STABILISING THE HIP AND PELVIS DURING RUNNING: IS THERE AN EXPLOSIVE SOLUTION FOR UNINJURED ATHLETES?

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We compared the effectiveness of a conventional (slow-controlled) to a novel (explosive) eight week training program designed to improve lateral stability at the pelvis and hip during a running task. Parameters included: frontal-plane kinematics (500 Hz); electromyography recordings (1000 Hz) of gluteus medius (GM) and tensor fasciae latae (both sides); and oxygen kinetics. The groups were matched for hip and pelvis kinematics. After the training, reduction in peak angles at the hip and pelvis improved compared to baseline data regardless of group membership. Differences between groups were also found. Only the explosively trained group displayed changed GM onset times, where GM activation occurred earlier prior to ground contact when running. These differences in GM onsets support the notion of specific training adaptations, and the mechanism for hip and pelvis stability may not be the same for both groups. In addition, only the explosive group improved running performance (economy) further justifying this method of prescription.

KEY WORDS: Pelvic obliquity, Hip adduction, Running economy, Electromyography.

INTRODUCTION: Unstable frontal plane kinematics at the pelvis and hip during running have been linked with chronic/overuse injuries (e.g., Noehren, Davis & Hamill, 2007). The primary muscle used for lateral stability is the gluteus medius (GM). It prevents contra-lateral pelvic drop, and eccentrically controls hip adduction during the absorption phase. When instability is observed, the exercises prescribed to reduce joint amplitudes are based on increasing GM strength and control (e.g., Presswood, Cronin, Keogh & Whatman, 2008). Taken from a rehabilitation context, where patients are less mobile and experiencing pain, these exercises begin with non weight-bearing activities, and progress to “functional” weight-bearing activities. This conventional approach seems inappropriate for athletes. Generally, athletes who display instability at the hip and/or pelvis are pain free, moving freely and are only at risk of a chronic injury. Since, limited carryover above and below training velocity is expected from these slow-controlled exercises (Fleck & Kraemer, 1997), we consider this training less effective than more explosive exercises. We contend that explosive-strength exercises offer additional benefits to the athlete who is unstable but injury free. Evidence for this notion is currently not available, highlighting the purpose of this investigation.

METHODS: Participants: State Institute netballers (n = 8, age = 20.1 ± 2.1 years, stature = 178.2 ± 4.1 cm, mass = 69.1 ± 4.7 kg) all injury free took part in the study. Due to illness (unrelated to the study), one participant dropped out before the final trial. The testing protocol was repeated on three occasions over a period of 11 weeks. In week 1, baseline testing was performed, followed one week later by pre-intervention testing. These data were used to establish test-retest reliability. After an eight week training intervention, a final testing session was completed.

Data collection: At the start of each testing session anthropometric measures (Norton et al., 1996) were taken and used to estimate joint centres. Preparation of muscle sites and electromyography (EMG) electrode placement followed the Surface Electromyography for the Non-Invasive Assessment of Muscles initiative (Hermens, Freriks, Disselhorst-Klug & Rau, 1999). Bipolar Ag/AgCl surface electrodes (Bortec Bipole electrodes, Bortec Biomedical Ltd, Calgary, Canada) were placed on muscle sites, and the sacroiliac joint was used for the ground electrode. EMG data sampled at 1000 Hz was normalised against the participant’s 100% maximum voluntary isometric contractions (MVIC) for the corresponding muscle. The

