HABITUAL BAREFOOT VERSUS HABITUAL SHOD RUN TRAINING EFFECTS ON DYNAMIC BALANCE

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HABITUAL BAREFOOT VERSUS HABITUAL SHOD RUN TRAINING EFFECTS

ON DYNAMIC BALANCE

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ABSTRACT

HABITUAL BAREFOOT VERSUS HABITUAL SHOD RUN TRAINING EFFECTS ON DYNAMIC BALANCE

by

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August 2013

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Context: Balance and proprioception play an important role in injury prevention, sport performance and an essential factor in recovery from surgery, and improvement in activities of daily living. Previous investigations have found that an increased sensory input on the plantar surface of the foot, with textured surfaces, increased dynamic postural stability while the stimulus is applied and immediately post stimulation. Whether or not increased sensory input on the plantar surface of the foot over time will increase dynamic postural control has not been investigated. The recent increase in popularity in barefoot running presented the opportunity to assess a group who has an increased textural input on the plantar surface of the foot by barefoot running. The primary hypothesis of the present study investigated if runners who train in a barefoot condition will have an improved dynamic postural stability as compared with runners who train in traditional running shoes as measured with a modified Star Excursion Balance Test (SEBT) and the Biodex Balance SD athletic single leg balance test.

Objective: To investigate dynamic postural stability quantified by SEBT and Biodex Balance SD in habitual barefoot and habitual shod runners.

Design: Case Control Study.

Setting: University Biomechanics/Athletic Training Laboratory.

Patients or Other Participants: 20 active runners, ten traditionally barefoot runners with age of 36.2 years ±9.95, height 173.48 cm ±8.88, weight 69.40 kg ±11.16 and averaged 25.90 km per week ±14.58, and ten shod runners with age of 28.1 years ±11.11, height 168.91 cm ±10.59, weight 66.05 kg ±15.89 and averaged 29.77 km per week ±10.99.

Interventions: Each participant performed three trials in three directions of the SEBT, and three trials of athletic singles leg balance test on the Biodex Balance SD with each leg.

Main Outcome Measure(s): Reach distances for each directional component of the SEBT were normalized by leg length measurements; three trial average divided by leg length multiplied by 100. Overall stability, anterior/posterior and medial/lateral indices were recorded from the Biodex Balance SD athletic single leg balance test.

Results: The SEBT testing produced no significant differences ($P>0.05$) in the three directions. No significant difference between the groups was observed in the Biodex Balance testing in relation to Overall Stability Index (OSI), Medial/Lateral Index

(MLI) or the Anterior/Posterior Index (API). However, there were significant correlations, moderate and moderately high, between each of the Biodex measures and leg length on the left and right leg with subjects with shorter leg lengths having better performance on the Biodex.

Conclusions: Habitual run training in a barefoot condition does not seem to change overall dynamic postural stability as measured. Therefore, the textured sensory stimulation effect of running barefoot does not improve with training over time. Further study is needed to isolate the sensory input in more functionally appropriate testing for these groups.

Key Words: Barefoot running, postural stability, Star Excursion Balance Test, Biodex Balance SD.

CHAPTER I

INTRODUCTION

Balance and proprioception play an important role in injury prevention sport performance and an important factor in recovery from surgery, injury and in improving activities of daily living (ADL's).[1] An important factor in balance is the sensory receptors on the plantar surface of the foot.

Investigations have found that the afferent receptors on the plantar surface of the foot contribute a great amount to balance across several populations.[1-7] These receptors send signals to the brain in relation to the body's position in space.[1,3,8,9] The brain then interprets these signals and controls the muscles to provide the correct corrective movements to maintain balance.[1,5,9] The body's ability to maintain balance is important in life and sports to avoid injuries from falls, incorrect positioning or general movement balance.[5,10,11]

Within the running population exist a group of athletes who run in a barefoot condition, including populations from across a wide spectrum, including elite athletes.[12] Elite coaches have been using barefoot training for years for their athletes.[11,12] The research is ambiguous as to whether or not barefoot running decreases injury rates.[1,10,13-15] The majority of the research has found that barefoot running did kinematically position the body to be at less risk of certain injuries.[1,2,5,12,13,16]

Several studies have looked at whether or not textured surfaces against the foot's plantar surface improves balance and/or proprioceptive awareness.[1,4,16] These studies used a variety of subjects including athletes.[1,3,4] Soccer players were studied with textured inserts and ankle positional awareness, which observed improved balance on textured surfaces.[16] The same results were reported by Palluel, Gouw, Oliver[4] using elderly subjects and textured sandals.[5] Both studies observed that textured surfaces seemed to improve balance, suggesting that sensory stimulation may contribute to improved balance.[4,16]

One investigation noted significant differences in balance with the athletes jumping and landing on the single anterior cruciate ligament (ACL) repaired leg.[6] However, the results were based on knee angles and sway upon landing and did observe several advantages to testing balance in a barefoot condition such as being able to highlight functional adaptations because there is no shock reduction protection from a shoe.[6]

The athletic population, more specifically habitually barefoot runners (HBR), has not been widely studied. It has been shown that the bare foot can receive more proprioceptive input than a shod foot.[2,3,6,11] This investigation will study whether or not training in a barefoot condition will cause a "conditioning" or more efficiency in dynamic balance. If there is an improvement it could either be from sensory improvements or from an increase in intrinsic foot muscle conditioning or some other factor. Another goal of the investigation is to determine whether or not a habitually barefoot runner will have better dynamic balance than that of a habitual shod runner.

Purpose

Since little research has been conducted on the effects of habitual barefoot run training on balance, this study was designed to determine if habitually barefoot running has an effect on balance, more specifically dynamic balance.

Operational Definitions

1. Habitually barefoot runner is someone who averages at least 9 miles per week running in the barefoot condition over the last 6 months.
2. Habitually shod runner is someone who averages at least 9 miles per week running in the shod condition over the last six months.
3. Dynamic balance is the ability to maintain the center of gravity over the base of support on an unstable platform and/or the ability to maintain the center of gravity while the body is in motion or during movements.
4. Non-dominant and dominant leg is the dominant will be designated by self-report. The leg that the subject generally uses to kick a ball.

