cant main effects were observed. First, in both the normal and wide step conditions, a greater increase in mean frequency of activity in the vastus medialis compared with the vastus lateralis ($P < 0.01$) was evident. However, there were no significant differences in frequency between the normal and wide step conditions. Secondly, there was a greater increase in average amplitude in the vastus medialis than in the vastus lateralis ($P < 0.01$). This was only found for the normal step width. No medial–lateral differences were seen in the support phase; however, significant differences ($P < 0.001$) were observed in muscle activity (root mean square and mean amplitude) between the step and support phases, reflecting differences in movement and stabilization.

Previous studies have reported an increase in vastus medialis activity relative to vastus lateralis activity during increasing squat widths (Anderson *et al.*, 1998: *Journal of Sport Rehabilitation*, **7**, 236–247). No such evidence was seen in this preliminary study of novice individuals. Further studies are being carried out on all the phases of the step sequence and will be analysed in individuals who regularly participate in step aerobics to determine whether imbalances develop with increased step aerobic activity.

Relationship between muscular strength endurance and biomechanical changes during a run to exhaustion at the velocity at $\dot{V}O_{2max}$ in well-trained runners

P.R. Hayes,[1] E. Davies,[1] S. Stewart[1] and S. Bowen[2]

[1]*Division of Sport Sciences, University of Northumbria, Wynne-Jones Centre, Newcastle-upon-Tyne NE1 8ST and [2]Biomedical Services, University of Aberdeen Medical School, Foresterhill, Aberdeen AB25 2ZD, UK*

Previous research (Gazeau *et al.*, 1997: *Archives of Physiology and Biochemistry*, **105**, 583–590) has identified biomechanical changes during a run to exhaustion at the velocity at $\dot{V}O_{2max}$. Many athletics coaches advocate the use of resistance training, believing that it delays the onset of fatigue. The aim of this study was to establish the relationship between muscular strength endurance and these biomechanical changes during high-intensity running.

Six sub-elite middle-distance runners (age 24.2 ± 4.2 years, height 1.81 ± 0.03 m, mass 73.4 ± 4.4 kg, $\dot{V}O_{2max}$ 61.7 ± 5.6 ml$\cdot$kg$^{-1}\cdot$min^{-1}; mean $\pm s$) participated. The sample was deemed to be homogeneous based on the participants' velocity at $\dot{V}O_{2max}$ data (coefficient of variation = 3.9%). The participants completed an incremental protocol to determine their velocity at $\dot{V}O_{2max}$, a run to exhaustion at their velocity at $\dot{V}O_{2max}$ and measurements of isokinetic muscular strength endurance. The isokinetic test consisted of 30 maximal eccentric and concentric contractions for the measurement of work done. This was performed at 3.14 rad$\cdot$s^{-1} for the knee extensors and flexors, hip extensors and flexors, and the ankle plantar flexors. The biomechanical changes were assessed at the beginning and just before the end of the run to exhaustion. The measurements at the beginning of exercise were taken from the first right foot strike, 20 s into the run. The end of exercise measures were taken from the first right foot strike, 8 s before the participant terminated the run. The mean time

to exhaustion was 419 ± 80 s and the mean distance covered was 2396 ± 486 m. The absolute changes in the biomechanical variables were correlated with the isokinetic muscular strength endurance scores.

Several significant ($P < 0.05$) correlations were noted. The changes in stride length correlated with hip extension both eccentrically ($r = -0.818$) and concentrically ($r = -0.934$), eccentric knee flexion ($r = -0.957$) and maximal hip extension angle ($r = -0.857$). Support time correlated with time to exhaustion ($r = -0.943$) and with the distance covered during the run to exhaustion ($r = -0.931$). The very strong negative relationships between the change in support time with both the time to exhaustion and distance covered suggest that participants with the greatest increase in support time fatigue the quickest. We propose that muscular strength endurance of the hamstrings (hip extensor and knee flexor), and probably that of the gluteus maximus (hip extensor), plays an important role in maintaining selected stride mechanics during a run to exhaustion at the velocity at $\dot{V}O_{2max}$. The participants with greater muscular strength endurance of the hip extensors and knee flexors experienced smaller changes in stride mechanics.

