The Effect of Backward Treadmill Walking on Lower Extremity Kinetics

Scott Billing

University of North Dakota

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THE EFFECT OF BACKWARD TREADMILL WALKING
ON LOWER EXTREMITY KINETICS

By

Scott Billing
Bachelor of Science in Physical Therapy
University of North Dakota, 1994

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1995
This Independent Study, submitted by Scott Billing in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Signature)
(Faculty Preceptor)

(Signature)
(Graduate School Advisor)

(Signature)
(Chairperson, Physical Therapy)
PERMISSION

Title The Effects of Backward Treadmill Walking on Lower Extremity Kinetics

Department Physical Therapy

Degree Master of Physical Therapy

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Signature

Date 4-17-95
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ACKNOWLEDGMENTS

I would sincerely like to thank the MCRH Sports Acceleration Program for their use of space and equipment, as well as Erin Simunds, M.S., P.T.; Sue Jeno, M.A., P.T.; and Tom Mohr, Ph.D., P.T., for their countless hours of time and support.
ABSTRACT

Many physical therapy diagnoses require minimal anterior loading of the knee in their rehabilitation protocols. These include, but are not limited to, tibial plateau fractures, patellofemoral pain, patellar fractures, quadriceps tendinitis, and status post anterior cruciate ligament reconstruction. In the clinical setting, backward walking (BW), or "retro-walking," is often used during the rehabilitation of such diagnoses. We propose backward walking will initiate greater hamstring recruitment due to the kinematics and kinetics of this gait pattern and thereby result in less anterior knee stress. It is the purpose of this research project to determine if hamstring recruitment can increase in a closed kinetic chain (CKC).

Motor points from the quadriceps (QD), medial hamstrings (MH), lateral hamstrings (LH), and lateral gastrocnemius (LG) were found on the right lower extremity. In addition, footswitch electrodes were placed over the heel, the ball of the great toe, the fifth metatarsal head, and the third metatarsal head. Data were collected from two trials of each forward walking (FW) and BW on a treadmill at two miles per hour.

The percent of maximal voluntary contraction (%MVC) was greatest in the LG, and followed in decreasing order by the VMO, MH, and LH,
respectively. This trend held true for both gait cycles. However, the difference in %MVC was significantly greater ($\alpha = .05$) for the QD, MH, and LH during BW stance compared to forward stance. The LG had less EMG activity, but was not statistically significant. Increases in the electrical activity of the VMO was greater than that of either the MH or LH. Thus, although hamstring recruitment did increase, it was not to the same degree as the VMO. Because of this, backward walking may be best suited for patients who require hamstring strengthening, but particularly quadriceps strengthening.
CHAPTER I
INTRODUCTION

Many physical therapy diagnoses require minimal anterior loading of the knee in their rehabilitation protocols. These include, but are not limited to, tibial plateau fractures, patellofemoral pain, patellar fractures, quadriceps tendonitis, and status post anterior cruciate ligament reconstruction.

Closed kinetic chain exercises are often prescribed soon after weight bearing is allowed for patients with these diagnoses. A kinetic chain refers to a combination of successively linked motor segments.\(^1^3\) Closed kinetic chain (CKC) movements occur when the distal end of the extremity is fixed and produce a predictable pattern of movement in other successive segments. Open kinetic chain (OKC) movements occur when the extremity is freely moving and movements are not always predictable in successive segments. An example of CKC occurs when a person is in a weight-bearing position and OKC occurs when the limb is not in contact with the ground; i.e., in the swing phase of gait.

CKC exercises have advantages over OKC exercises. CKC exercises allow more functional patterns of movement and provide for multiplanar isometric, concentric, and eccentric contractions.\(^1\) There is also a more optimal
development of proprioceptors which may "forget" their role in controlling lower extremity acceleration and deceleration when immobilized.¹

A biomechanical property of CKC is the ability of a muscle to have reverse action.⁴ The insertion is fixed and the origin moves closer to the insertion. For example, knee extension may occur through the contraction of the hamstrings instead of the quadriceps. The medial hamstrings insert on the posteromedial and anteromedial tibial condyle and the lateral hamstrings insert on the lateral tibial condyle.³ This insertion can result in decreased anterior stress on the knee secondary to the resultant post translation of the tibia with hamstring contraction.² CKC biomechanics lead to a rehabilitation activity that is appropriate for many patients with knee pathology.