Delimitations

This study is delimited to:

1. Habitually barefoot runners and shod runners who have been training in their respective condition for at least the previous 6 months.
2. To runners from the central Texas area.
3. Subjects 18 to 55 years of age.
4. Runners who average at least nine miles per week in the respective condition.

Limitations

Due to the results of the study delimitations, certain experimental inferences can be made.

1. Cannot be applied to individuals with brain, neuropathy or chronic balance issues.
2. This study will not investigate the exact mechanism that may cause different performance between the groups, if any.
3. The study cannot be applied to novice or inexperienced runners.

Assumptions

Certain assumptions are accepted in this investigation in reference to the participants.

1. Subjects are honest and truthful in reference to the running their respective conditions.
2. Subjects will give maximum effort when performing the balance assessments.
3. Subjects will complete the medical health questionnaire accurately.

Significance of the Study

The accepted notion that heel cushioning, arch supports and tread surface on shoes decreases injuries and improves performance is being challenged by recent research. In fact, these factors may lead to biomechanical disadvantage that can increase injury rates.[10,12,17-20] Sports performance, safety during locomotion and injury prevention are significant benefits from improved dynamic balance.[8] Improved balance in sports allows for improved performance.[12,21] If research can determine that barefoot training can improve the ability to balance dynamically then further study could use that information to determine if this can be translated to direct improvement in sport performance. The ability to improve dynamic balance may allow an athlete or general population to become more agile and decrease injury risks.[11,12]

Persons with disabilities or disease that interfere with balance could benefit from research into whether or not receptors on the plantar surface of the foot and proprioceptive feedback during dynamic balancing activities can be improved through barefoot training. The elderly tend to loose dynamic balance ability.[4] Palluel, Gouw, Oliver[4] observed that elderly persons balance improved within 5 minutes of wearing a textured sandal. Alternately, Webster et al.[6] found that there was no improvement in dynamic balance when testing a one-leg jump in a barefoot condition on a post-surgical ACL athlete. The study did not test on textured surfaces, no barefoot training was implemented and no instability factor other than landing on one leg was used.

If it can be shown that training barefoot can improve dynamic balance, it would a step toward in determining methods to perform balance training. The ability to decrease injury rates in athletics is an important factor for Athletic Trainers. Improved dynamic balance may decrease injury risk for sports.[6,11,12] If research can determine if balance can be improved by barefoot run training, this would be an important training method to be integrated into every athlete's training program. Also, this information may be useful in rehabilitation programs where increasing dynamic balance is a goal.

CHAPTER II

LITERATURE REVIEW

Introduction

Some may run for fun, to race, or perhaps for the many health benefits, which include increased cardiovascular fitness, reducing the risk factors for hypertension and heart disease,[22] increased bone density[23] and a decrease in depression and a positive affect on mood.[22] Some runners have experimented with barefoot running in an attempt to curtail injuries that they have sustained running in traditional running shoes.[15] The promise of enjoying running with less injury has recruited many to the idea.

Some previous research has gone into comparisons of efficiency of running barefoot versus shod, differences in gait[5,14,15,24,25] and some margin into the relation to proprioception and balance.[1-3,5,10,12,13,16] This research looks into differences between the two techniques and attempts to define if injury rates are related and looks into the sensory input that the plantar surface of the foot may have a biomechanical effect in running.[1,2,5,12,13,16] When walking, the foot is the first point of contact between the body and the external environment providing sensory information to the central nervous system for stability and locomotion.[10,22] The intent of this review is to discuss the research performed in this area and how it relates to the comparison of barefoot and shod running in respect to balance and proprioception.

Barefoot Running History

The human condition began without shoes in just bare feet. At some point, ancient man developed rudimentary footwear. It might have begun with animal skins strapped to feet. It has not be determined if this was in response to cold or surface makeup. Eventually shoes became more substantial and seem to coincide with improved surfaces that developed.[12,14]

As surfaces change to accommodate a more industrial society, the walking and running surfaces also changed. Divert et al.[14] reported that as we became more active and surfaces improved, the thought was that we needed more padding or cushioning in our shoes. This cushioning, by design, actually reduces the feel of the surface.[14] However, in Third World countries runners still run with no shoes for lack of funds or lack of importation of shoes. Abebi Bikila, a barefoot runner from a Third World country, won the gold medal in the 1960 Olympic marathon event.[25]

It has been discussed that the incidence of running related injuries have increased in recent years instead of the expected decline with the improvements of cushioning and motion controlled shoes. This, in turn, has led to an increased interest in barefoot running.[5,10,12,14,25] The literature is unclear on the exact increase in barefoot running in percentages or numbers.

Injuries

The thoughts were that cushioned motion controlled shoes allow less injury to occur by limiting motion and acting as a shock absorber upon impact of foot and running surface.[5,15,25] Recent studies seem to refute that assumption by finding increase incidences of injury. It was shown that the injury incident rate was fifty percent,[12,15] and a more recent study noted an injury rate of forty-nine percent.[26] One study noted significantly higher injury rates in those shod in Haiti than those barefoot.[10] In contrast, a study found that the force generated in a cushioned shoe was less than that in the barefoot condition.[24] However, in that study the barefoot condition was only completed with heel strikes.[24]

When most individuals switch to running barefoot they go from a heel striker to a forefoot or mid-foot striker.[5,15] Some data suggests that injury risk may be associated with covering of the sensory receptors on the plantar surface of the foot.[10,12,15] No studies have actually shown a decrease in running related injuries due to barefoot running, but have shown a decrease in the biomechanical risks of injury.[1,10,12-15]

Special Populations

Diabetics with certain neuropathies can be in danger during barefoot activities. Sacco, Akashi and Henning[27] noted that diabetic individuals who have decreased sensory issues due to neuropathy are more prone to sustain injuries on plantar surface of the foot and not likely to know that the injury occurred.[27] This may lead to more serious injury or infection.[27]

Some research has also investigated the effect of shoes on children. Squadrone and Galozzi[25] observed a higher incidence in deformity of the foot among children who wore shoes at an early age as compared with those who did not.[25] It was not discussed whether it was due to ill-fitting shoes or other factors.