MVIC protocol is described elsewhere by Carcia and Martin (2007). EMG signals were processed and filtered using root mean square (RMS) smoothing (constant time windows = 100ms for MVIC and 25ms for running), a high pass filter with a 10 Hz cut-off and a low pass filter with 500 Hz cut-off. Retro-reflective ball markers (14mm diameter) identified the landmarks for the Plug-in-Gait lower limb marker set. Running kinematics was captured (500 Hz) using six cameras (model MX 13+) and Vicon MX motion analysis system (Vicon, Oxford, United Kingdom) with Vicon Nexus (version 1.3) software. All kinematic data were filtered using a Woltring filtering routine (Woltring, 1995). A metabolic cart (MOXUS Modular VO_2 system, MAX II Metabolic System, AEI Technologies, Pittsburgh, USA) was used to determine running economy (ml/kg/min). All running was performed on a high powered treadmill (H/P/Cosmos Sports and Medical GmbH, Pulsar 3p 4.0, Amsporplatz, Nussdorf-Traunstein, Germany) set to a 1% grade to reflect the energy cost of outdoor running. The running protocol included four minute stages at 8, 10, 12 and 14km/h. Data was collected during the final minute of running at the 10, 12 and 14km/h stages, including 3-D kinematics, EMG activity of the GM and tensor fasciae latae (TFL) muscles, and VO_2 kinetics for the calculation of running economy. Participants were matched based on the degree of frontal plane pelvic and hip instability demonstrated in the second testing session and assigned an eight-week training intervention designed to improve lateral hip/pelvic stability. Group 1 performed slow/controlled resistance exercises (Table 1). Group 2 performed explosive exercises (Table 2). Progressive overload was achieved for each exercise through either an increases in volume or intensity, or by increasing the complexity of the exercise performed. During the eight week training intervention period an average of 11 of the 16 planned training sessions were completed.

Table 1: Slow/controlled training intervention.

Exercise		Week 1	Week 2	Week 3	Week 4
1	Lying straight leg hip abduction	2 x 8	3 x 8	3 x 10	3 x 12
2	Split squats (static lunges)	2 x 8	3 x 8	3 x 10	3 x 12
3	Pelvic drops	2 x 8	3 x 8	3 x 10	3 x 12
		Week 5	**Week 6**	**Week 7**	**Week 8**
1	Reformer bed hip abduction (standing)	2 x 8	3 x 8	3 x 10	3 x 12
2	Single leg squats	2 x 8	3 x 8	3 x 10	3 x 12
3	Lateral lunges	2 x 8	3 x 8	3 x 10	3 x 12

Table 2: Explosive training intervention.

Exercise		Week 1	Week 2	Week 3	Week 4
1	Plyometric forward hops on gymnastics mat	2 x 6	2 x 6	3 x 6	4 x 6
2	Trampoline single leg hops (hands overhead*)	3 x 8	3 x 10	3 x 8	3 x 10
3	Split jerks (alternate forward leg)	4 x 4	4 x 4	4 x 4	4 x 4
		Week 5	**Week 6**	**Week 7**	**Week 8**
1	Plyometric lateral hops on floor (hip abduction)	2 x 6	2 x 6	3 x 6	4 x 6
2	Trampoline single leg hops (hands overhead*)	3 x 8	3 x 10	3 x 8	3 x 10
3	Split jerks (alternate forward leg)	4 x 4	4 x 4	4 x 4	4 x 4

* = overhead plate hold: 2.5kg in weeks 3-4; 5.0kg in weeks 5-6; 10.0kg in weeks 7-8

Data Analysis: Data analyses were performed using SPSS 15.0 for windows (Chicago, Illinois). Reliability using all participants' data (n=8) was assessed using dependent t-tests, typical error of measurement (TEM), coefficient of variation (CV%) and smallest worthwhile change (SWC). Non-parametric equivalents of *t*-tests were used to assess the effect of training and also group differences. A Wilcoxon signed-rank test, assessed the difference from pre- to post-intervention scores for the whole sample (n=7). A Mann-Whitney test, assessed group differences in baseline data and then group differences for changes in test variables from test 1 to test 2. Finally, corresponding effect size (r), median, minimum and maximum scores were also presented.

RESULTS: Reliability: At 12 and 14 km/h pace, test-retest reliability for all parameters was better than at 10 km/h. This was most evident for the EMG variables; TEM and CV scores were consistently higher when measured at 10 km/h (CV range 10.8 – 31.5%) compared to 12 km/h (5.4 – 23.8%) and 14 km/h (4.6 – 24.2%). Analysis was therefore performed on data collected at 12 and 14 km/h running velocities only. Despite showing CV scores > 5%, TEM for the EMG muscle onset time variables were judged as practically acceptable (SWC ranged between 1 to 4 ms). The TEM for the GM and TFL muscle onset variables, for example, ranged from just 5 to 8 ms.

