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Four Weeks of Minimalist Style Running Training Reduced Lumbar Paraspinal Muscle Activation during Shod Running

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FOUR WEEKS OF MINIMALIST STYLE RUNNING TRAINING REDUCED LUMBAR PARASPINAL MUSCLE ACTIVATION DURING SHOD RUNNING

By

Stephanie Barton

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A doctoral project submitted in partial fulfillment

of the requirements for the

Doctorate of Physical Therapy

Department of Physical Therapy

School of Allied Health Sciences

The Graduate College

University of Nevada, Las Vegas

May 2015

We recommend the doctoral project prepared under our supervision by

Stephanie Barton, David Brown, and Talia Joyce

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Four Weeks of Minimalist Style Running Training Reduced Lumbar Paraspinal Muscle Activation during Shod Running

is approved in partial fulfillment of the requirements for the degree of

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ABSTRACT

Background and Purpose: Research has shown that the risk of low back dysfunctions in runners is related to the increased mileage of distance running. Repetitive shock loading of the spinal structures during running has been indicated as one of the important biomechanical mechanisms underlying such injury. Acute changes in foot strike pattern, like those seen during minimalist style running, have been shown to lead to modifications in lumbar range of motion. Minimalist style running could lead to changes in lumbar biomechanics and muscle activation, potentially reducing the loading on the musculoskeletal structures of the lower back. However, the long term effects of minimalist style running on lumbar biomechanics have not been evaluated. The purpose of this study was to investigate the effects a 4-week training program aimed at transitioning recreational runners to minimalist style footwear would have on lower back kinematics and lumbar paraspinal muscle activation.

Subjects: 17 volunteers between the ages of 18-45 years who were habitually shod runners and averaged running 10-50 km per week participated in the study. Data from 15 volunteers was used in the analysis of the biomechanics. Inclusion and exclusion criteria were used to determine the appropriateness of each volunteer for this study.

Methods: Subjects participated in three data collection sessions at the beginning, during (2-week), and at the end of a 4-week training program. The training consists of progressively increasing the distance each runner ran in the minimalist shoes up to 30-50% of their regular running distance while maintaining the overall distance (minimalist + normal shoes) comparable to before training. Running trials were collected with the subject wearing their normal running shoes. Subjects were asked to run at a prescribed speed (11.2 km/h), and a blinded self-selected speed. During running, kinematics of the lower back in the sagittal plane was recorded using an electro-goniometer. Surface EMG was used to monitor the activation of the lower back (L3 level) paraspinal muscles. Data collected during 10 stance phases were averaged and used for analysis. One-way repeated measures ANOVA tests were used to analyze the effect of training on lumbar kinematics and lumbar paraspinal muscle activation.

Results: For the 11.2 km/h running speed, statistically significant differences were found in mean lower back posture (PRE = 1.9 ± 15.3 degrees, MID = 0.4 ± 13.0 degrees, POST = -6.0 ± 13.3 degrees, p = 0.001) and contralateral lumbar paraspinal muscle activation (PRE = 47.0 ± 34.0%, MID = 24.9 ± 8.2%, POST = 29.4 ± 11.3%, p = 0.039) after training. For the self-selected running speed, statistically significant differences were found in mean lower back posture (PRE = 2.3 ± 15.5 degrees, MID = 0.9 ± 13.9 degrees, POST = -5.7 ± 14.2 degrees, p = 0.002) and contralateral lumbar paraspinal muscle activation (PRE = 41.6 ± 28.6%, MID = 23.4 ± 6.2%, POST = 30.3 ± 11.6%, p = 0.047) after training. During both speeds, lower back posture became more extended and contralateral lumbar paraspinal muscle activation decreased. No significant differences were noted in overall lower back range of motion or ipsilateral paraspinal muscle activation over the training period at either speed.

Conclusions: Including minimalist running shoes and barefoot exercises into a runners' training regime can alter the lumbar spinal kinematics and muscle activation. Specifically the runners adapted a more extended lumbar posture and reduced the lumbar paraspinal muscle activation after training. This effect carried over to shod running.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Running is a popular form of exercise to promote fitness and health. It is also one of the quickest expanding participation segments of all exercises in the U.S. It was estimated that 19 million people ran more than 100 times in the year of 2011, a 9.3% increase from 2010.[1] The number of marathon finishers increased by more than 75.5% in the last decade.[2] In addition, in 2013 it is estimated that a record high 541,000 people finished at least one marathon distance race.[3] The increases in endurance road races may be attributed to the high increases in recreational runners competing for personal achievement and health benefits associated with distance running. However, according to a 2013 survey on running event participants, 10.1% of the runners reported experiencing a running injury to their lower back region in the last 12 months.[5] This is an increase from the 9.4% reported in 2011.[6] Walter et al. has shown injuries pertaining to the back, pelvis, hip and thigh account for approximately 25-35% of all running related injuries.[7] In addition, it has also been shown that running more than 20 miles per week increases the odds of persistent LBP five-fold.[8]

The foot strike impact and the associated repetitive loading of the spinal structures from the ground reaction force has been proposed as a likely mechanism underlying running related injuries including lower back dysfunctions.[3,9,10,11] In an imaging study by Dimitriadis et al., the researchers observed significant strain in the intervertebral discs after 1 hour of running. Furthermore, the disc-height reduction was concentrated in the lumbosacral region of the spine.[12] Similarly, Garbutt et al. observed that running speed is positively related to the extent of stature shrinkage measured immediately after running.[13] It is therefore logical to believe that the magnitude of loading of the spinal structures during running is an important contributing factor to the development of lower back pain in runners. Consequently, the inability for a runner to attenuate the shock loading may lead to increased shock loading and risk of developing lower back pain over time. In fact, Hamill et al. has demonstrated that runners with lower back pain exhibited the greatest lower extremity joint stiffness during running.[11]

The recent growing interest in the body's natural ability to attenuate the shock has led to the resurgence of the use of minimalist footwear and barefoot running as a means to reduce the risk of running related injuries.[14] The popularity in a shift towards minimalist running style has been created based on the theory that it results in a foot strike shift form the midfoot or forefoot, while reducing stride length and increasing stride frequency. Such alterations in running parameters reduce the shock of foot strike on the knee and hip-pelvis-lumbar complex, due to the attenuation more distally at the foot and ankle.[15,16,17] The overall more "compliant" movement pattern has been considered to reduce the adverse effects of impact loading and is safer for the musculoskeletal health of runners.