Other studies cite the effect of forces and loading while shod as compared to barefoot condition in relation to osteoarthritis. Shakoor and Block[28] found a decrease pain among osteoarthritic patients who walked barefoot. The authors concluded that shoes may detrimentally increase loads on the lower extremity joints.[28]

Barefoot Specific Injuries

Some more acute injuries that can occur while barefoot running could be from hazardous materials in or on the running surface.[12,25] Hazards such as rocks, glass, sharp objects and heat from the surface can damage the foot. Although, pertaining to cuts and abrasions, the plantar surface has been shown to resist penetration in comparison to other body areas.[25] There may also be a risk from biological agents such as viruses and bacteria infecting a cut or abrasion. Bishop et al.[17] noted an increase in injury rates among barefoot runners if they continued to heel strike after switching from shod running. Most of the current research shows that soon after changing to a barefoot condition, most runners become forefoot/mid-foot strikers.[10,14,15]

Gait and Biomechanical Differences

Stride length when in a barefoot condition decreases when compared to that of the shod condition.[9,10,12,29] Also, an increase in stride frequency has been noted in the barefoot condition.[10,30] There is an increase in the flexion at the knee and an increase in plantar flexion at the ankle.[3,12,17,18,29] It was found that the plantar flexion allowed the foot and the arch of the foot to act as a better absorber during the shock of impact while running.[12,17,20,28]

Running can be most injurious during the foot strike on the running surface.[17] This impact can occur three ways: a rear foot strike, or heel strike; a mid-foot strike, in which the heel and ball of the foot land at the same time; and a forefoot strike, in which the ball of the foot lands before the heel comes down.[31] The initial impact of a shod runner with a heel strike, which is predominant in shod runners, is more abrupt and creates more force going up the chain to a straighter knee and leg.[10,12,17,18,25,32] In contrast, the predominantly forefoot/mid-foot strike of a barefoot runner has less abrupt of an impact force and is on a more bent knee.[6,13,19,30] Manor et al.[33] observed a change in gait mechanics when the subject's feet were desensitized using ice. However, it was also observed that it did not change spatial abilities. Nurse et al.[3] found that gait patterns did change due to a change in sensory inputs on the foot. The research also shows that the gastrocnemius muscle pre-activates for the upcoming strike and prepares to act as a shock absorber when barefoot.[3,12,17]

Running Efficiency

Some research data shows that the depression of the arch supplies roughly seventeen percent of the energy for each stance phase with barefoot runners.[12] Hanson et al.[15] studied the effect of barefoot and shod running on VO^2 max and concluded that barefoot running is more efficient than shod running. Divert et al.[14] tested the hypothesis that the mass of the shoe may contribute to the less efficiency. He found that the mass of the shoe did affect the running efficiency related to VO^2 max. The study also reported the shod foot may lead to decreased elastic storage energy capacity.

Gearing of the ankle has a link to knee joint kinematics.[18] Braunstein et al.[18] found that the gearing of the ankle during shod running increased the mechanical stress on the knee joint, which was noted as a contributor to a higher risk of injury and/or failure. The study also showed that wearing running shoes affects gearing at the ankle and knee joints mainly by altering the length of the moment arm of the ground reaction force in comparison to barefoot running.[18]

Proprioception

Sensory receptors on the plantar surface of the foot are only second in number to those on the palm of the hand, which function in regulation of stance and balance.[17] These are primarily made up of afferent fibers.[1-3,7,19,21,34,35] Nurse et al.[3] noted that afferent feedback from these receptors in the feet is important for balance and proprioception. The authors continued that stimulation of the foot receptors while walking and running can affect the motor neuron activity in the muscles of the legs.

Although limited to dynamic landing, Webster's et al.[6] objective was to determine biomechanical differences in single limb landing with and without shoe wear in subjects with ACL repairs. The results showed no significant difference biomechanically, however the author stated that there is an advantage to testing clinically while in a barefoot condition. The advantages to testing in a barefoot condition are easier marker placement and that it alleviates the need for standardization of shoe wear.[6]

Textured Surfaces

It was reported by Palluel, Nougier, Oliver[4] that elderly subjects benefited with textured surfaces in reference to balance. Balance problems are often related to a loss of plantar-sensitivity in elderly people. Elderly subjects who had balance issues were given sandals with a textured surface that contacted the plantar surface of the foot. Immediately there was no notable improvement in balance; however, after five minutes of walking with the textured surface the subject had improved balance and proprioception.

With varying results, Hatton et al.[1] investigated if standing on a textured surface affected different measures of balance in adults. The authors found that standing on a textured surface did have a significant effect on mediolateral sway. However, the results showed no significant difference in anterior-posterior sway and center of pressure.

While looking specifically at ankle positional awareness, Waddington and Adams[16] observed the effect of a textured soccer shoe insert on balance and proprioception. Textured insoles were put into the target group's soccer shoes and the control group had smooth insoles. When comparing the sensitivity of ankle inversion movement, the researchers found that there was a correlation between the textured insoles and improved sensitivity of proprioception in the soccer players.

It has been shown that mechanoreceptors in the plantar surface of the foot have a correlation to safe and effective locomotion. Robbins and Gouw[5] found that footwear is unsafe due to perceptual illusions and masking of the receptors with shoes. It was shown in 2005 that cutaneous reflexes from the foot contribute to the maintenance of stability during walking.[2]

Summary and Conclusions

The majority of the research seems to suggest barefoot running has some risk of injury that can be attenuated by not running on hazardous surfaces. It also suggests that the biomechanical measures, such as forefoot/mid-foot strikes, longitudinal arch's effect, increased knee flexion/foot plantarflexion at impact and muscle pre-activation may be increased in barefoot running. Many factors that may predispose a runner to injury may be avoided or reduced by running barefoot as opposed to shod. In fact, as shown above, walking barefoot seems to also have beneficial effects.

