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Research Paper

Retrowalking: A New Concept in Physiotherapy and Rehabilitation

Medical Science

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ABSTRACT

The purpose of this review was to assess the current literature and provide new insights into the role of retrowalking in physiotherapy. Retrowalking or backward walking has recently emerged as a new concept in physiotherapy and rehabilitation. Retrowalking has a distinct pattern of muscle activation and is associated with decreased walking speed, increased cadence and decreased stride length. It is related with increased metabolic costs and evokes greater cardiorespiratory response when compared to forward walking at similar speeds. Its role in patellofemoral pain and anterior cruciate ligament injury rehabilitation has been investigated showing positive results. Beneficial results of retrowalking, though with limited evidence have been seen in conditions such as stroke, cerebral palsy and Parkinsonism where it has improved balance and gait. Few studies investigating its efficacy in knee osteoarthritis have reported positive outcomes on pain, disability and balance. Further researches should be done to explore the role of retrowalking in physiotherapy management of neurological and musculoskeletal conditions causing disability.

Walking and running are favorite recreational and leisure physical activities cherished by humans. They are used to improve mental and physical health levels (Roe and Aspinall; 2011, Warburton et al.; 2006). Most of the previous research on walking has focussed on forward propulsion or walking. Nowadays, retrowalking is gaining popularity in the field of fitness and rehabilitation. Retrowalking or backward walking is a method of locomotion with roots in ancient China where it was utilized to attain physical fitness and well being (Hoogkamer et al.; 2014). It has emerged as a beneficial exercise in terms of improving oxygen uptake, cardiopulmonary fitness and muscle activity while simultaneously decreasing joint stress.

Biomechanics of Retrowalking

Whether any differences exist between forward walking (FW) and backward walking (BW) has intrigued many researchers. The kinetic and kinematic parameters of forward and backward locomotion have been compared extensively (Flynn and Soutas-Little; 1993, Grasso et al.; 1998, Kramer and Reid; 1981, Lee et al.; 2013, Thorstensson; 1986, Threlkeld et al.; 1989, Winter et al.; 1989, Vilensky et al.; 1987, Devita and Stribling; 1990). Some researchers found no differences between them and stated that backward walking was almost a mirror image of FW. They found that joint patterns were similar to FW but with simple temporal reversal (Winter et al.; 1989). However, BW differs from FW from biomechanical perspective. Also, it is a challenging task as the person walking backwards has no idea of the obstacles behind him.

The gait characteristics of BW when compared with FW differ greatly (Grasso et al.; 1998). Initiation with toe strike is the hallmark of BW. The stance phase of FW begins with heel strike and ends with toe-off whereas in case of BW, the toes are the first ones to contact the ground. The heel is lifted off the ground at the end of the stance phase. There are many anteroposterior anatomical and functional asymmetries of the foot and leg. The muscle mass and strength of the posterior calf and anterior thigh muscles is greater than anterior leg and posterior thigh muscles. Also, the disparity in the shape of the foot anteriorly and posteriorly serves different functions during walking. These asymmetries act as a biomechanical restriction to forward and backward gait and account for the differences between them. Differences in muscle activity pattern have been reported through electromyography (EMG) studies as well (Grasso et al; 1998, Vilensky et al.; 1987). Studies done by Thorstensson (1986) and Grasso et al (1998) have concluded that early stance in FW involves coactivation of both flexors and extensors at hip, knee and ankle. However, early stance of backward gait involves activation of knee extensors and ankle plantar flexors. The average EMG activity over one gait cycle was higher in backward gait as compared to forward gait, which suggests greater energy expenditure in BW (Grasso et al.; 1998). Similarly, the ground reaction forces and joint angles also differ during BW and FW (Thorstensson; 1986, Vilensky et al.; 1987, Winter et al; 1989). However, the elevation angles remain the same when walking backward. Many studies have stated that the eccentric activity and decelerating function of quadriceps is exchanged by an isometric activity and stabilizing function during single stance (Cipriani et al.; 1995, Flynn and Soutas-Little; 1993).