A previous study from Delgado et al demonstrated that acute changes in foot strike location from the heel to the forefoot when barefoot can lead to decreased overall lumbar range of motion in the sagittal plane during running.[18] Significantly reduced shock attenuation and leg impact during the forefoot running were also observed. The authors speculated that in forefoot running, less force was transmitted to the lumbar spine resulting in the overall reduction of the lumbar range of motion. However, there are a number of important limitations in this study: first, the effects of foot strike pattern on lumbar kinematics were examined in a single data collection session. The participants were instructed to run in a certain pattern, which may or may not translate to long-term movement change. The runners also reported that the forefoot strike pattern to be more uncomfortable. Second, while the overall reduction in lumbar range of motion was observed, this may be resulted from an increase in lumbar paraspinal muscle activation.

Third, clinically it may be unrealistic and ill-advised to suggest drastic changes in footwear and running style in common runners. It may be more important to evaluate the long-term benefits of minimalist-style running as a training tool to induce the beneficial movement pattern changes.

The purpose of this study was to investigate the effects of a 4-week transition program to minimalist style running on the lower back kinematics and lumbar paraspinal muscle activation in runners habitually wearing traditional cushioned running shoes. The goal of the transition program was to allow the runners to gradually incorporate minimalist style running into up to 50% of their regular training mileage. Specifically, we investigated if the minimalist style running training can affect the runner's lumbar posture and muscle activation during their habitual shod running condition. We hypothesized that by incorporating the minimalist style running to the runners' training, there will be a reduction of paraspinal muscle activation during the stance phase of running.

METHODS

Subjects

A sample of convenience of 17 volunteers from the southern Nevada running population were recruited to participate in the study. The inclusion criteria for the participants were: 1) age 18-45 years (to avoid arthritic changes associated with older age); 2) current recreational runners who run 10-50 km during a typical week and 3) engaged in habitually shod running. Participants were excluded from the study if they exhibit any of the following: previous experience with minimalist or barefoot running, any orthopedic surgeries that permanently change the musculoskeletal structure of the lower extremity and spine (i.e. joint replacement, ACL reconstruction, spinal discectomy…etc.), any injuries or conditions within the last 8 weeks that prevented their normal running training, and any conditions that prevent running safely on a treadmill. Two participants dropped out of the study due to an unrelated athletic injury and personal reasons, resulting in 8 male and 7 female participants who completed the 4-week program (Table 1).

Table 1. Demographic, anthropometric and running training characteristics of study participants; mean ± standard deviation

	Mean ± SD
Age, years	24.67 ± 2.637
Weight, kg	70.447 ± 12.682
Height, m	1.719 ± 0.091
Body Mass Index	23.867 ± 2.688
Gender	
Female	7
Male	8
Habitual foot strike pattern (pre-training)	
Rearfoot	10
Midfoot	4
Forefoot	1
Running Training Distance, km	
Typical week	17.261 ± 5.463
Week Prior to Intervention	13.391 ± 7.328
Single Run	5.366 ± 1.817

Prior to participation, the objectives, procedures, and risks of the study were explained to each participant. Informed consent approved by the Institutional Review Board of the University of Nevada, Las Vegas was obtained.

Instrumentation

All testing was done with the participants running on a Precor treadmill with the side rails removed (PrecorC956; Woodinville, WA, USA). Lower back motion was captured using a twin-axis goniometer (SG Series; Biometrics Ltd., Newport, UK) connected to a wireless transceiver (Delsys Trigno Biaxial Goniometer Adapter; Delsys Inc., Natick, MA). The goniometric data was capture at 2000 Hz in the sagittal plane, and 148 Hz in the frontal plane. Electromyography (EMG) signals of the paraspinal muscles were captured using wireless EMG electrodes (Delsys Trigno Wireless System). The inter-electrode distance is 10 mm. Foot strike incidents were recorded using two thin film pressure sensors (Model 402; Interlink Electronics Inc. Camarillo, CA, USA) placed inside of the shoes connected through a Delsys wireless transceiver (Delsys Trigno 4-Channel FSR Sensor). The pressure sensor is round and 12.7 mm in diameter with a thickness of 0.45 mm. The minimal actuation force is 0.1N. Foot strike pressure data was sampled at 2000 Hz for the rearfoot, and 148 Hz for the forefoot. EMG, lower back motion goniometry, and foot strike pressure data were synced with the motion capture system through a trigger module.

Procedure

Data was collected at the Sports Injury Research Center at the University of Nevada, Las Vegas. Each participant was tested in three testing sessions (PRE, MID, POST); the PRE session was conducted on the day prior to the beginning of the 4-week transition program; the MID was at the 2-week point; the POST was completed at the end of the program (4-week).

During each session, the testing began by measuring the runner’s height, weight, and other demographic and anthropometric information. The runner was then instructed to lie prone on a treatment table for EMG electrode placement. The skin surface of the back at the lumbar (L3-L4) level was cleaned with an alcohol swab and an abrasive rub. Pairs of wireless EMG electrodes were placed over the runner's lumbar paraspinal muscles belly bilaterally.

Maximal voluntary isometric contraction (MVIC) trials were conducted for the purpose of normalizing the muscle activation level. A strap was placed across the chest area and another across the gluteal region in order to stabilize the subject on a treatment table. The straps were placed so the spine was in a neutral alignment. Two investigators provided additional stabilization of the legs as the person performed the maximal back extension. The participant was asked to perform maximal isometric contraction of the spinal extensors for five seconds during each trial. Two MVIC trials were collected. Next, the goniometer was secured to the participant's lower back centered on the L3 level (spanning L2 to L4). Two pressure sensors were attached to the plantar surface of the foot of the dominant leg (defined as the leg they prefer to kick a ball with). One sensor was attached to the rearfoot and the other on the first metatarsal head.