Training effects: All kinematic data sets, except peak pelvic obliquity angle on the dominant side ($P = 0.078$, $r = 0.50$) decreased from pre- to post-intervention ($P = 0.016$-0.047, $r = 0.54$-0.63).

Group differences: Baseline scores did not differ between groups for all variables ($P > 0.050$). In addition, no group differences for the change in scores in all kinematic variables were found. The explosive trained group did, however, display greater change in the onset of GM activation compared to the slow-controlled trained group at both 12 and 14 km/h, and on both sides. At 12 km/h, the change in dominant side GM muscle onset time was different ($P=0.057$, $r=0.80$), where the explosive trained group demonstrated a 22 (20 to 35) ms increase in muscle activation time prior to ground contact, compared to the slow-controlled group's median of 3 (1 to 6) ms. Similarly, non-dominant GM muscle activation time was different between groups ($P=0.057$, $r=0.80$). Again, a greater change in muscle onset time was found in the explosive trained group with a 16 (10 to 45) ms increase in activation time prior to ground contact, compared to the slow-controlled group's median of 0 (-1 to 2) ms, which resembled no change. Similar between group differences for GM onset times were found at 14 km/h (Figure 1). Running economy also improved from pre- to post- intervention in the explosive trained group, whilst a decrement was observed in two of the slow-controlled group (Figure 1). The changes in running economy were different between groups at both12 km/h ($P= 0.057$, $r = 0.80$) and 14 km/h ($P=0.057$, $r=0.80$) velocities.

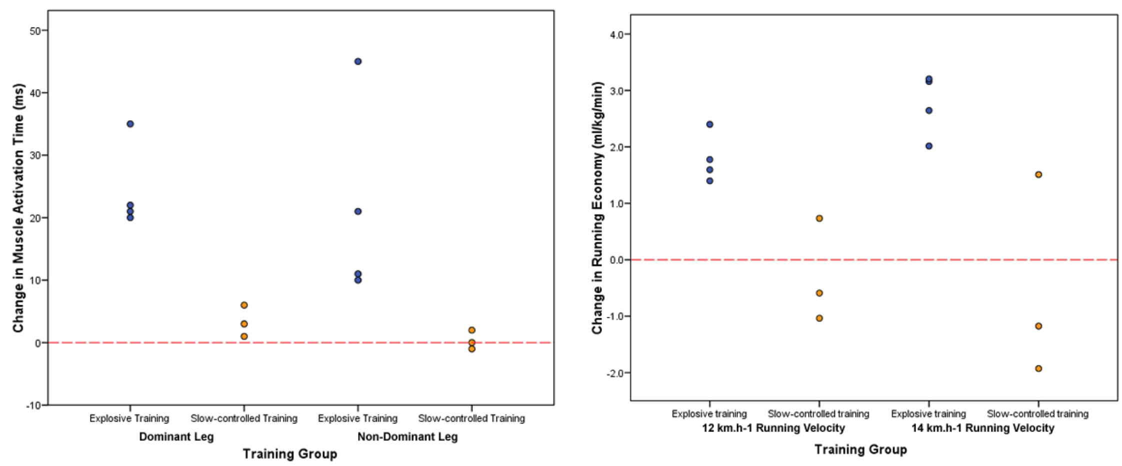

Figure 1: Group differences for changes in GM muscle onset at 14 km/h (left pane) and changes in running economy at 12 km/h and 14 km/h (right pane).