Jansen et al (2012) studied the effects of muscles on the acceleration of center of mass (COM) in forward and backward gait. The eccentric and decelerating action of quadriceps muscles during FW is replaced by an isometric action during single stance. A concentric and accelerating action of quadriceps was seen during preswing in BW. The changes in the role of gastrocnemius muscle were also notable. Its role in deceleration during first half of single support and forward acceleration of the COM in the second half of the single support and preswing during FW are replaced by acceleration during single support and deceleration during loading response and preswing. Thus, it is evident that the muscles playing as main horizontal accelerators during FW act as decelerators during backward walking.

A reversal of function was notable in the muscle control of horizontal movement of COM during backward gait. But, there was no change in the anti-gravity contributions of the muscles. Therefore, when walking direction is reversed, similar muscles can be used to attain opposite functional demands at the level of horizontal control of the COM. However, the vertical function is maintained (Jansen et al. 2012).

Backward walking was related with decreased speed, increased cadence and decreased stride length as compared to FW (Kramer and Reid; 1981, Lee et al.; 2013, Vilensky et al.; 1987). Thus, owing to the unique features, beneficial effects of retrowalking or BW are seen in various conditions as shown in Fig.1.

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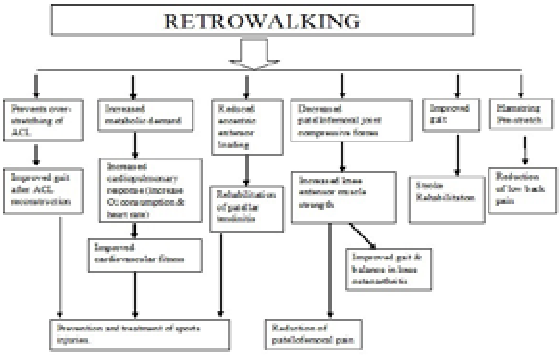

Figure1. Showing various benefits of retrowalking in rehabilitation.

Cardiopulmonary and metabolic effects of retrowalking

Retrowalking places higher metabolic demands and elicits greater cardiopulmonary response than FW (Flynn et al; 1994). Studies have documented the cardiopulmonary and metabolic costs of backward motion at 0%, 1% and 5% treadmill elevations (Myatt et al.; 1995, Flynn et al. 1994, Chaloupka et al.; 1997). Another study investigated effects of BW on a treadmill at a speed of 67.0m/min and grades of 5%, 7.5% and 10%. Their findings were in agreement with earlier studies showing that a greater cardio respiratory response (expressed in terms of oxygen uptake, expired ventilation and heart rate) was evoked as compared to FW under same conditions (Hooper et al; 2004).

According to the energy cost estimates of American College of Sports Medicine, a study done by Myatt et al. (1995) reported that BW consumes 38-119% more energy than FW at the same speed (Myatt et al.; 1995). They investigated the relationship between oxygen consumption (VO_2), heart rate and BW at selected speeds. The oxygen consumption and heart rate increased with BW speed. They also derived equations to predict VO_2 or heart rate of patients during BW at selected speeds in men. Clarkson et al. (1997) determined and established relationships between oxygen consumption, heart rate and BW speeds in young and healthy women. A curvilinear relationship existed between oxygen consumption and speed. Same relationship existed between heart rate and speed.These studies provided information on prescription of BW speeds in men and women to maintain aerobic conditioning during rehabilitation of athletes with patellofemoral pain or anterior cruciate ligament injuries.