The testing began with a warm-up period in which the subject walked on the treadmill beginning at 3 mph for one minute, the speed increased 0.5mph every minute until the runner reached the prescribed running speeds. This was important for the runner to familiarize with running with the attached instruments. If the runner reported discomfort during this period or if any instruments malfunctioned during this period, the investigators made necessary adjustments before the runner resumed warm-up. The runner wore their usual running shoes during the first phase of the testing. The runner was asked to run at 2 different speeds: 7 mph and a self-selected speed. The runner was unable to see the treadmill display while selecting the self-selected speed as an investigator changed the speed according to the runner's indication. They were instructed to select a speed that felt close to their typical running training speed. Three 20-second trials were collected at each speed. After the running trials were collected, the runner was given a short rest period (~5 minutes) and fitted with a pair of standardized minimalist shoes (Brooks® PureDrift; Brooks Sports, Inc., Seattle, WA, USA; Figure1). The sock liner of the shoes was removed as specified by the manufacturer to nullify the heel-to-toe offset. The testing protocol was repeated in this second phase with the runner wearing the minimalist shoes during the trials.

Figure 1. Brooks® PureDrift

After the running data collection session, the runner completed a survey regarding the history of their training. An investigator explained the transition program the runner was to adhere to for the next four weeks. A pair of minimalist running shoes identical to the pair the runners wore during testing was given to each runner.

Transition to Minimalist Style Running

Every two weeks the runner was instructed to increase the distance they ran in their minimalist shoes by only 10-20%. This was intended to allow the runner to safely make the transition to doing 30 - 50% of their running in the minimalist shoes by the end of 4 weeks. This program was designed to decrease the risks that are present in transitioning to a minimally shod running style. Since it is recommended that minimalist shoe running should be gradually incorporated into a person's normal running regimen to allow the intrinsic foot muscles and other body structures to adapt to the different mechanics, a progressive increase in the distance run in the minimalist shoes was recommended.

Postural changes were recommended to the runner according to published anecdotal guide books.[19] These postural change suggestions included keeping the head level with shoulders relaxed and trunk straight, engaging the core muscles and a slight bend at the knee throughout the running stride. The runners were also recommended to try to land upon the forefoot as gently as possible. However, no explicit feedback regarding their running form was given to the runners.

Table 2. A weekly progression for the transition into minimalist shoes is outline below including the average preferred running speed recorded during the three sessions. Drills were recommended to reduce the risk for injury.

	Percentage Recommended to run in Minimalist Footwear	Ave. Preferred Running Speed in m/s		Recommended Drills to be Performed
		regular	minimalist	
Week 1	10%	3.25 ± 0.33	3.21 ± 0.35	Walk in Place 2x/day Marble drill 1x/day
Week 2	20%	3.13 ± 0.31	3.14 ± 0.27	Jump drill 2x/day Walk in Place 2x/day Marble drill 1x/day
Week 3	20%-30%	N/T	N/T	Jump drill 3x/day Walk in Place 2x/day Marble drill 1x/day
Week 4	≥30%	3.19 ± 0.31	3.21 ± 0.33	Jump drill 3x/day Walk in Place 2x/day Marble drill 1x/day

The runners were asked to keep a running log which included the day and time of each run, the distance and which shoes (normal or minimalist) they wore, as well as any symptoms the runner experienced. Each participant was asked to record all of this information on their weekly training log every day for four consecutive weeks. Normal training program and running surface was to be maintained by the participant even when running in the minimalist shoes. Participants were advised to wear only their normal running shoes or the minimalist shoes provided and not changing the footwear during the 4 week period. Participants were also instructed to perform a schedule of exercise drills including: the Marble Drill (Figure 2), Hop Drill (Figure 3), and Walking Drill (Figure 4) as accessory exercises to increase the strength and flexibility of the feet, as suggested by the transitioning guideline (Table 2).[19]

