Backward Walking: Understand Function and the Associated Benefits.

Janet S. Dufek, Ph.D., FACSM
jdufek@unlv.nevada.edu
Visiting Research Associate Professor, University of Nevada, Las Vegas
Research Scientist, Human Performance & Wellness, Inc.

Barry T. Bates, B.S.E., Ph.D.
btbates@uoregon.edu
Senior Scientist, Human Performance & Wellness, Inc.
Professor Emeritus, University of Oregon
Adjunct Professor, University of Nevada Las Vegas

Amanda Tritsch, A.T.C.
tritscha@unlv.nevada.edu
Graduate Assistant, University of Nevada, Las Vegas

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 backwards? What benefit(s) might backward walking offer the participant?

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, along with selected research results of other investigators.

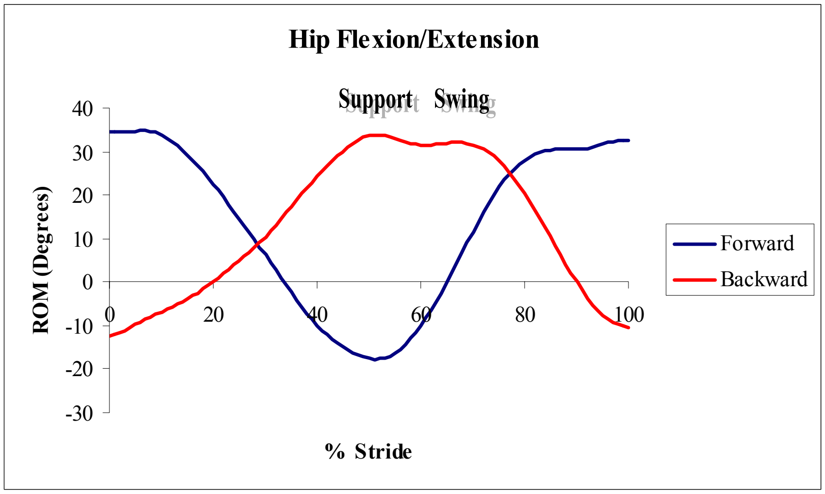
Bioimechanical Comparisons

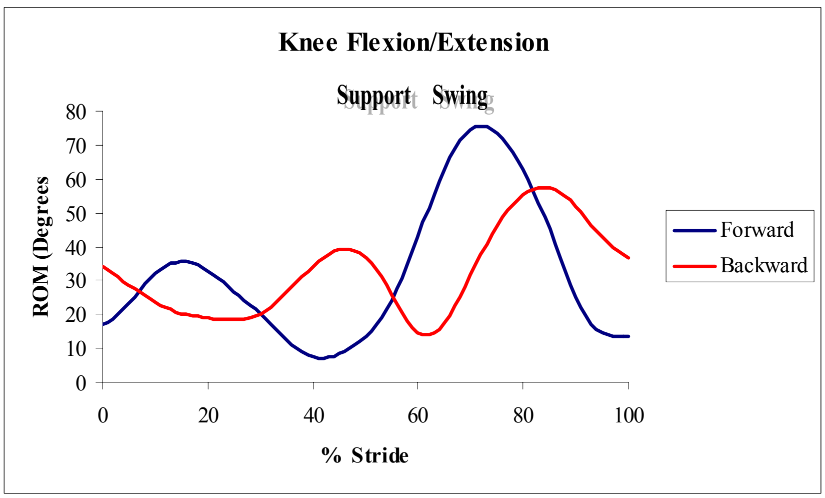
When one compares physical efforts of backward and forward running, runners typically perceive equal efforts during backward running at speeds of about 80% of those of forward running. One generally cannot run as fast backward as forward. The same is true for backward walking; it is difficult to walk at the same speed forward and backward, for any given perceived effort. This is due in part to the anatomical construction of the body, as well as aspects of skilled/learned performance.

