FORWARD AND BACKWARD LOCOMOTION
UNDERSTANDING THE BENEFITS

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Introduction

Humans generally learn to walk and run in a forward direction with little difficulty. This is inherently logical since our field of view is in the forward direction. What about locomoting in the opposite direction, that is, walking or running backwards? What benefit(s), if any, might backward locomotion offer?

In our laboratory at the University of Oregon, we started to investigate forward/backward walking and running in the mid 1980s. We were intrigued by anecdotal evidence suggesting that backward running and/or walking provided unique training and/or rehabilitative benefits. We have since biomechanically investigated these various modes of locomotion and can share the results of our various experiments, coupled with selected research results of other investigators.

Biomechanical Comparisons

When one compares physical efforts of backward and forward running, runners typically perceive equal efforts during backward running at speeds of about 80% of those of forward running. One cannot run as fast backward as forward due to certain anatomical constraints that limit the flexion-extension movements of the lower extremities. This can be understood by observing that the ankle, knee and hip joints are not structurally mirror images on the anterior and posterior sides of the joints. In addition, for matched velocities of running, stride length is generally longer during forward running while stride rate is greater during backward running (Arata, 1999). These facts also influence joint kinematic differences observed when comparing forward and backward locomotion.

From a motor/system control perspective, Grasso and colleagues (1998) classified locomotion in the family of “reversible movements”. Stated in a basic form, this means if one ascribes to the notion that Central Pattern Generators (CPGs) control motion at each joint for a task, i.e., forward walking, then backward walking can be achieved by reversing the sign of the phase coupling (reversing the CPG) for each joint.

Bates, et al. (1986a, 1986b) have shown that while similar kinematic positions result between forward running touchdown and backward running takeoff (and vice versa), the demands on the body system do not result in one directional mode merely being the reverse of the other. When comparing the measured differences between modes of locomotion, empirical results (Arata, 1999; Bates, et.al, 1986a, 1986b, Devita & Stribling,

1991, Sveistrup & Bates, 1991) have shown that there are numerous performance differences. For example, in comparing forward and backward running, it has been shown that backward running results in:

- A more erect posture (less trunk inclination) than during forward running;

- Increased stride rate, decreased stride length and increased support time;

- Toe-heel versus heel-toe foot contact pattern;

- Reduced overall range of motion at the hip joint (greater flexion and lesser extension);

- Increased active functional range of motion at the knee joint;

- Elimination of eccentric knee joint flexion and the associated joint stresses (knee joint exhibits greater flexion at touch down followed by a nearly isometric/fixed position during the initial stance phase);

- Combined maximum knee extension with hip flexion (greater hamstrings activation with hip flexion);

- Role reversal of muscular structures supporting the ankle and knee joints (knee joint serves as primary power producer while ankle joint primarily absorbs shock);

- Modifications of lower extremity muscular activity.

Many of these kinematic differences also hold true when comparing forward and backward walking. Additional documented biomechanical differences (Grasso, et al., 1998) between directions of walking include:

- Direction of knee joint shear force is reversed (initially backward during forward walking while directed initially forward during backward walking);

- Vertical contact force is greater at contact versus push-off in backward walking where vertical forces at similar phases of forward walking are nearly equal;

- Electromyographical (muscle) activity of the lower extremities is greater in backward versus forward walking, suggesting greater energy expenditure;

- Muscle activity patterns are unique for each direction of walking.

In addition to the biomechanical differences between directions of walking and running, increased physiological demands when walking or running backwards have been documented. For example, Flynn, et al. (1994) indicated that during backward walking, VO2 and heart rate were 78 and 47% greater than during matched speed forward walking, respectively. These same variable comparisons were 31 and 15% greater when running backward compared to running forward. These data clearly indicate that retro motion is more stressful to the cardiovascular system when performed at the same forward velocity.

Derived Benefits

The increased physiological demands on the human system can be viewed as a benefit for the high-level athlete interested in alternative training method modalities to his/her activity-specific training routine or for the recreational athlete or individual interested in burning more calories in a lesser time.

Another benefit of retro locomotion includes practice and training of skills used in specific sports. Many court

and field sports, such as basketball, American football and soccer all incorporate backward running during competition. Performing the activity during training may allow one to improve performance and/or reduce potential for injury.

Variability during exercise for the high level or recreational athlete may be a means of reducing the potential for injury (Dufek, 2002). Such “exercise variability” may be achieved by including retro locomotion (walking or running) into a typical forward walking or running exercise program. The kinematic differences between directions of motion identified above lead to slightly different applications of force to the body. These slight changes in force application might allow one to avoid some chronic overuse injuries experienced by many athletes and exercise enthusiasts.