The research shows that modern footwear is made to be comfortable. However, that comfort seems to block the receptors that have been shown to contribute to balance and proprioception. The cushioning and heel lift may also change the kinematics of the lower extremity and more specifically at the ankle and position of the foot. The research has shown that sensory receptors in the plantar surface of the foot do have an effect on proprioception and balance. Nurse et al.[3] observed that plantar flexion increased with the addition of a textured shoe insert. It seems clear that the data reflects improved mechanics while running when in a barefoot condition and proprioception from the receptors on the plantar surface of the foot providing sensory feedback.

Investigations into the sensory portion of the plantar surface of the foot include limited testing on athletes and/or habitually barefoot runners. Robbins et al.[11] argues that stable equilibrium during locomotion is required for both superior performance of sports and prevention of injuries. Further query needs to be made into whether habitual barefoot runners actually gain a sensory "conditioning" from barefoot training as opposed to shod runners. Further study is also needed regarding barefoot running mechanics and injury prevention.

CHAPTER III

METHODS

This study will attempt to determine if habitually barefoot runners have better dynamic balance than habitually shod runners. This chapter will go into more details about the subjects that will be participating the study, the tests and instruments that will be used to gather the data will be explained and the specific procedures that will be implemented during the study will be delineated. Finally, the design and analysis will be described.

Subjects

Twenty (n=20) male and female participants will make up the groups of the study. The two groups will be divided into two groups of ten by the method in which they run train, either habitual barefoot runners or habitually shod runners. These participants will be recruited from barefoot and traditional running clubs in the Central Texas areas. The subjects will complete an informed consent form (appendix A). The subjects need to have been training in their respective conditions for at least the last six months and average a minimum of nine miles per week. They must also be free of injury for at least six months and free of any history of neuromuscular disease, stroke, diabetes, ear disorders, dizziness or surgeries in last 12 months. This information will be determined with a self-report questionnaire (appendix B). Demographic information will be obtained via a demographic form (appendix C). The University's Institutional Review Board will approve all research.

Instruments

The Biodex Balance System (Biodex Medical Systems, Inc., Shirley, New York) will be used to assess dynamic balance. The Biodex uses a movable stability platform that allows up to 20 degrees of surface tilt with 360 degrees range of motion with different settings of instability.[36] The Biodex system has been shown to be good in test/retest reliability in testing balance.[37] The screen of the machine shows a graph in which the subject attempts to use their balance to keep a dot in the middle of the graph. The variation in movement is scored.

A modified Star Excursion Balance Test dynamic balance test (SEBT) will also be implemented. The SEBT has been found to have high interrater reliability, ranging from intraclass correlation coefficient (ICC) values of 0.67 to 0.96, and high intrarater reliability, 0.81 to 0.93.[38,39] This testing is made up of three "rays" coming out from a center point with markings on the floor. The support foot is in the center and the participant reaches maximally with the reach limb and lightly touches it to the floor along the ray and the distance is measured.

Procedures

The subjects will be tested at Texas State University-San Marcos Biomechanics/Athletic Training laboratory. The order in which the subjects will be tested will be decided by a random number assignment to each participant. This number will then be used to numerically order the participants for testing with each subject testing individually. This number will also be used to determine which leg is tested by whether it is an odd or even number. The subjects will have a five-minute warm up on the stationary bicycle.

The subjects' demographic information will be typed into the Biodex machine. The specific Biodex protocol employs a one-legged athletic balance with a platform stability setting of four. With both hands on the rails and in a barefoot condition, the subject will be asked to step onto the platform in the designated position for a familiarization test. A total number of three practice trials to reduce learning effect.[36] The researcher will explain that once the test begins they will remove their hands from the rails and not to touch the rails for the 20 seconds that the testing last. Instructions are also given to keep the dot on the screen in the center of the chart on the Biodex. Once the familiarization testing is complete, the testing will continue with the each leg determined by random number assignment. Testing will include three separate 20-second tests with one-minute rests between tests for the each leg. The data will be recorded and printed from the Biodex machine.

The SEBT will be performed with the participants standing in the middle of three lines extending out in an anterior, posterior medial and posterior lateral, from center. The 3 "ray" design was found to be comparable to the original eight rays design and less time consuming.[40, 41] The participant will be asked to reach as far as they can along each of the three lines, touch on the line with the most distal part of the reach foot, and return the non-stance leg back to the center while maintaining a single-leg stance with the other leg in the center of the "star" without allowing the contact to affect balance. Participants will be allowed to practice reaching in each of the three directions four times to minimize the learning effect.[42] Following a 5-minute rest, participants will perform three trials in each of the three directions, beginning with the anterior direction, and clockwise or counter-clockwise around the grid. If the random number assigned ends in an odd number, the subject will move in a clockwise manner. If an even number the participant will move in a counter-clockwise manner. The investigator will record each reach distance with a mark on the tape as the distance from the center to the point of maximum excursion by the reach leg. All SEBT testing with have the each leg positioned in the center of the grid as the support leg.

Following the conclusion of all trials, the investigator will measure the distances of each excursion with a standard tape measure. If the investigator observes that the participant used the reaching leg for a substantial amount of support at any time, removed his or her foot from the center of the grid, or was unable to maintain balance on the support leg throughout the trial, the trial would be discarded and repeated.

Design and Analysis

The dependent variable in this study is dynamic balance and is is continuous. The independent variable in this study is the habitual run training method of the subject and is categorical.

The groups in the study consist of ten subjects in each group, the habitual barefoot runners and the habitual shod runners. Demographic information will be analyzed with central tendency score. The testing that both groups will receive is dynamic balance testing made up of three 20-second trials on a single leg on a Biodex machine (overall stability, anterior/posterior and medial lateral indices) and by performing the SEBT (anterior, posterior medial and posterior lateral directions). Both groups will be tested in the barefoot condition only and with non-dominant and dominant leg as stance leg.