Figure 2. Marble drill progression

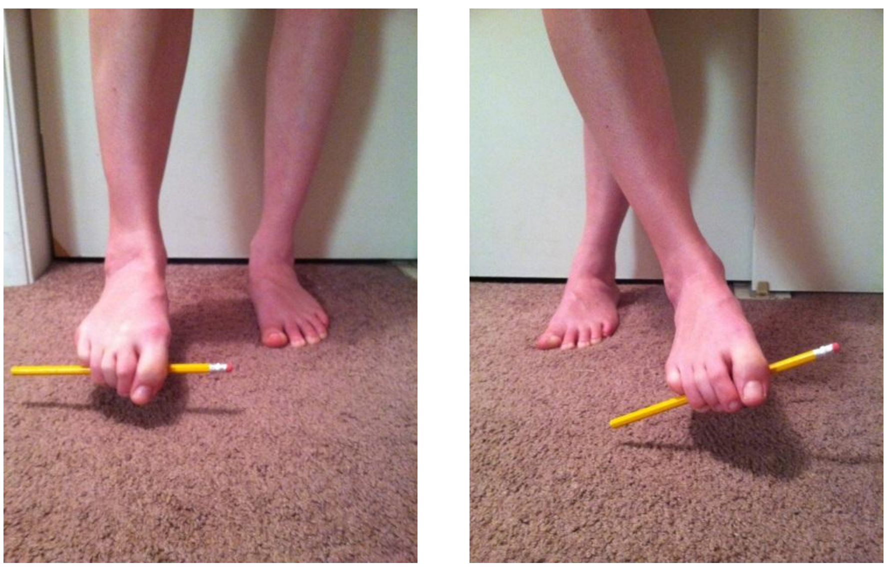


Figure 3. Jump drill progression

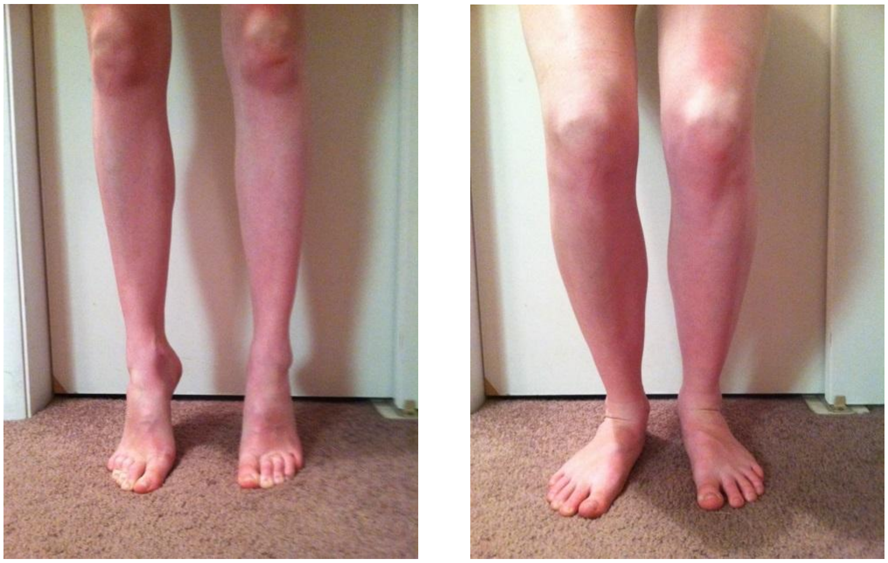
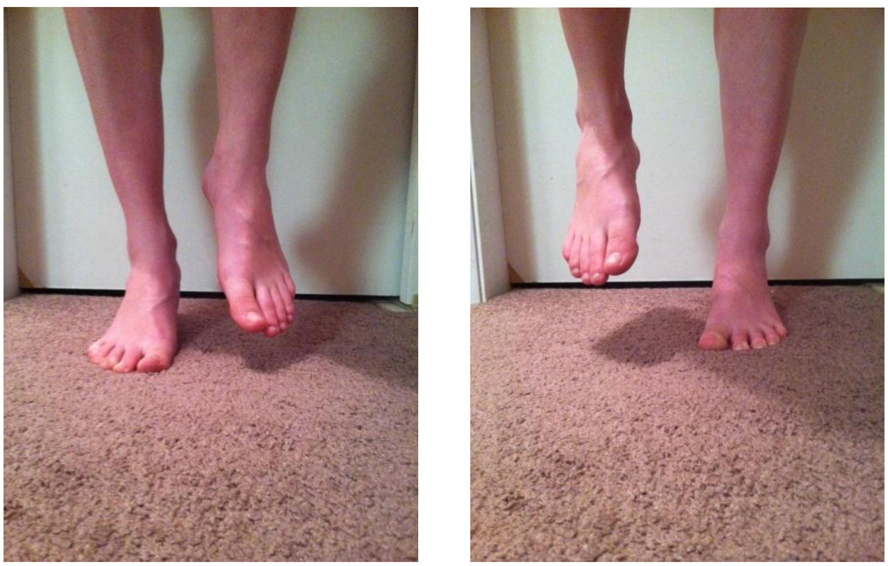


Figure 4. Walk in place drill progression



The participants were also asked to document the drill exercises they performed in the weekly training log. The type and amount of drills performed each week varied across all participants regardless of their receiving the same instruction of recommended drills at the beginning of the transitioning period. A booklet with the above instructions and exercise drills were given to each runner for reference. In the subsequent testing sessions (MID and POST), the weekly training logs were reviewed and data logged by the same investigator, followed by question and answer sessions in which the investigator followed up with any concerns and challenges. An exit questionnaire was given to each participant after the last testing session. The main question was whether they preferred their traditional running footwear, or the minimalist footwear. A follow-up question was to determine whether or not participants were interested in continuing to incorporate the minimalist footwear into their training regimen.

Data Analysis

Changes in running distances wearing the normal and minimalist shoes, as well as the drill exercises performed over the 4-week training period were analyzed descriptively (Table 3).

Table 3. Weekly running distance performed by the participants in minimalist and conventional shoes.

	Week 1	Week 2	Week 3	Week 4
Total running distance (km) – minimalist	3.60 ± 3.35	4.21 ± 2.17	7.10 ± 2.85	7.75 ± 4.02
Average distance per run (km) – minimalist	2.62 ± 1.95	3.80 ± 2.03	4.29 ± 1.42	4.70 ± 1.52
Total running distance (km) - Conventional	14.52 ± 7.35	12.45 ± 6.40	9.76 ± 6.31	6.37 ± 3.84
Average individual run distance (km) – conventional	6.31 ± 2.45	5.44 ± 2.08	5.80 ± 4.79	5.05 ± 3.57
% distance minimally shod	18.8%	31.3%	42.1%	54.9%

Lower back kinematics and muscle activation data were computed during the stance phase of the dominant leg during the running trials. The stance phase was identified using the foot pressure sensors; specifically the stance phase was identified as from the initial heel contact to when the forefoot (1^{st} metatarsal head) lost contact with the running surface. For lower back kinematics during the stance phase of running, mean lower back posture (mean lower back flexion/extension angle during stance phase), peak lower back flexion, peak lower back extension, and lower back range of motion were computed. Mean lumbar muscle activation during the stance phase was computed for both the contralateral and the ipsilateral paraspinal muscles. The muscle activation magnitudes were normalized to the highest 500 millisecond average activation magnitude during the MVIC trials, and reported as percentages of the MVIC. For each running trial, 10 stance phases were identified; the lower back kinematic and muscle activation magnitudes were obtained by averaging over the 10 stance phases. The average values from 3 collected running trials were used for statistical analysis.

Statistical Analysis

One-way repeated measures ANOVA tests were used to compare the lower back kinematic and muscle activation variables before (PRE) during (MID, 2-week), and after (POST) the 4-week training program. Data obtained from the 3.1m/s and the preferred running speed were analyzed separately. Post-hoc comparisons with Bonferroni correction were conducted when the main effect is significant. All statistical procedures were conducted using SPSS® 22.0 (International Business Machines Corp. New York, USA). Significance level was set at 0.05.

RESULTS

For the 3.1 m/s running speed, significant differences were detected in mean lower back posture, peak lower back flexion, peak lower back extension, and contralateral lumbar muscle activation (Table 3). Post-hoc comparisons showed that the mean lower back posture was significantly less flexed when compared to before training (PRE vs. POST, $p = 0.001$). Similarly, peak lower back flexion angle was significantly lower after training (PRE vs. POST, $p < 0.001$; MID vs. POST, $p = 0.001$). The peak lower back extension angle increased significantly after training (PRE vs. POST, $p < 0.001$; MID vs. POST, $p = 0.033$). There was no significant change in the overall lower back range of motion before, during, and after the training ($p = 0.496$). The contralateral lumbar paraspinal muscle activation changed significantly after training ($p = 0.039$). Post-hoc comparison showed that there is a significant reduction of muscle activation before and after two weeks of training (Table 3; pre vs. mid, $p = 0.049$). No significant difference in muscle activation was observed on the ipsilateral paraspinal muscle (Table 4; $p = 0.225$).