A many number of reasons have been stated to be possible for the increased metabolic cost associated with BW (Myatt et al.; 1995, Chaloupka et al. 1997). First, the eccentric action of the quadriceps femoris muscle in FW is replaced by its isometric and concentric action in BW during early to midstance and then mid to late stance period respectively. Positive work related to concentric contraction bears a greater cost than the negative work associated with eccentric contraction. BW is related with more concentric muscle activity and thus positive work bearing a greater metabolic cost. Second, the modifications in gait parameters such as decrease in stride length and increase in stride frequency during BW are imperative. The optimal length tension relationship of muscle leads the subjects to experience an increased oxygen uptake. The muscles fail to produce maximal forces and are unable to undergo energy efficient activity. Third, concentric activity of quadriceps muscle in BW uses more ATPs as compared to its eccentric activity in FW. Fourth, BW is an unaccustomed activity with a certain amount of unfamiliarity. A novel task requires recruitment of more motor units resulting in higher skeletal muscle activation thus increasing the oxygen consumption. Moreover, underdeveloped neuromotor pathways exist for BW. Thus, all these factors lead to an increase in the oxygen demand during BW (Clarkson et al.; 1997, Flynn et al.; 1994, Hooper et al.2004; Myatt et al.; 1995).

Retrowalking attains beneficial intensities of heart rate and oxygen consumption at slower speeds and lower treadmill grades. This reduces the damage potential of BW as compared to FW at similar speed and grades. While undergoing rehabilitation, an injured athlete may continue to exercise using BW or backward running at intensity sufficient enough to maintain cardiovascular fitness (Flynn et al., 1994).

Retrowalking in sports injury prevention and rehabilitation

Sports such as hockey, netball, basketball, soccer, rugby, American football and tennis demand a great amount of speed and agility in backward, lateral and forward directions. BW and BR are included in the standard conditioning and training programmes for such sports (Agbonlahor et. al.; 2009 Hoogkamer et al.; 2014 Terblanche et al.; 2005). They improve endurance and aerobic capacity of the athletes. Thus, backward locomotion imparts both task-specific training and an improvement in general fitness in an athlete (Hoogkamer et al.; 2014).

People undertaking professional running and recreational jogging may develop pain during their training. Knee joint is most commonly involved in runners. Patellofemoral dysfunction is common in them due to the stance phase of running which involves large eccentric power absorption by quadriceps. This is important for the deceleration of the body and lays greater biomechanical loads on the knee joint. An important component of a rehabilitation programme for patellofemoral pain syndrome and jumper's knee (infrapatellar tendinitis) is quadriceps muscle strengthening. But, the condition of an injured joint may worsen if activities causing biomechanical overload are included (Flynn and Soutas-Little; 1993).

Recently, closed chain exercises are becoming popular in the field of rehabilitation for lower limb injuries (Cipriani et al.; 1995). Closed chain exercises have been proven to be better than open chain exercises used conventionally in rehabilitation. Retrowalking or BW has been one of the extensively researched closed chain exercises. The role of BW and BR in enhancing rehabilitation outcomes has been documented successfully in many studies. This is attributed to increase in muscle strength and reduction in joint stress. Mackie and Dean (1984) evaluated quadriceps power developed through an isokinetic programme of BR. They reported greater increases in quadriceps power in subjects engaged in BR compared to those in forward running.

Threlkeld et al. (1989) analyzed the kinematic and kinetics of BR in runners. Knee extensor strength was increased with lower vertical ground reaction force production decreasing harmful joint stresses. Thus, it may be used clinically to reduce stress on the previously injured joints and strengthen knee extensors.

Devita and Stribling (1990) investigated lower limb joint moments of force and joint muscle powers during BR. They stated that the magnitude of hip moment and power patterns remained unchanged but direction was opposite when compared to forward running. However, an exchange was seen between the roles of knee and ankle muscles during BR. Knee extensors had greater moment and power output as compared with ankle. The ankle plantarflexors served as primary shock absorbers during early stance of BR. The huge knee moment produced thus reinforces the fact that BR training increases knee extensor torque.