Comparisons will be made between both training methods (groups) using a MANOVA. This would help identify if there is a relationship between the training condition of the runner and dynamic balance ability.

Since Gribble et al.[43] found that there was a strong correlation between leg lengths and reach distance on the SEBT, leg length measurements will be made of the participant. The measurement will be completed with a standard tape measure measuring from anterior superior iliac spine (ASIS) to ipsilateral medial malleolus. The raw score average of the SEBT was divided by leg length and multiplied by 100 to normalize the data.

Taken into account will be the subject's foot type. This will be determined by measuring the subject's navicular drop. This is performed by first putting the subject's foot in sub-talar neutral non weight bearing and mark the navicular prominence with a marker and mark an index card with the distance from the floor. The subject will then stand with weight on the measurement foot and the tester will use the index card next to the foot and mark the spot the mark has moved. The tester will then measure the two marks on the card in millimeters and record it on the demographic information. Cote et al.[44] divided the foot type into three types; excessively pronated (> 10mm), excessively supinated (< 4mm) or normal (between 5-9mm). Cote et al. found a correlation between foot type with static and dynamic stability.[44]

CHAPTER IV

MANUSCRIPT

Introduction

Balance and proprioception play an important role in injury prevention sport performance and an important factor in recovery from surgery, injury and in improving activities of daily living (ADL's).[1] One important factor in balance is the sensory receptors on the plantar surface of the foot.

Investigations have found that the afferent receptors on the plantar surface of the foot contribute a great amount to balance across several populations.[1-7] These receptors send signals to the brain in relation to the body's position in space.[1,3,8,9] The brain then interprets these signals and controls the muscles to provide the correct corrective movements to maintain balance.[1,5,9] The body's ability to maintain balance is important in life and sports to avoid injuries from falls, incorrect positioning or general movement balance.[5,10,11]

Within the running population exist a group of athletes who run in a barefoot condition. According to Robbins and Hanna,[12] this group contains populations from across a wide spectrum, including elite athletes. Elite coaches have been using barefoot training for years for their athletes.[11,12] The majority of the research has found that barefoot running did seem to kinematically position the body to be at less risk of certain injuries, however it is ambiguous as to whether or not barefoot running decreases injury rates.[1,2,5,10,12,13-15]

Several studies have looked at whether or not textured surfaces against the foot's plantar surface improves balance and/or proprioceptive awareness.[1,4,16] These studies used a variety of subjects including athletes.[1,3,4] Soccer players were studied with textured inserts and ankle positional awareness, which observed improved positional awareness.[16] The same results were reported by Palluel, Gouw, Oliver[4] using elderly subjects and textured sandals. Both studies observed that textured surfaces seemed to improve balance, suggesting that sensory stimulation may contribute to improved balance while the stimulus was applied.[4,16] A third study observed that mechanical stimulation of the plantar surface had an effect on improvement immediately, but not necessarily a lasting effect.[45]

The athletic population, more specifically habitually barefoot runners (HBR), has not been widely studied. It has been shown that the bare foot can receive more proprioceptive input than a shod foot.[2,3,6,11] This investigation studied whether or not training in a barefoot condition will cause a "conditioning" or more efficiency in dynamic balance. Another goal is to study whether or not a habitually barefoot runner will have better dynamic balance than that of a habitual shod runner.

Previous investigation found modern footwear is made to be comfortable. However, that comfort seems to block the receptors that have been shown to contribute to balance and proprioception. The cushioning and heel lift may also change the kinematics of the lower extremity and more specifically at the ankle and position of the foot. Nurse et al.[3] observed that plantar flexion was increases with the addition of a textured shoe insert. The data suggests improved mechanics while running when in a barefoot condition and proprioception from the receptors on the plantar surface of the foot providing sensory feedback.[6] Investigations into the sensory portion of the plantar surface of the foot include limited testing on athletes and/or habitually barefoot runners. Robbins et al.[11] argue that stable equilibrium during locomotion is required for both superior performance of sports and prevention of injuries. Further query was needed to be made into whether habitual barefoot runners actually gain a sensory "conditioning" from barefoot training as opposed to shod runners.

Methods

Subjects

Twenty (n=20) male and female participants made up the groups of the study. The two groups were divided into two groups of ten, either habitual barefoot runners or habitually shod runners. These participants were volunteers from barefoot and traditional running clubs in the Central Texas areas. The subjects completed an informed consent form (appendix A). The participants have been training in their respective conditions for at least the last six months and averaged a minimum of nine miles per week. They were also free of injury for at least six months and free of any history of neuromuscular disease, stroke, ear disorders, dizziness or surgeries in last 12 months. The University's Institutional Review Board approved this investigation.

Table 1. Demographics

	Barefoot		Shod	
n	10		10	
Age (yrs)	36.2	±9.95	28.1	±11.11
Height (cm)	173.48	±8.88	168.91	±10.59
Weight (kg)	69.40	±11.16	66.05	±15.89
Avg km/week	25.90	±14.58	29.77	±10.99
Leg Length L (cm)	90.03	±5.20	89.2	±7.42
Leg Length R (cm)	90.25	±4.77	89.3	±7.62

Instruments

The Biodex Balance System (Biodex Medical Systems, Inc., Shirley, New York) was used to assess dynamic balance. The Biodex uses a movable stability platform that allows up to 20 degrees of surface tilt with 360 degrees range of motion with different settings of instability.[36] The Biodex system has been shown to be good in test/retest reliability in testing balance.[37] The variation in movement was scored.

The modified Star Excursion Balance Test dynamic balance test (SEBT) is made up of three "rays" coming out from a center point with markings on the floor. The support foot is in the center and the participant reached maximally with the reach limb and lightly touched it to the floor along the ray and the distance was measured. The SEBT has been found to have high interpreter reliability, ranging from intraclass correlation coefficient (ICC) values of 0.67 to 0.96, and high intrarater reliability, 0.81 to 0.93.[38,39] The SEBT allows the opportunity to assess dynamic postural stability with body movement task as opposed to the Biodex which has an unstable platform.[40]

Procedures

Testing was at the Texas State University-San Marcos Biomechanics/Athletic Training laboratory. The order in which the subjects were tested was determined by a computer generated random number assignment to each participant via Microsoft Excel for Mac 2011 version 14.2.2 Microsoft Corporation random number generation. This number was used to determine order of SEBT or Biodex tests, first leg and what direction the SEBT was performed. The subjects completed a five-minute warm up on the stationary bicycle.