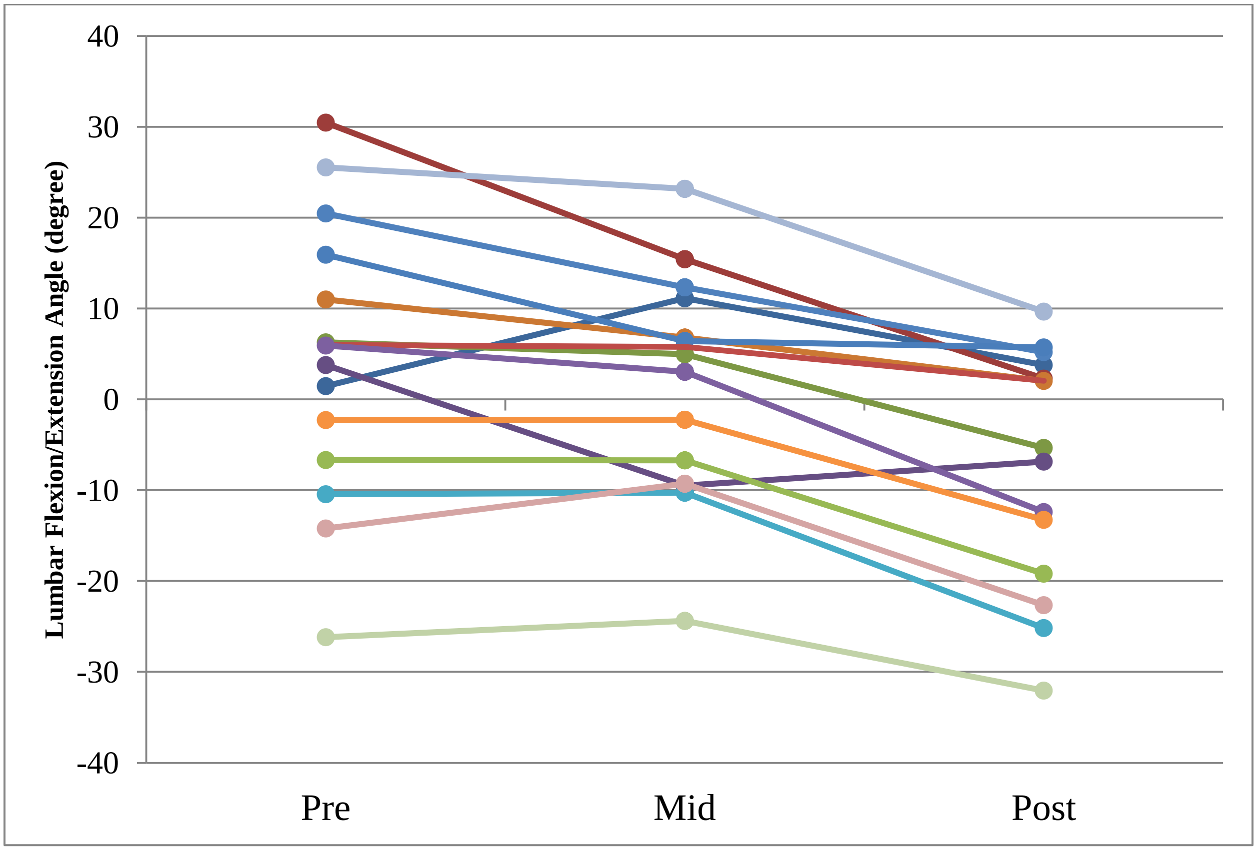
For the preferred running speed, significant differences were also detected in mean lower back posture, peak lower back flexion, peak lower back extension, and contralateral lumbar muscle activation (Table 3). Post-doc comparisons showed that the mean lower back posture was significantly less flexed when compared to before training (PRE vs. POST, $p = 0.002$). Peak lower back flexion angle was significantly lower after training (PRE vs. POST, $p < 0.001$). The peak lower back extension angle increased significantly after training (PRE vs. POST, $p < 0.001$; MID vs. POST, $p = 0.046$). There was no significant change in the overall lower back range of motion before, during, and after the training ($p = 0.325$). The contralateral lumbar paraspinal muscle activation changed significantly after training ($p = 0.047$). No significant difference in muscle activation was observed on the ipsilateral paraspinal muscle (Table 4; $p = 0.262$)

Table 4: Comparison of lumbar kinematic and paraspinal muscle activation PRE, MID, and POST the 4-week transition training to minimalist style running.

	3.1 m/s running speed				Preferred running speed			
	PRE	MID	POST	*p* value	PRE	MID	POST	*p* value
Mean lower back posture (degree)	1.9 ± 15.3	0.4 ± 13.0	-6.0 ± 13.3*	0.001	2.3 ± 15.5	0.9 ± 13.9	-5.7 ± 14.2*	0.002
Peak lower back flexion (degree)	8.6 ± 15.7	7.6 ± 15.1	-0.3 ± 13.7*#	<0.001	9.1 ± 16.3	8.0 ± 15.4	-0.3 ± 14.7*	<0.001
Peak lower back extension (degree)	4.8 ± 14.3	6.7 ± 11.8	12.6 ± 12.4*#	0.005	4.4 ± 14.7	6.7 ± 12.5	12.4 ± 13.5*#	0.007
Overall lower back ROM (degree)	13.3 ± 2.4	14.3 ± 6.1	12.3 ± 4.4	0.496	13.5 ± 2.4	14.7 ± 6.0	12.1 ± 4.6	0.325
Contralateral lumbar muscle activation (% of MVIC)	47.0 ± 34.0	24.9 ± 8.2	29.4 ± 11.3*#	0.039	41.6 ± 28.6	23.4 ± 6.2	30.3 ± 11.6*	0.047
Ipsilateral lumbar muscle activation (% of MVIC)	26.5 ± 15.8	17.0 ± 4.1	25.5 ± 17.2	0.225	28.8 ± 22.5	16.7 ± 3.8	25.9 ± 17.8	0.262

*indicates a significant difference from PRE condition and # indicates a significant difference from the MID condition.

Figure 5: Changes of mean lumbar posture during the stance phase for each participant PRE, MID, and POST a 4-week transition training to minimalist style running.



Note: 1. Positive value denotes lumbar flexion. 2. Data obtained during the 3.1 m/s running speed.

