of 10 circles in the other condition. The force data were recorded at 1000 Hz. Our local ethics committee approved all experimental protocols. Prior to the experiment, each gymnast provided written informed consent.

Figure 2: The suspended aid used for this study.

Data analysis: The force data were smoothed at 100 Hz using a forth-order Butterworth digital filter and scaled to each gymnast's body mass (BM). Loading time histories, impact and active peak forces, average forces, and the loading rate were analyzed. An impact peak was defined as the maximal xyz-resultant peak value that occurred within 50 ms after a contact (Nigg, 2000). Loading rate was computed by the regression maximum slope method with three points (Woodard et al., 1999). Seven circles out of 10 (3^{rd}-9^{th}) were used so that the mean data for each variable were computed from the data of 21 circles (3 x 7 circles). Note that all discrete values were found for each single circle then averaged. To examine the influence of using the aid, circles with no aid were compared to circles with the aid. To find the variables that showed practical significance, the dominance statistic (Cliff's *d*, Cliff, 1993), was computed as an effect size measure for each comparison. The Wilcoxon signed-rank test was performed for eight discrete variables with the Holm's correction (Knudson, 2009). The experiment-wise error rate was set at $p < 0.025$, so after the Holm's correction, a critical P value for each test ranged from 0.003 to 0.025. All statistical significance tests were performed using PASW Statistics 18.0 (SPSS Inc., 2009).

RESULTS AND DISCUSSION: The influence of the aid on the pommel reaction forces: The use of the aid clearly decreased the magnitude of the pommel reaction forces in all aspects, namely, the impact peak, the loading rate, the active peak, and the average forces. This study showed that 25 - 35% active-peak attenuation and 22 - 25% average-force reduction resulted from the use of the aid. Also, the impact peaks and the loading rates decreased to approximately 50% on average. We found large variability for the impact peak and the loading rate between the gymnasts and even within a gymnast. However, all gymnasts experienced smaller impact peaks with the aid compared to their trials without the aid.

Table 1: The comparison of force variables between circles with the aid and circles without the aid.

Variables		With the aid	No aid	Difference	Cliff's *d*	*Z*-statistic (*P*)
Active peak	L	0.85 ± 0.06	1.13 ± 0.09	- 0.28	- 0.99	- 3.92 (0.00009)*
	R	0.86 ± 0.08	1.33 ± 0.09	- 0.47	- 1.00	- 3.92 (0.00009)*
Average force	L	0.59 ± 0.05	0.76 ± 0.04	- 0.17	- 1.00	- 3.92 (0.00009)*
	R	0.59 ± 0.05	0.78 ± 0.04	- 0.19	- 1.00	- 3.92 (0.00009)*
Impact peak	L	0.22 ± 0.09	0.47 ± 0.10	- 0.25	- 0.92	- 3.92 (0.00009)*
	R	0.37 ± 0.22	0.82 ± 0.31	- 0.45	- 0.75	- 3.88 (0.00010)*
Loading rate	L	16.0 ± 6.2	32.6 ± 15.8	- 16.6	- 0.71	- 3.82 (0.00013)*
	R	15.2 ± 5.7	24.2 ± 7.6	- 9.0	- 0.70	- 3.50 (0.00046)*

The letters "L" and "R" indicate a left hand and right hand, respectively. These hands are for counterclockwise circles as shown in Figure 1. The values are shown as (mean ± standard deviation). The unit is BW.
The stars next to the *p*-values indicate the statistical significance.