There is presently discussion regarding how functional OKC exercises may be. If there is distal loading of the tibia in an OKC, the result is an increase in the anterior forces on the knee.² This undue anterior stress can be detrimental to the rehabilitation process. Several authors describe anterior/posterior (A/P) shear force potential and warn against OKC exercises.¹,²,⁵ The magnitude of A/P knee shear force is related to the quadriceps (quad) to hamstring (ham) ratio.² Quad to ham ratios have been observed to be 2.25:1 during isokinetic leg extension exercises at 30 degrees per second (dps) and 4.65:1 for isotonic leg extension exercises at 60 dps. The quad to ham ratio for CKC exercises range from 1.41:1 to 1.64:1² Thus,
with CKC exercises, there is a greater increase in hamstring recruitment than that of the quadriceps.

In many clinics, CKC exercises are used as part of the rehabilitation protocols for the previously mentioned diagnoses. Backward walking, or "retro-walking," is considered a CKC exercise. We propose backward walking will initiate greater hamstring recruitment due to the kinematics and kinetics of this gait pattern. It is the purpose of this research project to determine if hamstring recruitment can increase in a CKC to, in turn, reduce anterior knee stress.

Kinematics and kinetics are of primary concern when considering exercise prescription. Kinematics between forward and backward gait have many differences.

Kinematics

Stance

When comparing forward gait to backward gait, there are many differences. In forward gait, contact is initially made with the heel. The hip flexes during most of stance and reaches its maximum during double support/terminal stance. It then extends through the remainder of the phase. The knee flexes at initial contact, extends through mid-stance, and finally flexes just prior to toe off. The ankle is held in dorsiflexion at initial contact, then rapidly plantarflexes through loading response and dorsiflexes through the remainder of stance.
In backward gait, initial contact is made with the forefoot. Stance involves primarily hip flexion that begins just before contralateral heel off and continues throughout stance. The knee initially extends, remains at a constant position, then flexes again at the period of contralateral toe on, and finishes with heel off. After initial contact, there is a time of rapid dorsiflexion which ends with contralateral heel-off. Then, there is a cycle of slow plantarflexion during the remainder of stance.

Stance duration is shorter during backward walking (BW) than forward walking (FW). In both gait patterns, the amount of stance time is inversely proportional to the speed of walking. However, this is not a linear relationship and the decrease in stance time is significantly greater in backward walking.

Swing

There are pronounced differences in swing phase of gait as well. In forward swing, the hip flexes throughout the cycle. The knee initially flexes, then extends through mid and terminal swing to a position of full extension at the end of swing phase. The ankle dorsiflexes through initial swing to neutral and is then held here through mid and terminal swing.

In backward swing, the hip extends throughout the phase, while the knee flexes until the later part of terminal swing, and then extends slightly. The ankle shows a slight dorsiflexion/plantarflexion episode at heel-off, followed by a comparatively constant position during swing. A summary of BW kinematics is given in Table 1.
Table 1.--Backward Walking Kinematics

**STANCE**

<table>
<thead>
<tr>
<th></th>
<th><strong>Forward Gait</strong></th>
<th><strong>Backward Gait</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Contact</strong></td>
<td>- made with heel</td>
<td>- made with forefoot</td>
</tr>
<tr>
<td></td>
<td>- hip in flexion</td>
<td>- hip flexes</td>
</tr>
<tr>
<td></td>
<td>- knee is extended</td>
<td>- knee is flexed</td>
</tr>
<tr>
<td></td>
<td>- ankle in neutral</td>
<td>- ankle is dorsiflexed</td>
</tr>
<tr>
<td><strong>Loading Response</strong></td>
<td>- hip held in flexion</td>
<td>- hip flexes</td>
</tr>
<tr>
<td></td>
<td>- knee flexes</td>
<td>- knee extends</td>
</tr>
<tr>
<td></td>
<td>- ankle plantarflexes</td>
<td>- ankle dorsiflexes</td>
</tr>
<tr>
<td><strong>Mid-stance</strong></td>
<td>- hip to neutral</td>
<td>- hip flexes</td>
</tr>
<tr>
<td></td>
<td>- knee in flexion</td>
<td>- knee extended</td>
</tr>
<tr>
<td></td>
<td>- ankle in slight dorsiflexion</td>
<td>- ankle plantarflexes</td>
</tr>
<tr>
<td><strong>Terminal Stance</strong></td>
<td>- hip hyperextension</td>
<td>- hip continued flexion</td>
</tr>
<tr>
<td></td>
<td>- knee in neutral</td>
<td>- knee flexes</td>
</tr>
<tr>
<td></td>
<td>- ankle dorsiflexes</td>
<td>- ankle plantarflexes</td>
</tr>
<tr>
<td><strong>Pre-swing</strong></td>
<td>- hip flexion to neutral</td>
<td>- hip continued flexion</td>
</tr>
<tr>
<td></td>
<td>- knee continues flexion</td>
<td>- knee flexion</td>
</tr>
<tr>
<td></td>
<td>- ankle plantarflexes</td>
<td>- ankle continues to plantarflex</td>
</tr>
<tr>
<td></td>
<td>- stance ends toe off</td>
<td>- stance ends heel off</td>
</tr>
</tbody>
</table>