DISCUSSION

Our results have shown that the runners gradually adapted to a more extended lumbar posture while running and a reduction of paraspinal muscle activation over the 4-week minimalist style training program. Contralateral lumbar paraspinal muscle activation significantly decreased. These changes may indicate more efficient shock attenuation through the kinetic chain and potential for deceased load on the lower back, thus less frequency of LBP in runners.

Changes in lower back kinematics during forefoot strike running were first reported by Delgado et al. in 2013.[18] In the study, the foot strike pattern of 43 runners was analyzed during warm-up on the treadmill. The runners were then instructed to perform rearfoot and forefoot striking patterns and asked to reproduce these running patterns while barefoot on the treadmill. The authors reported a very small reduction (from 22.1 to 20.9°) in overall lumbar range of motion. Contrary to their findings, we observed no changes in the overall lumbar range of motion, but an overall tendency of runners running with a more extended lumbar posture (on average 7.9°, Figure 5) as they progress through the 4-week training program. The runners in our study also exhibited a gradual reduction in peak lumbar flexion angle and a gradual increase in the peak lumbar extension angle over the course of the training. The discrepancy in the results perhaps stemmed from the different methodology. In the previous study the peak lumbar spinal angles were recorded over both the swing and stance phases, while in this study we focused on the stance phase only. Also, we did not explicitly instruct the runners on the foot strike location during the running trials, but allowed the runners to naturally adapt to the minimalist style over time. In addition, in the Delgado et al. study runners ran their trials barefoot while in our study the runners worn minimalist footwear.

An increased upright posture seen in both preferred and 3.1m/s running speeds during the shod condition indicate a shift away from flexion during the stance phase. Lumbar posture in the current study is representative of mean flexion/extension angle during the stance phases, reflective of both the magnitudes and duration of flexion/extension. Lumbar flexion occurs during the initial loading phase of stance followed by a shift to lumbar extension after midstance.[20,21,22,23] This occurrence of flexion during the initial stages following foot strike is believe to be related to the attenuation of the impact forces, although there was no difference in the extension of injured versus non-injured runners.[22] The forward trunk lean during the initial contact period shifts the runners' center of mass forward, enhancing forward momentum to counteract the braking forces created during initial foot contact. Although the magnitudes of extension are much lower than those reported by Schache and his colleagues[20,21,22,23], related to the methods in which they were calculated, the increased extension may be seen as a result of less time spent in the braking phase of stance. A reduction in the braking phase of stance is related to foot strike and running patterns, which the transitioning program addressed.

This increase in upright posture may be related to the reduction of pararspinal muscle activity during running. Thorstensson et al. related EMG recordings of the lumbar erector spinal muscles to the movements of the trunk during walking and running concluding the main function for these muscles during running is to control sagittal motion.[40] Sánchez-Zuriaga et al. reported the erector spinal activation of subjects with and without a history of low back pain during trunk flexion and extension movements finding two activation peaks: one at the beginning of the movement as the spine began to flex forward representing an eccentric contraction and one at the end range of flexion as the spine began to extend representing concentric contraction. Kienbacher et al. researched the differences in lumbar paraspinal activation levels based on age and gender reporting lower paraspinal activity in standing upright when compared to standing with half trunk flexion and standing with full flexion of the spine in each of the groups.[38]

The training program was designed to allow the participating runners to transition to minimalist style running with a gradual progression to reduce the risk of injury associated with such transition. At the end of the 4-week period, the runners were expected to run 30-50% of their regular training mileage in the minimalist shoes. Other training programs in the literature recommended a longer period of time for a safe transition. For example, Miller et al. looked at the effects of minimalist shod running on intrinsic foot musculature after 12 weeks of minimally shod running. Participants were asked to transition over a period of 12 weeks and to reach approximately 48 percent of the time minimally shod. Results showed that those participates who used the transition program developed significant hypertrophy of the foot intrinsic muscles (i.e. abductor digiti minimi) and had increased longitudinal arch stiffness than compared to the group that continued running in their conventional footwear. Similarly, Miller et al., provided participants who were transitioning to running minimally shod with a handout to allow for safety and consistency in their workouts across participants. Our program is similar to the one used by Miller et al. in that exercises were included to help reduce the risk of injury over the course of training. The exercises our participants were instructed to perform were meant to be performed as an accessory to their normal runs.[24] Another study incorporating a transition to minimally shod running was by Ridge et al. Those participating runners transitioned to minimally shod running gradually each week across a 10-week period. In their program, the runners were asked to begin by doing a 1-2 mile of minimalist running during their first week of transitioning, and to add 1-2 mile each week. After the third week, runners were encouraged to continue increasing their minimalist mileage at their discretion. This was similar to our current study in that runners were asked to increase their distance of minimally shod running gradually however, we asked our participants to increase running based on percentages rather than specific distance values. The usage of percentages of total running distance allowed comparison of runners with different weekly running mileages.[25] It should be noted, that none of our participating runners reported any running related injury throughout the span of the data collection process. This may be attributed to the recommended drills to strengthen the intrinsic muscles of the feet or that the increase in minimalist running mileage was gradual enough to prevent injuries.

Our study demonstrates that runners do not need to completely transition into minimalist style of running to develop running form changes. The runners demonstrated a more extended lumbar posture after training, and the more extended posture carried over to when the runners ran in their habitually shod running condition. This could imply a change in movement pattern that was learned from the minimalist style training. We believe that this finding is clinically important as it is often unrealistic to ask a runner to completely shift to a different running style or footwear, even if the style can potential help prevent or alleviate running related injuries. In fact, it is theorized that incorrect transition of running styles can lead to many foot and leg injuries. In the Ridge et al. study previously mentioned magnetic resonance images from before and after the transition to quantify bone marrow edema in the feet. Bone marrow edema can manifest from the additional stress being placed on the foot and is also present if a stress fracture has occurred. Although the results are not significant; this study did find increases in bone marrow edema in over half of the runners who transitioned to minimalist shoes.[26] Another study published last year, followed 99 runners for 12 weeks as they trained for a 10km race. The researchers divided runners into 3 groups: neutral, partial minimalist, and full minimalist shoe. They found that runners in the neutral shoe group reported the fewest injuries and had a significantly lower number of injuries than the runners in the partial minimalist group. Also, runners in the full minimalist group reported greater incidence of shin and calf pain.[27] While a systematic review published By Perkins et al. on the risks and benefits of running barefoot or in minimalist shoes was unable to draw definite conclusions on the risk of injury, it may be safer to use the minimalist style running as a supplemental training.[28] Another study looking at postural changes in joggers with and without low back pain showed a reduction in knee flexion moment after lumbar paraspinal fatigue. This may be seen because of a forward leaning posture of the trunk which may increase the risk for knee injuries.[31] Future research is needed to investigate the specific benefit of such supplemental training.