On comparison of EMG and kinetic parameters of BR and forward running, investigators have reported that BR decreased patellofemoral joint reaction forces thus reducing the eccentric loading of the patellar tendon, which may be beneficial in treating patients with patellofemoral dysfunction (Flynn and Soutas-Little; 1993). They concluded that the muscle action of vastus medialis oblique and vastus lateralis was found to be primarily isometric and concentric during BR as compared to eccentric and concentric action during FW. Thus, BW could benefit in clinical conditions which warrant an increase in quadriceps muscle strength.

Patellofemoral joint compressive forces were investigated in backward and forward running (Flynn and Soutas-Little; 1995). Patellofemoral pain syndrome is an important cause of knee pain in adolescent runners. Atrophy of vastus medialis oblique muscle leads to damage of the extensor mechanism, poor muscular strength and imbalance between medial and lateral parts of quadriceps femoris. A comparison of patellofemoral joint compressive forces during forward running and BR on joggers reduced peak patellofemoral compressive forces during BR. At self selected speeds, BR had the ability to reduce patellofemoral joint compressive forces and may be combined with quadriceps strengthening exercises for an effective rehabilitation programme in runners.

The effects of a controlled exercise programme in the healing of damaged or repaired tissue are well-known (Cipriani et al.; 1995). An exercise programme should be well controlled and provide sufficient time for the injured tissues to acclimatize and strengthen. Both BW and running backward have been found to exhibit these beneficial effects. Running backward on a treadmill produces adequate stress to influence the strength of the tissue (Mackie and Dean; 1984).

The kinematic and EMG analysis of BW on treadmill have been further investigated (Cipriani et al.; 1995, Chen et al.; 2000). The changes in gait cycle produced by BW on a treadmill at inclinations of 0, 5 and 10% have been investigated (Cipriani et al.; 1995). Values of joint position for hip, knee and ankle and average EMG activity of rectus femoris, hamstrings, gastrocnemius and anterior tibialis were compared at three treadmill inclinations. They reported significant changes in the joint positions of the knee and ankle joints at initial contact. Also, significant changes were seen in the average EMG activity for muscles studied. However, notable changes were seen in gastrocnemius muscle at initial contact between 0 and 10% inclination grade. Thus, it was evident that inclined BW placed extra muscular demands on the subjects. This is especially true for muscles such as gastrocnemius, anterior tibialis and rectus femoris.

The joints undergo a greater range of motion as a result of increased levels of treadmill inclination (Cipriani et al. 1995). It has been documented that at initial contact, the knee flexion is approximately 31at a grade of 10%, knee flexion increases to about 42. This additional knee flexion range is important in the knee rehabilitation programmes developed for anterior cruciate ligament (ACL) reconstruction, post fracture management and joint replacement. Retrowalking or backward walking may also be used as an adjunct to main treatment for patients with anterior knee pain such as quadriceps and patellar tendinitis since it increases quadriceps muscle strength and decreases patellofemoral compressive forces.

Retrowalking also produces greater demands on the dorsiflexion range of the ankle and can be used in the ankle rehabilitation programmes for ankle sprain. Walking backward up an incline places greater demands on the ankle and knee in terms of increased range of motion and muscle function benefitting in post injury kinesthetic re-education.Thus, backward slope walking compared to a flat surface enhances its beneficial effects because of increased knee flexion, ankle dorsiflexion and muscle activity (Cipriani et al. 1995).

Researchers also promote the use of both BW and backward running in the training of athletes involved in long distance running. This is due to the increased knee extensor activity. This corrects the imbalance between knee flexors and extensors and helps to realign the quadriceps to hamstring strength ratio towards 60/40 which has been set as the ideal ratio (Hoogkamer et al.; 2014). Achievement and retaining of this muscle balance ratio helps in the prevention of further injuries.

The beneficial effects of inclined treadmill walking were further investigated (Chen et al. 2000). The analysis of kinematic parameters and EMG activity during comparison of forward and backward gait was performed at 10% inclination. The authors concluded that BW on inclined treadmill would augment the effects of BW on a flat surface due to increased levels of muscle activity.