**SWING**

<table>
<thead>
<tr>
<th></th>
<th><strong>Forward Gait</strong></th>
<th><strong>Backward Gait</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial Swing</strong></td>
<td>- hip flexes</td>
<td>- hip extends</td>
</tr>
<tr>
<td></td>
<td>- knee flexes</td>
<td>- knee flexes</td>
</tr>
<tr>
<td></td>
<td>- ankle dorsiflexes</td>
<td>- ankle dorsiflexes then plantarflexes to neutral</td>
</tr>
<tr>
<td><strong>Mid-swing</strong></td>
<td>- hip flexes</td>
<td>- hip extends</td>
</tr>
<tr>
<td></td>
<td>- knee flexes</td>
<td>- knee flexes</td>
</tr>
<tr>
<td></td>
<td>- ankle held in neutral</td>
<td>- ankle held in neutral</td>
</tr>
<tr>
<td><strong>Terminal Swing</strong></td>
<td>- hip flexes</td>
<td>- hip extends</td>
</tr>
<tr>
<td></td>
<td>- full knee extension</td>
<td>- knee extends</td>
</tr>
<tr>
<td></td>
<td>- ankle held in neutral</td>
<td>- ankle held in neutral</td>
</tr>
</tbody>
</table>
Although the kinematics of gait are important when considering exercise prescription, they are not the only factor involved. Kinetics become an important focus when determining what muscles are involved in exercise.

Kinetics

Flynn and Soutass-Little⁹ have run the only combined EMG and joint kinetics study regarding backward gait to date. The study was designed to directly compare muscle firing patterns and the mechanical power of work about the knee during forward running (FR) and backward running (BR). The purpose of their study was to compare selected EMG and kinetic parameters in the stance phase of forward running (FR) and backward running (BR). The muscle peak positive and negative mechanical power and total positive and negative mechanical work were calculated. EMG signals were collected from the right lower extremity on the rectus femoris, vastus lateralis, vastus medialis, biceps femoris, gastrocnemius, and tibialis anterior muscles. Statistical analysis indicated that significantly less peak positive power, negative power, and total positive work occurred at the knee during BR than during FR.

The type of muscle contractions was thus varied. The vastus lateralis and vastus medialis oblique functioned largely in an eccentric and concentric manner during FR, while they functioned in an isometric and concentric manner during BR. Flynn and Soutass-Little⁹ conclude that backward running appears to be a good method for achieving isometric and concentric muscle action of
the VMO and VL and may be useful in clinical conditions that require an increase in knee extensor strength.

Mean positive or negative peak power and total work at the knee joint varied between forward and backward running. Peak power for concentric movements averaged 475 watts in forward running (FR) and 404 watts in backward running. Peak power for eccentric movements was -817 watts in FR and -176 watts in BR. Total work (in joules) for concentric movements was 68 in FR and 26 in BR. In eccentric movements, FR averaged -40 joules of power output and -10 joules in BR.

In addition to differences in power and work, significant differences in muscle firing patterns between conditions were also observed (fig. 1). The percent of stance was calculated for the rectus femoris, vastus lateralis, vastus medialis, biceps femoris, gastrocnemius, and tibialis anterior. These muscles collectively were active 12% more in backward stance than forward stance.

Other research in the area of kinetics was published by Devita and Stribling. They measured lower extremity joint moments of force and joint muscle powers used for BR. They used high speed sagittal plane film records and ground reaction force data describing BR obtained from each of five male runners. BR hip moment and power patterns were similar in magnitude and opposite in direction to FR curves and produced more positive work in stance. Functional roles of knee and ankle muscles were interchanged between backward and forward running. The ankle plantarflexors became the primary
<table>
<thead>
<tr>
<th>Muscle</th>
<th>Initial Contact</th>
<th>Final Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus femoris</td>
<td>______________</td>
<td>FR</td>
</tr>
<tr>
<td>Vastus lateralis</td>
<td>______________</td>
<td>FR</td>
</tr>
<tr>
<td>Vastus medialis</td>
<td>______________</td>
<td>FR</td>
</tr>
<tr>
<td>Biceps femoris</td>
<td>______________</td>
<td>FR</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>______________</td>
<td>FR</td>
</tr>
<tr>
<td>Tibialis anterior</td>
<td>______________</td>
<td>BR</td>
</tr>
</tbody>
</table>

IC 10 20 30 40 50 60 70 80 90 FC

IC = Initial Contact
FC = Final Contact
Normal Firing ______________
Intermittent Firing - - - - -

Fig 1.--Firing patterns of muscles in backward running.⁶
shock absorbers producing the greatest negative power during early stance in BR. FR had greater ankle moment and power output for propulsion and greater knee negative power for impact attenuation. The large knee moment in BR indicated that BR training leads to increased knee extensor torque capabilities.