Lumbar paraspinal muscle activation during activity is an important contributing factor to lumbo-pelvic stability. Proper muscle activation is necessary to allow movement during functional activities and maintain the proper alignment of the spine and pelvis in response to the ground reaction force during the stance phase of running. A study from Kuriyama N et al. compared the electromyographic findings of the paraspinal muscles in healthy individuals and patients with LBP showed no or little activation of these muscles in healthy individuals while in patients with LBP showed continuous activation during specific movements.[29] This indicates that patients with LBP exhibit altered paraspinal muscle activation pattern perhaps to provide more stability to the lumbosacral complex. Back muscle activation during walking supports the evidence of altered paraspinal muscle activation in patients with LBP. Surface EMG measures show increased lumbar muscle activity during all periods of stride in patients with chronic LBP.[30] Comparable muscle alterations during the swing and double support phases of gait suggest difficulty with total muscle relaxation of the lumbar paraspinal muscles. The increased muscle activity and lack of relaxation during the gait cycle indicates a possible guarding mechanism is exhibited by patients with LBP. The increased loading from the paraspinal muscle contraction may also be related to the chronic back pain symptoms.

During activity, contralateral muscle activity generally exceeds the ipsilateral muscle activation with respect to lumbar paraspinal muscle and stance limb. The contralateral muscle activation adds postural control and stability to maintain the center of mass over the base of support. Contralateral lumbar paraspinal muscle activation, though significantly decreased with the transitioning program, exceeds that of the ipsilateral lumbar paraspinals. The greater activation likely continues to act to provide postural control and stability during activity. .

Biomechanical evaluations aimed to identify risk factors, prevention and treatment strategies related to running-related injuries have traditionally focused on lower extremity injuries such as patellofemoral pain and Achilles tendinopathy. Much of the current focus on running injury prevention has been focused around the changes in biomechanical factors related to differences in foot strike patterns. In comparison, research regarding the biomechanics of lumbar spine during running is lacking. Preliminary evidence suggests that dysfunction or weakness of the lumbar-pelvis-hip musculoskeletal complex can cause injuries in other parts of the body.[32,33] Hence, there is a critical need to understand the biomechanics of this region during running in order to prevent running-related injuries, and to provide effective treatment to runners with back injuries.

Many biomechanical factors may affect the presence of LBP in runners. Through adjustments in lower extremity joint stiffness, runners attenuate the ground reaction forces in an attempt to avoid injury. Hamill et al. (2009) compared lower extremity joint stiffness in runners with and without LBP. Lower extremity joint stiffness was calculated from moments and joint range of motion for each joint comprising the lower extremity during the energy absorption phase of support. All joints were compared between the runners with LBP, resolved LBP and those without LBP. Knee joint stiffness showed the only significant difference between LBP and the other two groups, with the increased stiffness related to decreased joint range of motion rather than increased joint moments. The increase in knee stiffness may decrease the ability of the lower extremity to absorb or dampen the impact in the LBP group compared to the other groups.[34] The lack of absorption creates greater shock induced on the lower back intensifying the lower back pain.

CONCLUSIONS

Our results demonstrated that a 4-week minimalist style running training significantly affected lower back kinematics and lumbar paraspinal muscle activation. Specifically, the participants ran with a less flexed, and more upright and extended posture after training. The contralateral paraspinal muscle activation is also significantly reduced. More importantly, these effects were observed when the runners ran wearing their regular running footwear. This demonstrates that including minimalist running shoes and barefoot exercises into a runners' training regime may alter their regular running pattern and mechanics in traditionally shod running.

LIMITATIONS

This study has a number of limitations. The biomechanical testing was done on a treadmill, which may not reflect the activities of the lumbar spine and paraspinal muscle during overground running. While we observed localized changes in the lumbar segment, these changes may be came from changes of overall trunk and pelvis kinematics, lumbar spinal lordosis, or a combination of the above. We were unable to discern the specific location of these changes. Furthermore, all of our runners were young and injury-free. Future research needs to focus on the feasibility and the clinical benefits of minimalist style running in runners with running related back injuries.

REFERENCES

1. Association NSG. 2011 Sports Participation - Ranked by Total Participation. 2011; http://www.nsga.org/files/public/2011_Participation_Ranked_by_Participation_web.pdf. Accessed May 14, 2013.
2. Tam N, Wilson JLA, Noakes TD, Tucker R. Barefoot running: an evaluation of current hypothesis, future research and clinical applications. British journal of sports medicine. Mar 2014;48(5).
3. Lamppa R. Running USA Annual Marathon Report. Updated March 23, 2014. Accessed August 4, 2014. http://www.runningusa.org/marathon-report-2014?returnTo=annual-reports.
4. Matava M. Running and Jogging Injuries: AOSSM Sports Tips. https://www.sportsmed.org/uploadedFiles/Content/Patient/Sports_Tips/ST%20Running%20and%20Jogging%2008.pdf. Published 2008. Accessed August 20, 2014.
5. Yoder T. 2013 National Runners Survery. Running USA. 2013. http://www.runningusa.org/2013-national-runner-survey. Accessed August 3, 2014.
6. Yoder T. 2011 National Runners Survey. 2011. http://www.runningusa.org/2013-national-runner-survey. Accessed August 5, 2014.
7. Whittle MW. Generation and attenuation of transient impulsive forces beneath the foot: a review. Gait & posture. Dec 1999;10(3):264-275.
8. Hamill J, Moses M, Seay J. Lower extremity joint stiffness in runners with low back pain. Res Sports Med. 2009;17(4):260-273.
9. Cavanagh PR, Lafortune MA. Ground reaction forces in distance running. *Journal of biomechanics.* 1980;13(5):397-406.
10. Dimitriadis AT, Papagelopoulos PJ, Smith FW, et al. Intervertebral disc changes after 1 h of running: a study on athletes. The Journal of international medical research. 2011;39(2):569-579.
11. McDougall C. Born to Run: Random House; 2011.