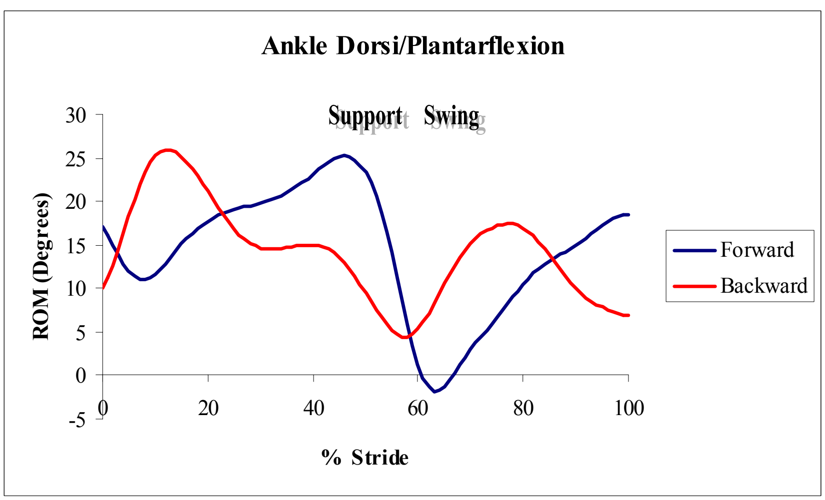
There are anatomical constraints that limit the flexion-extension movements of the lower extremities. This can be understood by observing that the ankle, knee and hip joints are not structurally mirror images on the anterior and posterior sides of the joints. For example, when standing erect, lift one leg and bend (flex) your knee. You will note a great range of motion, more that 90 degrees. Now, from the standing straight position, try to extend your knee. You might display motion of approximately 1 to 5 degrees, which is much less than in the other direction. In addition to joint range of motion constraints, 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. Similar constraints exist for backward walking. Comparisons of the lower extremity joint range of motion patterns for forward and backward motion are shown in Figure 1.

Our laboratory work has shown that the support-swing ratio of a walking stride in backward walking is similar to forward walking: 60% support and 40% swing. Viewing Figure 1, we observe that functional opposition of motion occurs at the hip joint between forward and backward walking. When walking forward, the hip joint exhibits extension followed by flexion during the support phase, whereas in backward walking, the hip joint is near full extension at contact and flexes throughout support, followed by extension in the swing phase. The knee joint motion between forward and backward walking can be viewed as quite similar, if one "time-reverses" the support phase for backward. In other words, the patterns are reversed. In forward walking, the knee joint flexes, extends, and then flexes in support whereas in backward, the knee joint initially extends, flexes, and extends in support, prior to flexing and extending during swing (similar to forward). The range of motion of the knee joint is less in backward versus forward. Ankle joint patterns are also comparatively reversed. In forward walking, one initially

Figure 1. Hip, Knee and Ankle Joint Range of Motion Comparative Patterns During One Complete Walking Stride.







plantarflexes, followed by dorsiflexion and plantarflexion, whereas in backward walking, due to the forefoot vs rearfoot contact pattern, the ankle initially dorsiflexes prior to dominant plantarflexion action in support.

The range of motion (ROM) values of the hip, knee, and ankle lower extremity joints for forward and backward walking, as exhibited by one exemplar subject, are given in Table 1. As can be seen from these data, lower extremity joint range of motion values are less during backward vs forward walking. This has potentially positive ramifications during rehabilitation when functional joint range of motion may be limited, allowing the patient to exercise without straining beyond their functional capabilities.

Table 1. Exemplar Lower Extremity Range of Motion Values: Forward vs Backward Walking.

		Hip		Knee		Ankle	
Support Phase			ROM		ROM		ROM
Forward	**Min**	-18.4		7.4		-6.6	
	Max	35.3	53.7	43.0	35.6	26.1	32.7
Backward	**Min**	-13.5		11.4		7.2	
	Max	36.3	49.8	41.2	29.8	26.8	19.6
Swing Phase							
Forward	**Min**	-8.3		13.4		-3.6	
	Max	32.9	41.2	74.9	61.5	17.7	21.3
Backward	**Min**	-10.7		11.0		6.6	
	Max	33.5	44.2	55.1	44.1	18.7	12.1

Notes: Values in degrees; Positive is flexion/dorsiflexion, Negative is extension/plantarflexion; ROM = range of motion.

Terblanche, et al. (2004) have discussed that the physiological demands of retro walking can be reduced after 12 exercise sessions by learning the novel movement patterns. It follows that the physiological efforts of retro walking would thus be reduced/minimized after "learning" the skill of walking backwards. One can therefore anticipate a greater physiologic (and caloric) demand during the first three weeks of a retro walking program. If one meets the condition of adaptation in this sense, the next step would be to increase walking speed, in order to increase the physiologic (and caloric) demands on the system. Therefore, backwards walking can be used in an exercise program following the principles of progression for added exercise benefits, similar to forward walking or running. The only difference may be the need for initial "accommodation" when retro walking, that is, allowing time to learn the motor skill.

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. The data shown in Figure 1 support the notion of walking as a reversible movement. This concept allows us to understand how retro walking is performed – it does not provide a basis for functionality and/or perceived benefits.

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, which is in contrast to the walking information. 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 slight performance differences. 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;
- Toe-heel versus heel-toe foot contact pattern;

- Reduced overall range of motion at the hip joint (greater flexion and lesser extension);
- Reduced overall range of motion at the knee joint (increased active functional range);
- Increase stride rate, decreased stride length and increased support time;
- Elimination of eccentric knee joint flexion (knee joint exhibits greater flexion at touch down followed by a nearly isometric/fixed position during the initial stance phase);
- Role reversal of muscular structure supporting the ankle and knee joints (knee joint served as primary power producer while ankle joint primarily absorbed shock);
- Modification of lower extremity muscular activity.