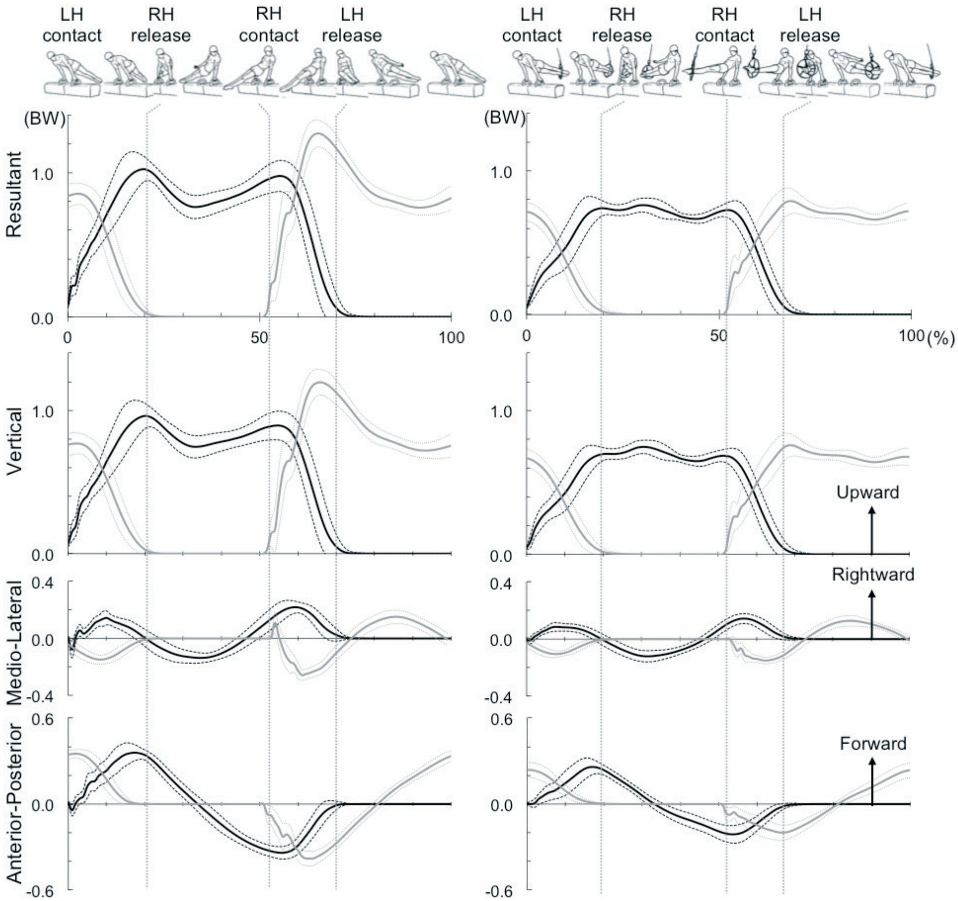

Figure 3: The pommel reaction forces on the left (black) and right (grey) hands during circles without the aid (left column) and circles with the aid (right column). The solid lines indicate the average of 20 gymnasts, and the broken lines indicate the ±1 standard deviation from the average. Twenty-one circles were averaged for each gymnast's data; therefore, the graphs show the average of 420 circles (21 × 20). Note that both impact- and active-peak values were attenuated due to the time normalizing and averaging processes.

Despite the reduction in magnitude, the time-normalized force curves remained similar in shape particularly in the horizontal components (Figure 3). Fujihara et al. (2009) confirmed that the horizontal components of the pommel reaction forces were responsible for the horizontal rotation of the mass centre during circles. This suggests that gymnasts can produce a similar mass-centre rotation on the horizontal plane even with the aid.

The implication and limitation of the study: There are several advantages to having a training option in which gymnasts experience a similar loading pattern on the upper extremities yet with smaller magnitude. A beginner would benefit from such a progressive loading mechanism for developing upper-extremity strength and coordination for learning circles. Also, less loading magnitude can help gymnasts practice more with less risk for overuse injuries. Elite gymnasts often train more than 20 hours per week, and several hundreds of circles are expected during daily pommel horse training. Therefore, not only

beginners but also advanced gymnasts would benefit from having such a training option to control their training volume as well as to learn more advanced skills beyond circles. The aid can also be useful for gymnasts on recoveries from upper-extremity injuries. The idea is similar to a body-weight-support harness used for walking rehabilitation (e.g. Norman et al., 1995).
Several limitations of this study should be considered for appropriate data interpretation. First, the values of impact peak and loading rate can remarkably vary depending on the dynamical situation for a circle, individual re-grasping technique, the definition of an impact peak, experimental setup, and data-processing procedure. Second, the results were based on only one type of suspended aids. With a different variation of a suspended aid, the amount of force reduction might vary. Finally, no assessment was made from a motor-learning perspective; therefore, whether or not the aid would actually help gymnasts learn circles was not assessed in this study.

CONCLUSIONS: Pommel horse exercises are the biggest culprit for chronic wrist pain in men's artistic gymnastics. The negative impact of wrist problems is not limited to pommel horse exercises but affects the various skills of other events. This study clearly showed that a suspended aid could reduce the magnitude of the pommel reaction forces during circles while maintaining the general loading pattern. Having such a training variation should be beneficial for all levels of gymnasts. Together with following studies focused on a more technical aspect from kinematic and kinetic viewpoints, the potentials and limitations of a suspended aid, a worldwide-well-known training aid, should be better understood to create a safer and more effective training protocol.

REFERENCES:

Cliff, N. (1993). Dominance statistics: Ordinal analyses to answer ordinal questions. *Psychological Bulletin, 114*(3), 494.

Fujihara, T., Fuchimoto, T., & Gervais, P. (2009). Biomechanical analysis of circles on pommel horse. *Sports Biomechanics, 8*(1), 22-38.

Gabel, G. T. (1998). Gymnastic wrist injuries. *Clinics in sports medicine, 17*(3), 611-621.

Hreljac, A. (2004). Impact and overuse injuries in runners. *Medicine & Science in Sports & Exercise, 36*(5), 845-849.

Karácsony, I., & Čuk, I. (1998). *Pommel horse exercises: methods, ideas, curiosities, history*. Ljubljana: University of Ljubljana and Hungarian Gymnastics Federation.

Knudson, D. (2009). Significant and meaningful effects in sports biomechanics research. *Sports Biomechanics, 8*(1), 96-104.

Markolf, K. L., Shapiro, M. S., Mandelbaum, B. R., & Teurlings, L. (1990). Wrist loading patterns during pommel horse exercises. *Journal of Biomechanics, 23*(10), 1001-1011.

Nigg, B. M. (2000). Forces acting on and in the human body. In B. M. Nigg, B. R. MacIntosh & J. Mester (Eds.), *Biomechanics and biology of movement* (pp. 253-268). Champaign, IL: Human Kinetics.

Norman, K. E., Pepin, A., Ladouceur, M., & Barbeau, H. (1995). A treadmill apparatus and harness support for evaluation and rehabilitation of gait. *Archives of Physical Medicine & Rehabilitation, 76*(8), 772-778.

Woodard, C. M., James, M. K., & Messier, S. P. (1999). Computational methods used in the determination of loading rate: experimental and clinical implications. *Journal of Applied Biomechanics, 15*(4), 404-417.

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