Retro-walking shows promise as a viable therapeutic exercise first because of its kinetics. If the ground reaction force can be absorbed in the forefoot and calf musculature, less force is transferred up to the knee, which may lead to less knee joint stress. Secondly, and perhaps more importantly for physical rehabilitation, Flynn and Soutass-Little have observed hamstring firing to increase 10% in backward running as compared to forward running. This may be due to the fact that a closed kinetic chain allows knee extension to occur through the reverse action of the hamstrings. An increase in hamstring recruitment may translate into decreased anterior stress on the knee joint.
CHAPTER II
METHODS
Subjects

Forty-two physical therapy graduate students ages 20 to 35 were surveyed. Eighteen were free of knee pain, any present knee ligament instability, and were able to perform treadmill walking without any pain. Six subjects were randomly chosen through sampling with replacement. All were informed of the purpose of the study, their rights as human subjects, and were given an opportunity to ask questions before they signed their consent form approved by the Institutional Review Board at the University of North Dakota (Appendix A).

Electromyography

Motor points for the quadriceps (QD), medial hamstrings (MH) lateral hamstrings (LH), and lateral gastrocnemius (LG) were found on the right lower extremity through the use of a small electrical stimulator. The skin over the motor point was then shaved and wiped with alcohol. After the skin was prepared, pre-gelled, self-adhesive electrodes were attached to the skin. In order to minimize “cross talk” between muscle groups, surface electrodes were placed 2 cm apart over the motor point of interest.11
A foot switch was used to determine when initial and final contact were made with the right lower extremity. Switch electrodes were placed 1) over the heel, 2) the ball of the great toe, 3) the fifth metatarsal head, and 4) the third metatarsal head. The electrodes were secured with tape to prevent migration during exercise.

An electrogoniometer was then applied to the right knee to obtain ROM. The proximal end of the goniometer was aligned with the long axis of the femur, and the distal end with the long axis of the fibula. Both proximal and distal ends were fixed with tape to reduce migration of the instrument during exercise. Knee goniometric zero was obtained by having the subject stand with his/her involved leg in full extension. The researcher verified the angle of zero with a hand-held goniometer. When $0^\circ$ was observed by the researcher, the computer was calibrated to zero.

The electrodes from the examined muscles, foot switch, and electrogoniometer were then connected to the transmitter which sat in a Velcro belt secured at the waist. EMG signals were first telemetered to a receiver, and then to a Noraxon computer. Both raw and rectified EMG data were obtained. Raw data provided information on timing of activity, while rectified EMG gave a quantitative value of the muscular activity.

Data Collection

The subjects were instructed on properly loading onto and off the treadmill for both forward and backward walking. They were also educated on
proper safety techniques for the exercise which included placing their hands on the railing in front of them to help provide greater stability.

They were then given a five-minute warm-up period to familiarize themselves with both forward and backward treadmill walking. After the warm-up period, maximal voluntary contractions (MVC) of the quadriceps, hamstrings, and gastrocnemius were performed to allow for normalization of the EMG data. The positioning for MVC test was performed in the standard manor of manual muscle testing described by Daniels and Worthingham, with the exception of ankle plantarflexion which was modified and performed in prone to accommodate the equipment secured at the waist.

Data were collected from two trials of forward walking at two miles per hour. The subjects were instructed to "step onto the treadmill and begin walking forward." Collection continued for 15 seconds and then the subjects were then instructed to 'step off the treadmill and stop." The same procedure was followed for the second trial.

After a one-minute rest period, data were collected from two trials of backward walking. The subjects were instructed to "step onto the treadmill and begin walking backward." Collection continued for 15 seconds and the subjects were then instructed to "step off the treadmill and stop." The same procedure was followed for the second trial.

When data collection was concluded, the electrodes were removed from the subject's leg. The skin was cleaned with an alcohol wipe and this
concluded their participation in the study. Results were made available at the subject’s request.