Many of these kinematic differences (see Figure 1) 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, VO_2 and heart rate were 78 and 47% higher than during matched speed forward walking, respectively. These same variable comparisons were 31 and 15% higher when running backward compared to running forward. These data clearly identify that retro motion generates a greater stress to the cardiovascular system, if performed at a velocity matched to that of forward motion. This can be a useful benefit in a number of sport, training, rehabilitation or fitness exercise situations.

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 methods to their activity-specific training routine or for the recreational athlete or individual interested in burning more calories in a lesser time. In addition, the increased physiological demands in backward vs foreward walking can be of benefit in the rehabilitation environment, when one is interested in spending lesser activity time (due to impairment) while expending a similar or greater number of calories.

In order to walk backwards efficiently, kinesthetic sense is developed and balance is enhanced. This is not unlike learning to walk (forward) on a treadmill. When first walking (forward) on a treadmill, there is a tendency to hold onto or touch the rails to assist with balance. Eventually, one develops the balance skills and is able to walk without use of the rails. The same is true in learning to walk backwards. Balance skills are necessarily developed in order to complete the task (walking backwards) without rails or other forms of support. This enhancement of balance can be especially important for a vulnerable population, such as the elderly, who typically experience more falls as they age. We believe a walking program which includes forward and backward walking can greatly enhance the balance and dynamic equilibrium of the participant.

Another benefit of retro motion 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 (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. This slight change in force application might allow one to avoid a chronic injury situation.

Retro for Rehabilitation

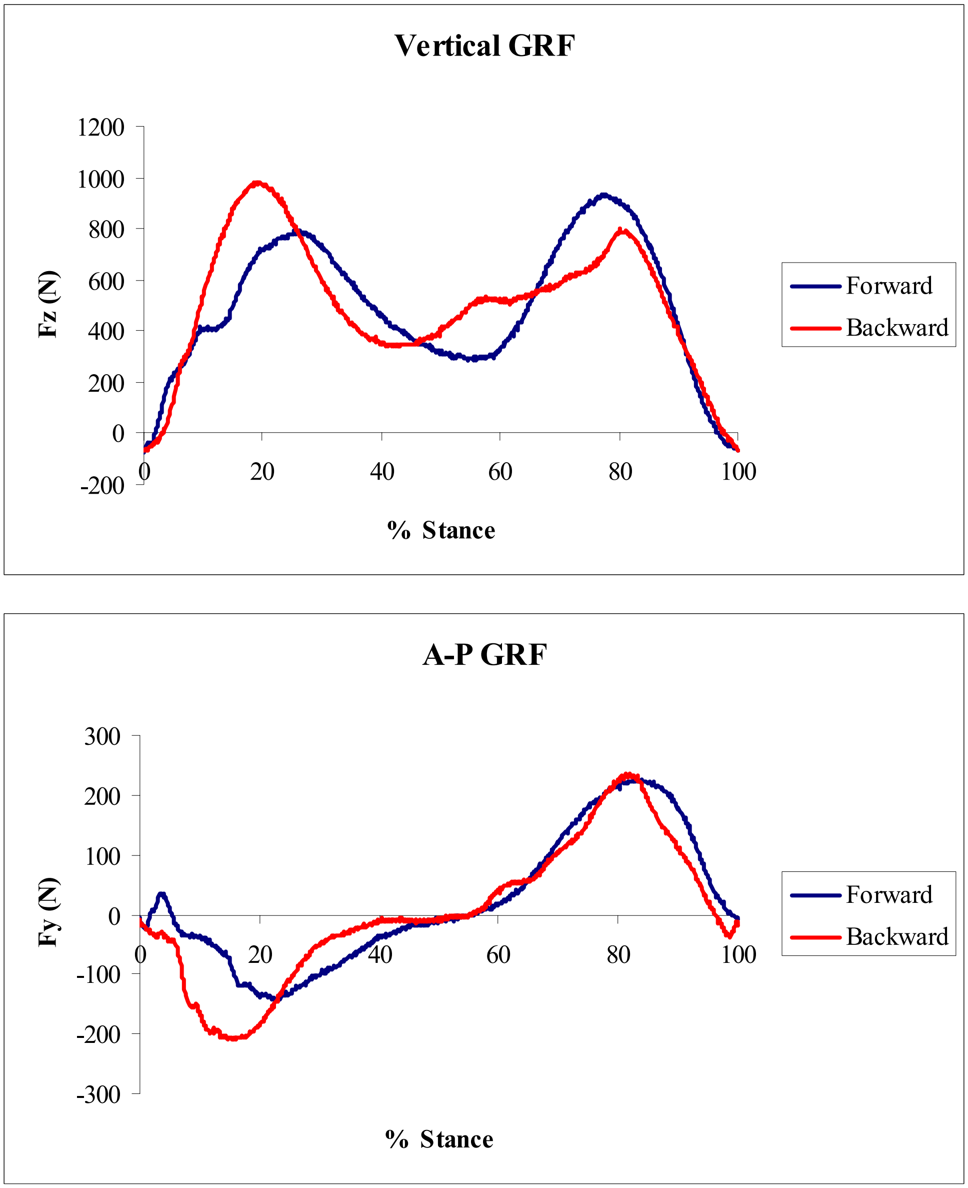
Rehabilitation is another area where retro locomotion may become useful. Backward walking, like forward walking, is an activity in which one always maintains contact with the ground (unlike running, which has an airborne phase). Consequently, the force imparted to the body at impact is less in walking compared to jogging or running. 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. To this end, walking forward and backward could be a means to maintain cardiovascular fitness (recall physiological benefits previously discussed) without risking further force-related trauma to the lower extremities.