DISCUSSION: Prescribing exercises that encompassed 'specific' muscle contraction types, contraction velocities, ground contact times and loading to running improved hip and pelvis stability, but also running economy. Stability at the pelvis and hip were improved in both groups, however, the differences in GM onsets suggest that the mechanisms may differ and are specific to training. The change in GM pre-activity in explosive the trained group only was interpreted as an improvement in feed-forward neuromuscular control and possible muscle architectural changes in response to explosive training. By increasing the time GM is active before ground contact, joints become stiffer, taking advantage of the force-curve in anticipation of ground contact (Beard et al., 1993). Similar positive adaptations have been reported following plyometric training, but for landing tasks preceding a jump and not running (Myer, Ford, McLean & Hewett, 2006). Furthermore, all explosive group members increased economy, whilst, a decrement was observed in two out of three slow-controlled group members. Increased stiffness of the muscle-tendon system, and the resultant increase in elastic energy storage and return in the muscles of the trunk and legs may explain these improvements. Stiffer, less compliant muscles in the legs and lower trunk can enhance running economy via increased energy from elastic storage and return, which has no additional oxygen cost (Kyrolainen, Belli & Komi, 2001). Explosive-strength training increases the stiffness of the muscle-tendon system in this way in response to exposure of high eccentric loading and maximal concentric muscle contractions (Kyrolainen et al., 2001).

CONCLUSION: These findings support the notion that athletes, who are injury free, but at risk of chronic running related injuries, may benefit more from ‘specific’ explosive-strength exercises compared to the conventional (rehabilitation) approach. In particular, for coaches, where time available to prepare athletes is limited, eight weeks of explosive training was found to decrease hip and pelvis joint angles and also improve economy. The conventional approach of slow-controlled training only improved kinematics and not economy. Limited by sample size, the findings from this study warrant further investigation.

REFERENCES:

Beard, D. J., Kyberd, P. J., Fergusson, C. M., & Dodd, C. A. (1993). Proprioception after rupture of the anterior cruciate ligament. An objective indication of the need for surgery? *Journal of Bone and Joint Surgery, 75*, 311-315.

Carcia, C., & Martin, R. (2007). The influence of gender on gluteus medius activity during a drop jump. *Physical Therapy is Sport, 8*, 169-176.

Fleck, S. J., & Kraemer, W. J. (1997). *Designing resistance training programs*. Champaign: Human Kinetics Books.

Hermens, H. J., Freriks, B., Disselhorst-Klug, C., & Rau, G. (1999). The recommendations for sensors and sensor placement procedures for surface electromyography. In H. J. Hermens, B. Freriks, R. Merletti, G. Hagg, D. Stegeman, J. Blok & G. Rau (Eds.), *SENIAM 8: European recommendations for surface electromyography* (pp. 25-54). Enschede: Roessingh Research and Development.

Kyrolainen, H., Belli, A., & Komi, P. V. (2001). Biomechanical factors affecting running economy. *Medicine & Science in Sports & Exercise, 33*, 1330-1337.

Myer, G. D., Ford, K. R., McLean, S. G., & Hewett, T. E. (2006). The effects of plyometric versus dynamic stabilization and balance training on lower extremity biomechanics. *American Journal of Sports Medicine, 34*, 445-455.

Noehren, B., Davis, I., & Hamill, J. (2007). Prospective study of the biomechanical factors associated with iliotibial band syndrome. *Clinical Biomechanics, 22*, 951-956.

Norton, K., Whittingham, N., Carter, L., Kerr, D., Gore, C., & Marfell-Jones, M. (1996). Measurement techniques in Anthropometry. In K. Norton & T. Olds (Eds.), *Anthropometrica* (1st ed., pp. 25-76). Sydney: University of New South Wales Press.

Presswood, L., Cronin, J., Keogh, J., & Whatman, C. (2008). Gluteus medius: Applied anatomy, dysfunction, assessment, and progressive strengthening. *Strength and Conditioning Journal, 30*, 41-53.

Woltring, H. J. (1995). Smoothing and differentiation techniques applied to 3-D data. In P. Allard, I. Stokes & J. P. Blanchi (Eds.), *Three-dimensional analysis of human movement* (pp. 79-99). Champaign: Human Kinetics.