Data Reduction

Analysis of the EMG data was performed using both Myosoft and Norquest software. The second trial was analyzed to allow for maximal learning of the gait cycles and procedure of testing. Average peak activity (APA) of the gait cycles was quantified by first choosing three random stance phases of forward and backward gait. Stance was defined as the period from great toe contact to heel off in BW and from heel contact to great toe off in FW. Within the stance phases analyzed, the computer identified the 30 greatest values of electrical activity. An average value for these peaks was then calculated by the computer to give a quantitative measure of APA.

To obtain the value for the APA of MVC, the same procedure was used with the exception that instead of three random gait cycles, the middle three seconds of muscle contraction were used. The 30 greatest values of electrical activity were again identified, and an average value for APA was calculated by the computer.

Statistical Analysis

Percent of MVC (%MVC) was calculated by dividing the APA of the MVC by the APA of the stance phase of the gait cycle. Average %MVC was then calculated for the stance phase of both forward and backward walking.
A paired t-test was performed to compare the %MVC of the two separate gait cycles. Alpha level was accepted at the p < .05 (two-tail) level of significance.
CHAPTER III

RESULTS

The raw data from the second trial was analyzed. Raw APA and calculated %MVC are given in Table 2. The average %MVC (Table 3) was calculated from these data. This analysis showed that during the stance phase of FW, the LG had the greatest %MVC followed by the VMO, MH, and the LH (fig. 2). The same pattern was observed during the stance phase of BW. All muscle groups, except the LG, showed a trend of more EMG activity during BW stance. This difference was significantly greater ($\alpha = .05$) for the QD, MH, and LH during BW stance (Table 4). The trend of less EMG activity in LG was not statistically significant.
Table 2.--Raw APA Data and Calculated %MVC

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Subject 1 APA %MVC</th>
<th>Subject 2 APA %MVC</th>
<th>Subject 3 APA %MVC</th>
<th>Subject 4 APA %MVC</th>
<th>Subject 5 APA %MVC</th>
<th>Subject 6 APA %MVC</th>
<th>%MVC x %MVC</th>
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<tbody>
<tr>
<td>QUADS</td>
<td>129</td>
<td>1568</td>
<td>8.23</td>
<td>44</td>
<td>387</td>
<td>11.37</td>
<td>16</td>
<td>173</td>
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<tr>
<td>M.HS</td>
<td>145</td>
<td>1026</td>
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<td>112</td>
<td>1011</td>
<td>11.08</td>
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<td>GASTROC</td>
<td>393</td>
<td>1101</td>
<td>35.69</td>
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<tr>
<td>Trial 2</td>
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<tr>
<td>QUADS</td>
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<td>11.63</td>
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<th>Subject 2 APA %MVC</th>
<th>Subject 3 APA %MVC</th>
<th>Subject 4 APA %MVC</th>
<th>Subject 5 APA %MVC</th>
<th>Subject 6 APA %MVC</th>
<th>%MVC x %MVC</th>
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<td>1101</td>
<td>11.72</td>
<td>77</td>
<td>685</td>
<td>11.24</td>
<td>74</td>
<td>203</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QUADS</td>
<td>246</td>
<td>1568</td>
<td>15.69</td>
<td>146</td>
<td>387</td>
<td>37.73</td>
<td>44</td>
<td>173</td>
</tr>
<tr>
<td>M.HS</td>
<td>199</td>
<td>1026</td>
<td>19.40</td>
<td>262</td>
<td>1101</td>
<td>25.91</td>
<td>47</td>
<td>271</td>
</tr>
<tr>
<td>L.HS</td>
<td>263</td>
<td>1838</td>
<td>14.31</td>
<td>107</td>
<td>760</td>
<td>14.08</td>
<td>56</td>
<td>279</td>
</tr>
<tr>
<td>GASTROC</td>
<td>152</td>
<td>1101</td>
<td>13.81</td>
<td>87</td>
<td>685</td>
<td>12.70</td>
<td>78</td>
<td>203</td>
</tr>
</tbody>
</table>

QUADS = Quadriceps  
M.HS = Medial Hamstrings  
L.HS = Lateral Hamstrings  
GASTROC = Gastrocnemius
Table 3.--Calculated Mean Percent of Maximal Voluntary Contraction (%MVC)