11. Robillard J. *The Barefoot Running Book: The Art and Science of Barefoot and Minimalist Shoe Running*: Plume; 2012.

12. Garbutt G, Boocock MG, Reilly T, Troup JD. Running speed and spinal shrinkage in runners with and without low back pain. Medicine and science in sports and exercise. Dec 1990;22(6):769-772.

13. Gonzalez P, Akuthota V, Min SJ, Sullivan WJ. The Prevalence of Low Back Pain in Recreational Distance Runners. Medicine and science in sports and exercise. May 2006;38(5):S349-S349.

14. Mercer JA, Vance J, Hreljac A, Hamill J. Relationship between shock attenuation and stride length during running at different velocities. European journal of applied physiology. Aug 2002;87(4-5):403-408.

14. Miller EE, Whitcome KK, Lieberman DE, Norton HL, Dyer RE. The effect of minmal shoes on arch structure and intrinsic foot muscle strength. *J of Sport and Health Sci*. 2014;3(2):74-85.

15**.** De Wit B, De Clercq D, Aerts P. Biomechanical analysis of the stance phase during barefoot and shod running. *Journal of biomechanics.* Mar 2000;33(3):269-278.

16. Robillard J. The Barefoot Running Book: The Art and Science of Barefoot and Minimalist Shoe Running: Plume; 2012.

17. Walter SD, Hart LE, McIntosh JM, Sutton JR. The Ontario cohort study of running-related injuries. Archives of internal medicine. Nov 1989;149(11):2561-2564.

18. Delgado T, Kubera-Shelton E, Robb R, et al. Effects of foot strike on low back posture, shock attenuation, and comfort in running. Med Sci Sports Exerc. 2013 Mar;45(3):490-6.

19. Staff Mc. USA Marathoning: 2011 Overview. 2011; http://www.marathonguide.com/Features/Articles/2011RecapOverview.cfm. Accessed July 22, 2013.

20. Saunders, S.W., Schache, A., Rath, D., Hodges, P.W. (2005). Changes in three dimensional lumbo-pelvic kinematics and trunk muscle activity with speed and mode of locomotion. Clinical Biomechanics. 20; 784-793.

21. Schache, A.G., Blanch, P., Rath, D., Wrigley, T., & Bennell, K. (2002). Three-dimensional angular kinematics of the lumbar spine and pelvis during running. Human Movement Science, 21; 273-293.

22. Schache, A.G., Blanch, P.B., Rath, D.A.,Wrigley, T.V., & Bennell, K.L. (2005). Are anthropometric and kinematic parameters of the lumbo-pelvic-hip complex related to running injuries. Research in Sports Medicine, 13; 127-147.

23. Schache, A.G., Blanch, P.B., Rath, D.A.,Wrigley, T.V.,Starr, R., & Bennell, K.L. (2001). A comparison of overground and treadmill running for measuring the three-dimensional kinematics of the lumbo-pelvic-hip complex. Clinical Biomechanics, 16; 667-680.

24. Miller EE, Whitcome KK, Lieberman DE, Norton HL, Dyer RE. The effect of minimal shoes on arch structure and intrinsic foot muscle strength. J of Sport and Health Sci. Jun 2014;3(2):74-85.

25. Ridge ST, et al., Foot bone marrow edema after 10-week transition to minimalist running shoes. Med Sci Sports Exerc. Jan 2013;45:1363-1368.

26. Ridge S, Johnson W, Mitchell U, Hunter I, et al. Foot bone marrow edema after a 10-wk transition to minimalist running shoes. Med Sci Sports Exerc. July 2013;45(7):1363-1368.

27. Ryan M, Elashi M, Newsham-West R, Taunton J. Examining injury risk and pain perception in runners using minimalist footwear. Br J Sports Med. Aug 2014;48(16):1257-62.

28. Perkins K, Hanney W, Rothschild C. The risks and benefits of running barefoot or in minimalist shoes: a systematic review. Sports Health. Nov 2014;6(6):475-80.

29. Kuriyama N and Hiromoto I. Electromyographic functional analysis of the lumbar spinal muscles with low back pain. J Nippon Med Sch. 2005;72(3):165-173.

30. Van der Hulst M, Vollenbroek-Hutten MM, Rietrnan JS, Schaake L, Groothuis-Oudshoorn KG, Hermens HJ. Back muscle activation patterns in chronic low back pain during walking: a “guarding” hypothesis. Clin J Pain. 2010;26(1):30-37.

31. Hart J, Kerrigan CD, Fritz J, Ingersoll CD. Jogging after lumbar paraspinal muscle fatigue. J Electromy Kines. 2009;44(5):475-481.

32. Hammill RR, Beazell JR, Hart. Neuromuscular consequences of low back pain and core dysfunction. Clin Sports Med. 2008;27(3):449-464.

33. Brumitt J. Successful rehabilitation of a recreational endurance runner: initial validation for the Bunkie test. J Bodyw Mov Ther. 2011;15(3):384-390.

34. Hamill J, Moses M, Seay J. Lower extremity joint stiffness in runners with low back pain. Res Sports Med. 2009;17(4):260-273

35. Hamill J, Gruber AH, Derrick TR. Lower extremity joint stiffness characteristics during running with different footfall patterns. Eur J Sports Sci. 2012;12:1-7.

36. Hart JM, Kerrigan DC, Fritz JM, et al. Jogging kinematics after lumbar paraspinal muscle fatigue. J Athl Train. 2009; 44(5): 475-481.

37. Derrick TR, Mercer JA. Ground/foot impacts: measurement, attenuation, and consequences. *Medicine and science in sports and exercise.* May 2004;36(5):830-831.

38. Kienbacher T, Paul B, Habenicht R, Starek C, et al. Age and gender related neuromuscular changes in trunk flexion-extension. *J Neuroeng Rehabil.* Jan 2015;12(1):3.

39. Sánchez-Zuriaga D, López-Pascual J, Garrido-Jaén D, García-Mas MA. A comparison of lumbopelvic motion patterns and erector spinae behavior between asymptomatic subjects and patients with recurrent low back pain during pain-free periods. *J Manipulative Physiol Ther*. Feb 2015;38(2):130-7.

40. Thorstensson A, Carlson H, Zomlefer M, Nilsson J. Lumbar back muscle activity in relation to trunk movements during locomotion in man. *Acta physiologica Scandinavica*. Jan 2009;116(1):13-20.

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