Changes in muscle activation characteristics during a gymnastic rings routine

G. Irwin, P.S. Glazier, R.J. Tong and J.R. Radway

School of Sport, Physical Education and Recreation, University of Wales Institute, Cyncoed Campus, Cardi CF23 6XD, UK

Specificity and overload are two integral principles abided by gymnasts during their conditioning and specific skill training programmes. However, specific muscular fatigue caused by overloading in key muscle groups might change activation characteristics, thus reducing the specificity and the effectiveness of training. The aim of this study was to determine how muscle activation characteristics change over repeated trials of a gymnastic rings routine.

Five male international gymnasts (age 21.0 ± 3.7 years, height 1.73 ± 0.4 m, mass 70.4 ± 5.7 kg) participated in this study. Before testing, written informed consent and ethical approval from the local ethics committee were obtained. Electrode sites on the belly of the biceps brachii, triceps brachii, pectoralis major and posterior deltoid were marked on each gymnast (Clarys and Cabri, 1993: *Journal of Sports Sciences*, **11**, 379–448) and prepared using the methods of Okamoto *et al.* (1987: *Electromyography and Clinical Neurophysiology*, **27**, 173–176). Passive Ag/AgCl surface electrodes were attached in a bipolar configuration with an interelectrode distance of approximately 1 cm at each of the anatomical sites. A common ground electrode was also attached to the nearest bone or tendon. Pre-amplifying cables were attached to each of the detector and common ground electrodes. All cables were taped together and attached to the gymnast with insulating tape in an attempt to minimize cable artifact.

Before starting a set of rings routines, each gymnast performed an isometric maximal voluntary contraction (MVC) for each muscle group for normalization purposes. Each gymnast then assumed a static half lever position (SHL),

which was held for 5 s to allow electromyography (EMG) signals to be recorded. All EMG signals were recorded using a four-channel ME3000P (Mega Electronics Ltd, Finland) portable microcomputer unit. All data were then transferred onto a Viglen PC utilizing the ME3000P version 1.5 software.

After a passive recovery of 10 min, each gymnast then undertook the following routine (R1) devised by a current national standard gymnastics coach in accordance with current FIG regulations: upstart to half lever – hold; lift to handstand – hold; lower through to inverted hang – hold; back lever; upstart to half lever hold; handstand – hold; longswing back to handstand – hold; lower to half lever – hold (5 s to allow EMG recordings); dismount. The routine was then repeated after 5 min recovery (R2) and again after a further 2 min rest (R3). Repeated-measures analysis of variance was used to identify significant differences, followed by a *post-hoc* Tukey's HSD test where appropriate.

Significant reductions in the normalized mean power frequency were observed in the posterior deltoid between the initial condition (SHL) and the three routines (SHL = 79% MVC and R1 = 62.2% MVC, $P < 0.01$; R2 = 64.8% MVC, $P < 0.01$; R3 = 65.8% MVC, $P < 0.05$). Significant reductions also existed between normalized median frequency in the same muscle group between the initial condition (SHL) and the three routines (SHL = 82.6% MVC and R1 = 64.8% MVC, $P < 0.01$; R2 = 66.8% MVC, $P < 0.01$; R3 = 63.6% MVC, $P < 0.05$). Averaged EMG results indicated a decline ($P > 0.05$) in muscle activity in all muscle groups analysed, albeit at differing rates, over repeated trials of a rings routine. However, these differences were not statistically significant, owing to the variation in the data. This may have been a reflection of the differences in inter-individual conditioning and the reliance on different muscle groups due to morphological variation.