<table>
<thead>
<tr>
<th></th>
<th>Forward Walking:</th>
<th>Backward Walking:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadriceps</td>
<td>9%</td>
<td>Quadriceps</td>
</tr>
<tr>
<td>Medial Hamstrings</td>
<td>13%</td>
<td>Medial Hamstrings</td>
</tr>
<tr>
<td>Lateral Hamstrings</td>
<td>10%</td>
<td>Lateral Hamstrings</td>
</tr>
<tr>
<td>Lateral Gastrocs</td>
<td>68%</td>
<td>Lateral Gastrocs</td>
</tr>
<tr>
<td>Muscles Compared</td>
<td>( t ) value</td>
<td>( p )</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------</td>
<td>--------</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>-3.31</td>
<td>.021</td>
</tr>
<tr>
<td>Medial Hamstrings</td>
<td>-3.72</td>
<td>.014*</td>
</tr>
<tr>
<td>Lateral Hamstrings</td>
<td>-5.90</td>
<td>.002*</td>
</tr>
<tr>
<td>Lateral Gastrocnemius</td>
<td>1.40</td>
<td>.219</td>
</tr>
</tbody>
</table>

* significant at \( p \leq .05 \)
CHAPTER IV
DISCUSSION

This study found that there was significantly greater EMG activity for the VMO, MH, and LH in the stance phase of backward walking compared to the stance phase of forward walking. The increase seen in hamstring activity was expected.

Increases in the MH and LH %MVC may have occurred through an increased demand for isometric contractions. Isometric contractions are needed to counteract ground reaction force and maintain a specific angle at the joint. In the hamstrings, this type of contraction would be needed to control hip flexion. This study incorporated no cinematography to determine exactly what angles were occurring at the hip, but Grey claims that there is a significant increase in hip flexion with backward gait. He feels that the hamstrings 1) function to initiate hip extension and knee flexion for backward swing and 2) contract to control hip flexion. This may be an explanation for the increase we observed in hamstring EMG activity.

Changes in the kinematics at the knee may also demand an increase in isometric activity of the hamstrings. Vilinsky states that initial contact is made with the knee in flexion and terminal extension occurs in the final stage of
stance. An increase in hamstring activity may be needed to refine this movement, thus preventing uncontrolled knee extension.

In contrast to the original hypothesis, the EMG activity of the VMO increased to a greater degree than that of the MH or LH. The difference in the \%MVC of the VMO may be attributed to initial contact being made with the forefoot during BW. In this situation, the knee is in greater flexion than FW. With the knee in flexion, the body's center of gravity falls posterior to the knee joint placing a greater demand on the quadriceps muscle group to counteract the tendency for continued knee flexion. Flynn and Soutass-Little state the muscle action of the knee extensors to be primarily isometric and concentric in nature for the stance phase of BR. If this were also the case in BW, it would account for the increase in EMG activity.

The lateral gastrocnemius did not show an increase in EMG activity as did the VMO and the hamstrings during BW. This would contrast the claims of Divita and Stribling who state that the ankle plantarflexors are the primary shock absorbers and produce the greatest negative power in backward running due to eccentric muscle contraction. Eccentric muscle activity produces more force than either concentric or isometric contractions. Thus, the \%MVC observed would be expected to be greater. According to Basmajian, both ballistic and eccentric muscle contractions may be difficult to detect with surface EMG. This may explain the decrease in activity of the LG observed in this study.
This study shows a trend for increased quadriceps activity during BW. Thus, this exercise may not be best suited for all diagnoses that require minimal loading of the extensor mechanism of the knee. However, anterior/posterior (A/P) shear may be reduced via general weight bearing through the knee. The magnitude of A/P shear force is related to quadriceps to hamstring ratio.\textsuperscript{13,14} According to Shelbourne and Nitz,\textsuperscript{15} closed kinetic chain exercises reduce A/P shear by increasing the joint compressive forces that occur when the extremity is loaded by body weight. Body weight provides joint stability and allows for more strenuous strengthening workouts without the degree of shearing forces that occur with open kinetic chain exercises. A decrease in A/P shear is indicated in the early stages of ACL rehabilitation, when stretching of the new graft is not desirable.\textsuperscript{15}

Although the %MVC increased to a greater magnitude in the VMO than the hamstrings in BW stance, the quadriceps to hamstring ratio (Q:H) in this study was 1.32:1 (Table 5). In a study by Graham et al,\textsuperscript{2} closed kinetic chain Q:H were shown to range from 1.41:1 to 1.64:1. These ratios are less than those of OKC exercises which have been reported to range from 2.25:1 to 4.65:1.\textsuperscript{13,14,16} It would appear that BW would be a good method of strengthening the hamstrings and particularly the VMO without excess A/P shear force.
Table 5.--Quadriceps to Hamstrings Ratios (%MVC)