Biodex

The specific protocol employs a one-legged athletic balance with a platform stability setting of four. Initially the participant was asked to step on the platform in the designated position for a familiarization test for each leg. A total number of three practice trials were performed to reduce learning effect.[36] Once the familiarization testing was complete on the designated leg, the testing continued and included three separate 20-second tests with one minute rests between tests for the each leg.

Star Excursion Balance Test

The modified SEBT was performed with the participants single leg standing in the middle of three lines extending out in an anterior, posterior medial and posterior lateral directions from center and performing a maximum reach and return with the non-stance foot while maintaining their balance. Participants were allowed to practice reaching in each of the directions four times to minimize the learning effect.[42] Following a 5-minute rest, participants performed three trials in each direction, beginning with the anterior direction, and clockwise or counter-clockwise around the grid followed by testing the remaining leg.

Design and Analysis

The continuous dependent variable in this study was dynamic balance. The independent variable in this study was the habitual run training method of the subject and is categorical.

The groups in the study consist of ten subjects in each group, the habitual barefoot runners and the habitual shod runners. Demographic information was analyzed with central tendency score. The testing that both groups received is dynamic balance testing made up of three 20-second trials on each leg on a Biodex machine (overall stability, anterior posterior and medial lateral indices) and by performing the SEBT. Both groups were tested in the barefoot condition only. Comparisons were made between both training methods (groups) using a MANOVA to determine if there is a relationship between the training condition of the runner and dynamic balance ability.

Since Gribble et al.[43] found that there was a strong correlation between leg lengths and reach distance on the SEBT, leg length measurements were made of the participant. This was completed with a standard tape measure measuring from ASIS to ipsilateral medial malleolus. The raw score average in each direction of the SEBT was divided by leg length and multiplied by 100 to normalize the data.

Results

The descriptive characteristics of the subjects are reported in Table 1. The results of the Biodex measurements are reported in Table 2. The results of the SEBT measurements are reported for the dominant and non-dominant legs in Table 3. To determine the mean differences between the barefoot and shod runners, a Multivariate Analysis of Variance (MANOVA) was conducted for the SEBT as well as the Biodex measures. For the Biodex measures, MANOVA revealed no significant differences between barefoot and shod runners Wilk's Lambda = 0.725, $F(6,13) = 0.82$, $p = .573$. Also, for the SEBT measures, MANOVA revealed no significant differences between barefoot and shod runners, Wilk's Lambda = 0.581, $F(6,13) = 1.56$, $p = .235$.

Table 2. Biodex Scores

	Barefoot		Shod	
Index	Non-Dominant	Dominant	Non-Dominant	Dominant
(OSI)	1.37 ±0.67	1.41 ±0.61	1.36 ±0.73	1.44 ±0.70
(MLI)	0.84 ±0.36	0.89 ±0.31	0.73 ±0.39	0.81 ±0.33
(API)	0.97 ±0.51	1.01 ±0.42	1.07 ±0.53	1.09 ±0.64

(OSI=Overall Stability Index, MLI=Medial Lateral Index, API=Anterior Posterior Index)

Table 3. Star Excursion Balance Test Scores

	Barefoot		Shod	
Direction	Non-Dominant	Dominant	Non-Dominant	Dominant
Anterior	70.94±4.18	72.58±5.77	71.99±5.80	68.20±7.61
Posterior Medial	82.74±11.34	81.96±10.5	83.46±7.24	77.98±9.09
Posterior Lateral	75.78±11.17	79.51±9.47	72.36±5.33	77.35±6.79

(All values in centimeters (cm))

The next stage of the analysis was to determine the correlation between leg length and each of the Biodex measures. The Pearson Product-Moment correlation coefficients comparing the Biodex scores to leg length are reported in Table 4. All of the Biodex measures, for both the dominant and non-dominant legs, were significantly related to both right and left leg length. For the dominant leg, the correlations between OSI and API measures and leg length were moderately high, but the correlations between MLI and leg length were only moderate. For the non-dominant leg, all of the correlations between the Biodex measures and leg length were moderate. Tests of homogeneity of intercept and slope between the types of runners indicated that for any level of leg length, barefoot and shod runners have the same slope and intercept for each of the Biodex measures, for both dominant and non-dominant legs. This result indicates that even when correcting for leg length, which is significantly related to the Biodex measures, there are no significant differences in Biodex scores between the barefoot and shod runners.

Table 4. Correlations Between Biodex Measures and Leg Length

Biodex Measure	Leg Length	
Dominant Leg	Right	Left
Overall Stability (OSI)	0.65	0.70
Medial Lateral (MLI)	0.45	0.50
Anterior Posterior (API)	0.69	0.73
Non-Dominant Leg		
Overall Stability (OSI)	0.55	0.57
Medial Lateral (MLI)	0.52	0.55
Anterior Posterior (API)	0.57	0.59

None of the SEBT measures, for either the dominant or non-dominant legs, were significantly related to either right or left leg length. This result was expected, since the SEBT measures were normalized using leg length as an adjusting factor. The lack of any significant relationship between the SEBT measures and leg length reflect the expected effect of the normalization process.

Discussion

The purpose of this study was to investigate whether or not runners that train in a barefoot condition demonstrate better dynamic postural stability over runners that train in a shod condition. To achieve this objective a Biodex Balance SD athletic single leg balance test and the Star Excursion Balance Test were used to score dynamic postural stability. The importance of postural stability in daily life, sports performance and rehabilitation warrant such investigation to gather valuable information for the Athletic Training profession.