Retro locomotion training benefits can be summarized as follows:

- Provide sport-specific activity training;

- Improve cardiovascular function;

- Provide stronger musculo-skeletal foundation;

- Improve muscle balance;

- Help prevent injuries;

- Facilitate neuro-muscular function;

- Facilitate balance and proprioception.

Retro for Rehabilitation

Rehabilitation is another area where retro locomotion may be beneficial. Backward walking and/or running can potentially provide unique benefits to the individual rehabilitating an injury as well as to the exercise enthusiast who is facing the inevitable effects of age and past specific training on the body. Some conditions that have been observed to respond positively to retro locomotion include the following:

- Muscle strains including low back, hip, groin and hamstrings;

- Ankle sprains;

- Post-surgical knee joint rehabilitation;

- Shin splint syndrome;

- Achilles tendon strains.

Backward walking, like forward walking, is an activity in which one always maintains contact with the ground (unlike running, which has an airborne phase). Consequently, the force imparted to the body at impact is less in walking compared to jogging or running providing a starting point for a rehabilitation or conditioning program. This alone can be a benefit if one is suffering from an impact-type injury which could manifest as a sore knee, stress fracture, or similar problem or has not been recently engaged in an active exercise program. To this end, walking forward and backward could be a means to acquire or maintain cardiovascular fitness (recall physiological benefits previously discussed) and create or improve muscle balance while minimizing force-related trauma to the lower extremities.

A treadmill with rails can be used to assist greatly in a forward and/or backward walking rehabilitation program. Since a lower extremity injury often causes a reduction in strength and/or pain in the affected limb, partially supporting body weight by using the rails can be helpful. Treadmill walking also assists in developing gait symmetry which is often a concern following injury or surgery. This can be accomplished while walking both forward and backward.

If one prefers to walk overground, we suggest a unique pattern of locomotion which incorporates both forward and backward walking while requiring both static and dynamic balance control on both the right and left limbs. The routine is simple in description and action – complex in potential benefits. We term this exercise "5 - 4" walking and it is performed as follows:

1) Walk forward five steps;

2) Balance briefly on the support leg as the swing leg is reversed in direction;

3) Walk backward four steps;

4) Balance briefly on the support leg as the swing leg is reversed in direction;

5) Repeat.

Note: the balance phase during each direction change should be 3 to 5 seconds inlength.

During this "5-4" walking and balance cycle, the neuromuscular system can be exercised extensively by incorporating dynamic gait (forward and backward) as well as static postural control on alternating legs. Mastery of this exercise may be helpful in the prevention of falls, especially for the elderly population. The exercise can be done overground initially with use of rails or the wall for support and eventually without external support as one learns to fully control the body and the directional changes. Another variation is to do this exercise with a partner for support and "eyes in the back of your head". The use of a partner is in fact a safe and fun way to experience any form of backward locomotion.

Summary

Documented biomechanical, physiological and neuromuscular differences between forward and backward locomotion have been briefly reviewed. These differences were discussed relative to the use of retro locomotion activities to enhance training regimes and improve/enhance rehabilitation and injury prevention programs.

References:

1. Arata, A.W. *Kinematic and kinetic evaluation of high speed backward running*. Unpublished doctoral dissertation, University of Oregon Microform Publications, 1999.

2. Bates, B.T. & McCaw, S.T. *A comparison between forward and backward locomotion*. Human Locomotion IV, Proceedings of the Biennial Conference of the Canadian Society for Biomechanics, Montreal, Quebec, Canada:307-308, 1986.

3. Bates, B.T., Morrison, E. & Hamill, J. *Differences between forward and backward running.* M. Adrian and H. Deutsch (Eds.). Proceedings of the 1984 Olympic Scientific Congress, Eugene, Oregon: University of Oregon Microform Publications:127-135, 1986.

4. Devita, P. & Stribling, J. *Lower extremity joint kinetics and energetics during backward running*. Medicine and Science in Sports and Exercise, 23:602-610, 1991.

5. Dufek, J.S. Exercise variability: *A prescription for overuse injury prevention.* Health and Fitness Journal, 6(4):18-23, 2002.

6. Flynn, T.W., Connery, S.M., Smutok, M.A. Zeballos, R.J & Weisman, I.M. *Comparison of cardiopulmonary responses to forward and backward walking and running.* Medicine and Science in Sports and Exercise, 26(1):89-94, 1994.

7. Grasso, R., Bianchi, L. & Lacquaniti, F. Motor patterns for human gait: *Backward versus forward locomotion.* Journal of Human Physiology, 80:1868-1885, 1998.

8. Sveistrup, H. & Bates, B.T. *Have you considered going backwards?* E. Zemper, G. Steigleman and S. James (Eds.). Proceedings of the VIIIth World Veterans' Championships Sport Science Symposium, Eugene, Oregon: University of Oregon Printing Services:23-28, 1991.