<table>
<thead>
<tr>
<th></th>
<th>Forward Walking</th>
<th>Backward Walking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quad to Medial Hamstrings</td>
<td>1:1.44</td>
<td>Quad to Medial Hamstrings 1.24:1</td>
</tr>
<tr>
<td>Quad to Lateral Hamstrings</td>
<td>1:1.11</td>
<td>Quad to Lateral Hamstrings 1.40:1</td>
</tr>
<tr>
<td>Quad to Average Hamstrings</td>
<td>1:1.28</td>
<td>Quad to Average Hamstrings 1.32:1</td>
</tr>
</tbody>
</table>
CHAPTER V

CONCLUSIONS

One should be careful when comparing the Q:H values of this study to that of Graham's. For an exercise to be considered for therapeutic rehabilitation, both the magnitude of muscle activity and the total time of contraction should be taken into account. A muscle may have large EMG values for a very short time, thus resulting in large %MVC values. For an exercise to be effective for rehabilitation, it should have activity over prolonged time for maximum benefit.\(^1\) This study did not address the issue of time of contraction.

Although it would seem that this type of exercise would be optimally suited for patients status post anterior cruciate ligament reconstruction, it should also be noted that the subjects in this study were screened for knee dysfunction. At the present time, there is no way to assess how joint effusion, decreased range of motion, and altered joint mechanics will affect the lower extremity kinetics of this exercise.

In addition to the concerns of pathology, lack of cinematography is one of this study's greatest limitations. It is very difficult to account for the changes in EMG activity that we saw with BW. At this point, we can only hypothesize
using earlier studies as reference. It should also be noted that nothing was
done to control variables such as pronation or supination of the foot, excess
tibial torsion, or extremes in genu valgus or varus, all of which will affect the
timing and magnitude of muscular action about the knee in a closed kinetic
chain.

In this study, muscles at the hip and ankle were not included. The
changes that we have seen may not necessarily be due to the kinetics and
kinematics occurring at and about the knee. As stated by Bunton,1 a CKC is a
chain that is affected by all the other components of that chain.

Future studies are needed to determine 1) exactly what is the timing of
activation of muscles, 2) what is the duration of contraction of the muscles
firing, and 3) if the increase in %MVC for the VMO and the hamstrings holds
true with pathological ACL patients. These studies should include the hip and
ankle as well as cinematography to more accurately account for kinematics and
lower extremity position and the resultant influence on lower extremity kinetics.
Backward treadmill walking is a therapeutic modality used commonly in the health care setting as part of the protocol for many lower extremity rehabilitation programs. One factor that often needs to be avoided with lower extremity rehabilitation is anterior stress on the knee complex. Closed kinetic chain exercise (CKC) has been shown to reduce anterior shear and loading through increased hamstring recruitment. Backward treadmill walking is a CKC exercise but, at present, there is no literature supporting increased hamstring recruitment during this activity. It is the purpose of this study to discover if backward treadmill walking can increase hamstring recruitment.

Six physical therapy graduate students aged 20-35 will participate in this study. They will have no present knee pain or ligamentous instability. Electromyographic (EMG) data will be recorded from the Quadriceps, Medial Hamstrings, Lateral Hamstrings, and Gastrocnemius muscles during both forward and backward treadmill walking. Statistical analysis of these data will be conducted to determine if there is a significant difference between hamstring recruitment in the two gait cycles.

The use of human subjects is necessary because clinically-based results are directly applicable to patient treatment.
PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

Subjects

Six physical therapy graduate students ages 20-35 will be used as subjects. All will be free of knee pain or any present knee ligament instability. Subjects will be informed of the purpose of the study, their rights as human subjects, and will be given an opportunity to ask questions before they sign their consent forms.

Procedure

EMG data will be collected on the right lower extremity of each subject. All mentioned techniques are common clinically and pose minimal risk to each subject.

Motor points from the quadriceps (QD), medial hamstrings (MH), lateral hamstrings (LH), and gastrocnemius (GN) will be found through the use of a small electrical stimulator. The skin over the motor point will be shaved and wiped with alcohol. After the skin is prepared, the electrodes, which are pre-gelled and self-adhesive, will be attached to the skin. The electrodes will then be connected to the transmitter which will sit in a Velcro belt secured at the waist. EMG signals will be telemetered to a receiver and then to a computer. Raw and rectified EMG data will be obtained. Raw data provide information on timing of activity while rectified EMG gives a quantitative value of the muscular activity.

The subject will be given a five-minute warm-up period to familiarize themselves with both forward and backward treadmill walking. Maximal voluntary contractions of the Quadriceps, Hamstrings, and Gastrocnemius will be performed to allow for normalization of the EMG data. Data will then be collected from two trials of both forward and backward walking at two miles per hour. Collection will continue for one minute per trial.

Electrodes will then be removed from the subject's leg, using proper removal technique. This will conclude his/her participation in the study. Results of the study will be made available at the subject's request.