Backward walking 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 on the body. Some of these benefits include similar patterns of vertical and anterior-posterior ground reaction force during the support phase with no comparatively excessive loads (Figure 2), increased hamstring stretch during the stride and enhancement of proprioception / balance control.

A treadmill with rails can be used to assist greatly in a walking rehabilitation program. Since a lower extremity injury often causes a reduction in strength of the affected limb, partially supporting body weight by using the rails can be helpful. As shown in Figure 3, this can be accomplished while walking both forward and backward.

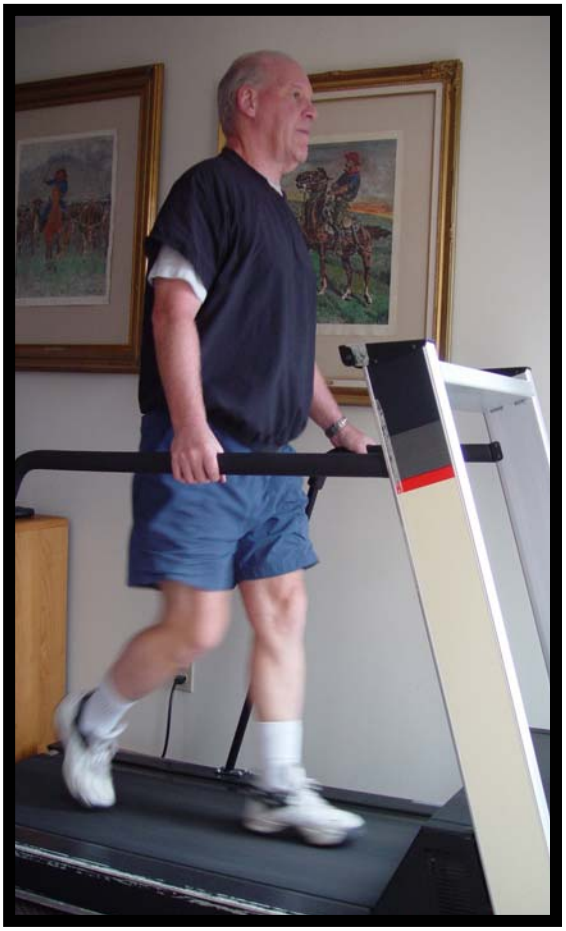
If one prefers to walk over ground, we suggest a unique pattern of locomotion which incorporates both forward and backward walking while requiring both static and dynamic balance control on both the right and left limbs. The routine is simple in description and action – complex in potential benefits.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

Figure 2. Vertical and Anterior-Posterior Ground Reaction Force (GRF) Comparative Patterns During The Stance Phase of Walking.



Note: All graphs normalized to 100% support time; Walking speeds similar at ~ 1.4 m/s.

Figure 3. Using Treadmill Rails to Assist in Walking Rehabilitation.



Forward Walking

Backward Walking

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 in length.

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. This 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. Mastery of this exercise may be helpful in the prevention of falls, especially for the elderly population.

Summary

Several documented differences between forward and backward locomotion have been reviewed. When comparing retro walking and running to forward walking and running, it has been shown that foot contact patterns differ, range of motion at the lower extremity joints is reduced during retro, stride rate increases in retro, physiological demands increase during retro, and firing patterns of lower extremity musculature differ between forward and backward. These factors can lead to use of retro 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.

9. Terblanche, E., Page, C., Kroff, J. & Venter, R.E. The effects of backward locomotion training on the body composition and cardiorespiratory fitness of young women. *Inernational Journal of Sports Medicine,* 25:1-6, 2004.