To summarize, we found a decrease in muscle activation characteristics in all muscle groups analysed over repeated trials of a rings routine. However, this decrease occurred at varying rates in relation to the initial condition (SHL) depending on the muscle group and gymnast. This reflects the specific fatigue and recovery rates of different muscle groups, dictated by fibre composition and metabolic demands. Additionally, the specific requirements of the activity may have led to an increased contribution of specific muscle groups leading to further fatigue of these groups.

Developing coordination in the overhand volleyball float serve: a constraints-led perspective

D. Kingsbury, K. Davids and S. Bennett

Department of Exercise and Sport Science, The Manchester Metropolitan University, Crewe + Alsager Faculty, Hassall Road, Alsager ST7 2HL, UK

Two important aspects of the task of coordinating movements with respect to the environment are the selection of movement patterns from the motor-perceptual workspace and the flexibility which this gives to the performer – that is, the ability to organize action around veridical (i.e. lawful) information from within the environment. The clear implica-

tion of this idea is that informational constraints guide and direct movement behaviour and, ultimately, the emergence of coordination patterns (e.g. McDonald *et al.*, 1995: *Acta Psychologica*, **88**, 127–165). The aim of this study was to determine how the motor patterns of novices were constrained by such temporal and spatial sources of information during the acquisition of skill in the overhand volleyball float serve. Based on previous research (Davids *et al.*, 1999: *International Journal of Sport Psychology*, **30**, 437–461), we investigated the relationship between ball toss peak (zenith) information and the observed movement patterns and kinematics.

Ten female undergraduate students (age 20.5 ± 1.3 years), with no prior experience of the volleyball serve and who provided informed consent, participated in the study. A regulation volleyball court (9.0×18.0 m) was marked on the floor of a large laboratory space, with a net raised to senior female height (2.23 m) in the correct position. Standard volleyballs (mass 0.27 kg, diameter 20.5 cm) were used throughout the study. The participants observed 10 trials of an elite performer completing the overhand float serve before serving themselves. They served the ball 20 times, towards the centre square of a target marked on the opposite court, from a standard position for serving (approximately 1 m from the baseline and 1.5 m from the sideline).

All participants were filmed using three-dimensional video-recording techniques (with two genlocked Panasonic AG-DP800H digital cameras, 50 Hz and 1/1000 s shutter speed, and Fujinon S14 zoom lenses). A performance volume was calibrated before testing using a reference frame of known dimensions placed in the serving zone (Peak Performance Technologies, Englewood, CO, USA). Selected video images were subsequently digitized using analysis software (Peak Motus v6.0, Peak Performance Technologies), smoothed and differentiated using a sixth-order Butterworth filter and then interpolated to 200 Hz.

Pearson's product–moment correlation coefficient revealed a significant temporal relationship between time of ball zenith and time of ball contact ($r = 0.844$, $P = 0.002$), suggesting that (regardless of movement pattern) novice performers can (and do) use the ball zenith to temporally guide movement behaviour (see Fig. 1). However, further spatial analysis revealed that the participants were unable to maintain a consistent ball zenith during the serving trials (measured using
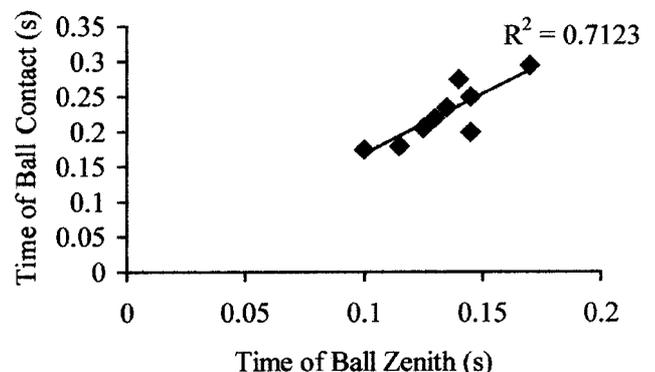

Fig. 1. Time of ball contact *vs* time of ball zenith.