EMG data will be statistically analyzed and the results will be reported. The subject's name will not be included anywhere in the report nor mentioned to anyone not involved in the study to maintain confidentiality.
3. **BENEFITS:** (Describe the benefits to the individual or society.)

Possible benefits to the health care practitioner include but are not limited to: (1) furthering knowledge concerning the kinetics of backwards treadmill walking so this rehabilitation modality can be applied more appropriately to patients with knee pathology and (2) further research may be stimulated.

4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

Possible physical risks in this study are minimal. The motor point location and EMG analysis are non-invasive techniques utilized in clinical practice.

In treadmill walking, there is the chance that the subject may trip and/or fall. We will reduce this possibility by using a treadmill that is equipped with handrails as well as an appropriate training period for each subject on the treadmill.

Minimal skin irritation from the EMG surface electrodes is also a possibility during this study. The possibility will be minimized by proper skin preparation prior to the study.

Subjects may experience slight fatigue following their participation. This would be no worse than that produced during minimal physical exercise.

Subjects are able to withdraw from the study at any time without fear of reprisal.
5. **CONSENT FORM**: A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

Consent forms will be kept in Sue Jenos' office, Room 151, Medical Science North Building for a two-year period.

6. **For FULL IRS REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

   Office of Research & Program Development  
   University of North Dakota  
   Box 8138, University Station  
   Grand Forks, North Dakota 58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall.

**For EXEMPT or EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

**SIGNATURES:**

__________________________  DATE: ____________________

Principal Investigator

__________________________  DATE: ____________________

Project Director or Student Adviser

__________________________  DATE: ____________________

Training or Center Grant Director

(Revised 8/1992)
STATEMENT OF INFORMED CONSENT

You are being invited to participate in a research project conducted by Scott Billing, Graduate Physical Therapy Student at the University of North Dakota. It is intended to study the effects of backward treadmill walking on hamstring recruitment. The purpose of this study is to discover if the biomechanical properties inherent with backward walking have an effect on this muscle group.

You were selected on the basis of the questionnaire that you completed regarding present knee pain and ligamentous instability. You will be asked to schedule a one-hour time period, at your convenience, during which time the research will be conducted. You are asked to wear or bring loose-fitting shorts to the study. Treadmill walking and application of the electromyographic electrodes will require your thigh and leg musculature to be exposed.

Upon arrival you will:

1. Be evaluated for ligamentous instability of the knee.
2. Be evaluated with a small electrical stimulator to find the motor points of your quadriceps, medial hamstrings, lateral hamstrings, and gastrocnemius muscles. This will cause a mild tingling sensation.
3. The areas over these motor points will be shaved and wiped with alcohol.
4. Four electromyographic (EMG) electrodes, which are self-adhesive, will be applied to the shaved areas.
5. You will be given a five-minute warm-up period to familiarize yourself with both forward and backward treadmill walking.
6. Maximal voluntary contractions of the quadriceps, hamstrings, and gastrocnemius will be performed to allow for normalization of data.
7. You will walk forward on the treadmill at a speed of two miles per hour. Two one-minute trials will be performed.
8. You will be given a two-minute rest period.
9. You will be asked to walk backward on the treadmill at a speed of two miles per hour. Two one-minute trials will be performed.

All the above measures are common exercise durations in physical therapy clinics. Total time required should not surpass one hour.

Although the process of treadmill walking always involves some degree of risk, the investigator in this study feels that the risk of injury or discomfort is minimal. The electrical stimulation used to find the electrode placement causes only minimal discomfort, and the electrodes used to monitor the muscle activity should cause no discomfort whatsoever.
The amount of physical activity you will be asked to perform is minimal compared to what you probably already do in a normal day.

Possible benefits include, but are not limited to: (1) furthering knowledge concerning the kinetics of backward treadmill walking and (2) further research on this topic may be stimulated.

Participation in this study is completely voluntary. You may withdraw at any time without fear of reprisal. Any questions concerning the study can be answered by contacting Scott Billing at (701) 775-4073 (home) or (701) 777-2831 (school). Your name will not appear anywhere in the study nor will it be made available to the general public.

I have read all of the above and willingly agree to participate in this study. All of my questions have been answered in regard to this study and I have been encouraged to seek answers for questions that may arise in the future. Information has been explained to me by Scott Billing.

________________________________________  ____________________________
Signature                                      Date

I have discussed the above points with the subject and it is my belief that he/she understands the risks, benefits, and responsibility involved in participation in this project.

________________________________________  ____________________________
Signature                                      Date
REFERENCES