Another study stated that an important difference between joint kinematic patterns of FW and BW was hamstring pre-stretch which occurs in BW before the time of thigh reversal (Whitley and Dufek; 2011). They owed this to the increased hip flexion and decreased extension. Hamstring and lower back flexibility may increase following BW training programme. It may prevent injuries due to hamstring tightness and low back pain due to tight hamstrings. Dufek et al. (2011) performed another study on athletes with low back pain. They stated that a 10-15 minute programme of BW for three weeks reduced low back pain and increased low back range of motion. However, a limitation of both the studies was that none of them included a control group with FW.

Retrowalking in neurological disorders
The effects of BW have been investigated in patients with stroke (Yang et al.; 2005, Weng et al.; 2006, Takami and Wakayama; 2010). Yang et al (2005) studied the effect of BW in stroke patients participating in a training programme involving 30 minutes of BW in addition to the conventional therapy for three weeks. Post training, the patients with BW showed greater improvement in walking speed, stride length and symmetry index. Another study concluded that improvement was seen in gait and balance of stroke patients undergoing backward training programme (Weng et al.; 2006). Walking speed, balance and motor functions of lower limb increased with BW in stroke patients.

Takami and Wakayama (2010) investigated the effect of a backward treadmill walking using partial body weight support for acute stroke patients with unstable gait. Partial body weight support treadmill BW improved mobility during early phase of acute stroke. Hackney and Earhart (2009) examined backward gait in Parkinson patients. Gait defects were more prominently seen during BW in these patients. Training with BW could thus improve outcomes.

Few studies have also investigated the effects of BW on balance. Zhang et al. (2008) compared static balance abilities of old women who underwent backward training to those who did not. Single leg standing duration was found to be increased in subjects with BW training. There was decreased fluctuation in gravity center of static standing with eyes closed (Hao and Chen; 2011). The effect of BW on balance in school-aged boys was studied (Hao and Chen; 2011). It was found to be effective in enhancing balance and in the prevention of fall injuries promoting an energetic lifestyle.Kim et al. (2013) investigated the effect of BW in children with cerebral palsy. They examined the efficacy of an eight week programme of BW on gait characteristics of the selected children. Walking speed, weight-bearing symmetry, step and stride length significantly improved after the training.

Retrowalking in musculoskeletal conditions
Retrowalking or BW involves distinctive patterns of muscle activation which overcome deleterious compressive forces at joints such as knee (Flynn and Soutas-Little; 1993). Few studies have been done recently on the use of retromotion in the treatment of knee conditions such as knee injuries and knee osteoarthritis.

Khadilkar and Bedekar (2011) investigated the effect of BW in patients with ACL reconstruction. They studied the effects of BW on dynamic power of quadriceps and hamstring muscles, knee proprioception, spatial and temporal variables of gait such as step length, stride length and cadence following ACL reconstruction. A protocol of ten minutes duration was given in which subjects were asked to walk backwards for a fixed distance. The progression was done by two minutes every week for four weeks. This was given in combination with the usual conventional exercises for ACL reconstruction. Addition of BW in the rehabilitation programme increased the strength of quadriceps and hamstring muscles along with an improvement in the gait parameters. However, knee proprioception remained unaffected.

Mechanical factors such as dynamic joint loading have been associated with progression of musculoskeletal conditions such as knee OA. A greater than normal external knee adduction moment is present during walking in patients with knee OA. They walk with increased loads on the medial compartment of knee (Baliunas et al.; 2002) and exhibit a gait pattern with reduced walking velocity, cadence and stride length along with an increase in stride time and double support time (Gok et al.;2002). These patients tend to decrease pain reducing the knee extensor moment (Kaufman et al.; 2001). They also experience greater axial forces at ankle, knee and hip joints. The treatment strategies used currently in the management of knee OA seek to reduce the first peak knee adduction moment and the load distribution at the knee joint. (Mundermann et al.; 2005).