It has been argued that the sensory receptors on the plantar surface of the foot are important for balance and proprioception.[1-8] Balance and proprioception are important to avoid injury. Hatton[1] found that medial lateral sway was improved when standing on a textured surface. Nurse et al.[3] observed improved balance in the elderly when wearing a textured insert. Preszner-Domjan et al.[45] observed improvements in medial lateral sway in static balance after and during a stimulus applied to the plantar surface of the foot, however did not measure long-term effects. Currently, there have been no investigations into whether repeated exposure to textured surfaces improves long-term balance or dynamic postural stability.

The objective of this study was to investigate whether or not repeated long term running in a barefoot condition, exposing the plantar surface of the foot with more sensory input, could affect dynamic postural stability long-term, due to a possible training of the sensory receptors.

We failed to reject the null hypothesis. The fact that the Biodex testing, and the SEBT data showed that no significant differences exist between the habitually shod and barefoot runners in relation to dynamic postural stability, we have to conclude the evidence shows no significant differences.

Testing that takes into account vision and vestibular inputs may be advantageous to study. Perhaps Neurocom testing might produce more detailed results because it takes into account balance strategies, vestibular and visual inputs. However, the Neurocom is not portable and may not test in functional movements.

Dynamic postural stability has so many inherent factors, as does running itself; consequently, it may be difficult to find a definite answer. An explanation for no significant findings may be that the foot's plantar subcutaneous receptors could have a higher threshold of stimulation in barefoot runners. This could be a result of habitual running on the bare foot, thereby increasing stimulus repeatedly and causing a higher threshold to activation. Another explanation is that the testing surfaces were flat and smooth thereby providing little stimulation to those receptors. Also, a minimum run volume could exist for barefoot runners to gain an improvement and perhaps the subjects in this study did not reach that level. The time a subject is actually barefoot when not running throughout the day may have some effect. The small sample size could have also played a role in no significant findings.

One variable that was not controlled for is the shoe types for the habitual shod runner. Different heel drop measurements, type of arch in a shoe, stability of the shoe, thickness of sole all may also play a role. Also, intrinsic foot muscle strength may be a distinguishing factor regarding differences between these groups.

The running mechanics of each group have been shown to be so different that possibly a more functional test to each group may be developed. Also the trend of current research is to test with a stimulus in static positions for short-term effect only.

Future research may be able to move towards testing the long-term effects of habitual stimulation and dynamic stability, as we attempted to investigate with this study Further investigation should also be made into the positive correlation between leg length and Biodex scores as this study showed a significant positive correlation. A correlation between leg length and the SEBT has been noted in previous research. This information could prove useful in rehabilitation and further research.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The purpose of this chapter is to summarize the thesis research and suggest recommendations for further study. The first section will discuss the purpose of the research and methodology used to accomplish the analysis; research results will be summarized and described. The second part of the chapter will discuss possible further research recommendations.

Summary

The Biodex Balance SD testing involved single leg stance on an unstable platform which produced three scores: Overall Stability Index (OSI), Anterior/Posterior Index (API) and Medial/Lateral Index (MLI) Index. These indices measure the amount of tilt in those directions from zero. The testing was conducted with three 20-second trials on both dominant and non-dominant legs.

The Star Excursion Balance Test (SEBT) required the participant to stand in the middle of a "star" consisting of three ray directions in which they attempted a maximum reach with the non-stance leg for three trials on each leg. This maximum reach was then normalized by averaging the three scores in each direction, dividing by leg length and multiplying by 100, consistent with Gribble et al.[43]

No statistical difference was determined to exist between barefoot and shod groups in overall, medial lateral or anterior posterior indices as measured with the Biodex Balance SD athletic single leg balance test. A positive correlation was found between leg length and each Biodex score as shown in Table 4.

The SEBT was a test used to determine dynamic postural stability. The data represents the average of three reach trials in each of the three directions on both non-dominant and dominant legs that was normalized for leg length. The leg noted represents the stance leg and results are in Table 3. The results reflect no significant differences in any of the three directions tested.

Conclusions

This investigation found no significant difference in dynamic postural stability between habitually barefoot and habitually shod runners as measured with the Biodex and SEBT.

Dynamic postural stability has so many inherent factors, as does running itself; consequently, it may be difficult to find a definite answer. An explanation for no significant findings may be that the foot's plantar subcutaneous receptors could have a higher threshold of stimulation in barefoot runners. This could be a result of habitual running on the bare foot, thereby increasing stimulus repeatedly and causing a higher threshold to activation. Another explanation is that the testing surfaces were flat and smooth thereby providing little stimulation to those receptors. Also, a minimum run volume could exist for barefoot runners to gain an improvement and perhaps the subjects in this study did not reach that level. The time a subject is actually barefoot when not running throughout the day could also play a role. The small sample size could have also played a role in no significant findings.

This investigation also found positive correlations between leg length and scores on the Biodex Balance Testing. Previous research has shown a correlation between leg length and SEBT reach distances and provided a formula (average of the three trials in each direction divided by leg length multiplied by 100), which this study used, to normalize the data.

Recommendations for Further Research

Perhaps further study is needed to investigate some method of normalizing the data for the Biodex Balance Testing. Present research has shown an immediate increase in postural stability with stimulation of the plantar surface of the foot. Those results only show an immediate improvement and this study investigated a long-term improvement. Perhaps more functional testing should be performed to more accurately assess the runners. Habitually barefoot runners are not necessarily barefoot 24 hours a day. There could be a threshold to where long-term exposure will improve balance. Dynamic postural stability is important in sports performance, injury prevention and activities of daily living, the data gathered here can aide further investigations into in those areas of practice.

APPENDIX A

Consent Form

I hereby give my consent for my participation in the research project entitled: Barefoot Versus Running in Shoes' Effects on Dynamic Balance. (IRB # 2012Z3801). I understand that the person responsible for this research project is Rusty Armstrong of the Department of Health and Human Performance, Texas State University (512) 245-2561. Rusty can be reached by email at rka13@txstate.edu

I. Purpose

Barefoot running has become more popular in recent years. Balance is important in daily life, athletic performance, injury prevention and rehabilitation. There is a link between receptors in the sole of the foot and balance. There may also be a link between improved foot muscle strength and balance. This research is looking into whether or not barefoot run training improves balance. If chosen to participate I will be given two separate balance assessments.