Gondhalekar and Deo (2013) studied the effect of retrowalking in addition to a conventional exercise programme in chronic knee osteoarthritis. They included three sessions of retrowalking per day for three weeks. Patients performed retrowalking for ten minutes per session on a flat surface with conventional treatment involving short wave diathermy and free exercises. Retrowalking as an adjunct was more effective in decreasing disability in knee osteoarthritis patients than conventional therapy alone. However, pain reduction was seen equally in retrowalking as well as in conventional therapy group.Shankar et al. (2013) investigated the effectiveness of retrowalking in chronic knee osteoarthritis. Subjects with grade 3 knee OA underwent retrowalking on a treadmill with 15 degree inclination since they believed it increased the firing rate of hamstring and quadriceps muscles. One session of ten minutes of retrowalking per day was given for a total of ten days. They reported significant reductions in pain and disability. Significant improvements in balance along with time, speed and distance of FW were also seen.

Khyatee et al. (2013) examined the effects of backward treadmill plain walking on pain and quadriceps muscle strength in subject with knee pain and quadriceps insufficiency. They included a protocol of retrowalking in their study which consisted of backward treadmill walking with a speed of 2 km/hr for five minutes during first five days and then progressed to a speed of 2.5 km/hr for the next five days amounting to a total duration of ten days alongwith a set of closed kinetic chain exercises. Retrotreadmill walking was effective in decreasing pain and increasing quadriceps muscle strength in knee pain and quadriceps insufficiency.

Rathi et al. (2014) performed a study on subjects with grade 1- 3 knee osteoarthritis. They evaluated the effectiveness of a ten minute retrowalking programme in combination with conventional therapy for a period of two weeks for six sessions. Retrowalking combined with conventional physiotherapy treatment was effective in reducing pain and disability and improved quadriceps strength. Nayyar et al. (2015) investigated the effects of retrowalking in grade 3 knee osteoarthritis patients. They compared pre and post intervention outcomes at baseline and on the 4^{th} day of the 4^{th} week. Retrowalking when given in combination with conventional therapy reduced pain, improved balance and functional outcomes. Somashekhar et al. (2015) compared the combination of retrowalking with trancutaneous electrical nerve stimulation and ultrasound therapy in patients with grade 2 chronic knee osteoarthritis. In both the groups, retrowalking was performed on a plane surface in a straight line with great pace for ten minutes with three sessions per day for three weeks. A combination of retrowalking with ultrasound therapy to knee produced better results in terms of reduced pain, improved functional outcomes and increased knee range.

Hasegawa et al. (2010) further explored the extension of BW to backward stair descending in knee OA patients. A three-dimensional motion analysis system compared lower extremity joint angles, joint moments and joint force of the support leg while forward and backward stair descending in knee OA patients. All parameters were found to be reduced in the backward descending movement when compared to forward descending including the joint force of the leading leg at landing. The center of body mass was mainly in control of knee and ankle joints during forward descending while hip joint controlled it during backward descent. Backward descending movement reduced stressful knee joint forces in the leading and the support legs. These changes were accompanied by reduction in knee joint flexion angle; knee extension moment and peak joint force and thus may be beneficial in patients with knee osteoarthritis.

Summary

Incontrovertible evidence exists regarding the role of retrowalking in rehabilitation. Much dissimilarity has been stated between FW and BW. There is scientific proof documenting the benefits of retrowalking in improving cardiorespiratory fitness in injured athletes while decreasing joint compressive forces and increasing muscle strength. It has been stated to be valuable in patients with patellofemoral pain and ACL injury. Although evidence is scarce but retrowalking has been shown to increase balance and improve gait in patients with stroke. Limited facts exist favouring the use of retrowalking in knee osteoarthritis patients where it has been shown to improve balance and decrease pain and disability in knee osteoarthritis. Future studies are required to extensively investigate the benefits of retrowalking in rehabilitation of debilitating neurological and musculoskeletal diseases.

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