The study will consist of at least ten healthy runners (18-55 years of age). They must have been running in their respective condition at least 9 miles a week for the last 6 months. Potential subjects with a history of neuromuscular disease, stroke, diabetes, ear disorders, dizziness or surgeries in last twelve months will be excluded from the study. For this reason answer the questions to the best of your ability.

I certify that I am in good health and to my knowledge I am able to perform a balance test. It is my understanding that I will be interviewed by trained health care professionals before any testing. They will determine if there are any reasons that would make it unsafe for me to take the test. I understand that it is important that I provide complete and accurate responses to the interviewer. I also recognize that my failure to do so could lead to possible unnecessary injury to myself during the tests.

You may refuse to answer the questions.

I hereby consent to voluntarily engage in balance testing.

The balance testing I will undergo will be performed on a Biodex balance machine and by a modified Star Excursion Balance Test. I have been clearly advised that it is my right and obligation to request that a test be stopped at any point if I feel unusual discomfort or fatigue. I have been advised that I should inform the operator immediately upon experiencing any discomfort or if I wish to stop the test. My

wishes in this regard shall be absolutely carried out. I have also been advised that I may withdraw from participation in this study at any time. **I also understand that full participation for the length of this protocol will be completed in one day of testing.**
A summary of findings will be provided to me upon completion of the study if I so request.

II. Risks

I understand and have been informed that there exists the possibility of adverse changes during the actual test. I have been informed that these changes could include a loss of balance. I may also experience muscle soreness following the test. I have been told that every effort will be made to lessen the risk of these occurrences. I understand that there is a risk of injury, loss of balance or dizziness as a result of my performance of this test. Knowing these risks, it is my desire to proceed to take the test as this form describes it. I understand that if this research project causes me any physical injury, treatment is not necessarily available at Texas State University or the Student Health Center. And that there is not necessarily any insurance carried by the University or its personnel applicable to cover any such injury. In the event that I require medical attention as a result of my participation in this research, I understand that I am personally responsible for any expenses incurred.

The study administrator is a nationally certified athletic trainer, state licensed athletic trainer and CPR/AED certified. He has been trained to identify emergency situations and how to properly offer emergency treatment if such occurrences should arise. He will be present during each experimental trial.

III. Benefits to be expected

The results of this test may or may not benefit me. Potential benefits relate mainly to my knowing if my form of running affects my balance.

IV. Compensation

I understand that I will be given thirty dollars gift card if I complete all testing. Should I not complete all sessions I may not be eligible for the travel stipend. I will incur no other penalty or loss of benefits.

V. Confidentiality and use of information

I have been informed that all information obtained will be treated as privileged and confidential. This information will not be released or revealed to any person without my express written consent. A file containing the consent form, results from the health history questionnaire and all collected data will be kept in a locked cabinet for five years. After the five years it will be destroyed. I do agree to the use of any data recorded for research or statistical purposes as long as it does not provide facts that could lead to my identification. Any other information obtained will be used only by the program staff to evaluate my training status or needs.

VI. Inquiries and freedom of consent

I fully understand that my participation in this research project is voluntary. Also that refusal to participate may disqualify me travel stipend of twenty dollars. But involves no other penalty or loss of benefits to which I may be entitled. I also fully understand that I may discontinue participation at any time without penalty or loss of benefits.

I further understand that there are also other remote risks that may be associated with this procedure. Despite the fact that a complete accounting of all these remote risks has not been provided to me, I still desire to proceed with the tests.

I understand if I have any questions about the research, research participants' rights, and/or research-related injuries to participants I can direct them to the IRB chair, Dr. Jon Lasser (512-
245-3413 – lasser@txstate.edu), or to Ms. Becky Northcut, Compliance Specialist (512-245-
2102).

I acknowledge that I have read this document in its entirety or that it has been read to me if I
have been unable to read same.

I consent to the rendition of all services and procedures as explained herein by all program personnel.

__________________ ___________
Participant's signature Date

__________________ ___________
Project Supervisor's Signature Date

APPENDIX B

Health History Questionnaire

Section A

1. When was the last time you had a physical examination?

2. If you have been told that you have any chronic or serious illnesses, please list them.

3. Give the following information pertaining to the last three times you have been hospitalized.

	Hospitalization 1	Hospitalization 2	Hospitalization 3
Reason for hospitalization			
Month and year of hospitalization			
Hospital			
City and State			

Section B

During the past 12 months...

1. Has a physician prescribed any medication for you? Yes__No___
2. Have you experienced any faintness or dizziness? Yes__No___
3. Have you had any injuries? Yes__No___
4. Have you experienced any balance issues? Yes__No___
5. Have you had any ear problems? Yes__No___
6. Have you had any surgery(s)? Yes__No__

At present...

Have you ever been told that you have any of the following illnesses?

1. Neuromuscular Disease Yes__No___________
2. Any condition affecting my balance Yes__No__________
3. Stroke Yes__No___________
4. Ear Disorder Yes__No___________
5. Lower Extremity Injury Yes__No__________

Section C

1. Participants must be runners (barefoot or with shoes) that average at least 9 miles a week for the last six months and between 18 and 50 years of age. Do you meet these study inclusion criteria?
   Yes__No___

3. If not, which criteria in #1, above, does not apply to you:
   ____
   ____

APPENDIX C

Code #:

Demographic Information

Last Name ______________________________________

First Name ______________________________________

Middle Initial ______________________________________

Date of Birth ______________________________________

Sex ______________________________________

Home Phone ______________________________________

Address ______________________________________

City ______________________________________

State ______________________________________

Zip Code ______________________________________

Work Phone ______________________________________

Family Physician ______________________________________

Height ______________________________________

Weight ______________________________________

Length of lower extremity R________L______

Mileage per week in condition

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VITA

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