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The Effect of 4-Week Barefoot Training on Foot Strike Kinematics at Touchdown

[1,2]Onwaree Ingkatecha

[1]*Burapha University, Faculty of Sport Science, Chonburi Province, Thailand.*
[2]*Mahidol University, College of Sport Science and Technology, Nakornpathom Province, Thailand.*

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ABSTRACT

Background: Footwear, the protective device, widely uses for injury prevention. The designs based on research are varied for suitable activities. The modern running footwear tends to promote the rearfoot strike pattern. In the past, people ran barefoot but there has been no evidence of kinematic data of foot strike pattern of barefoot running. **Objective:** The purpose of the study was to investigate the foot strike pattern between barefoot and shod running after 4-week of barefoot running. Fifteen male and fifteen female collegiate students participated in the study. Motion capture system with six infrared cameras (Qualisys AB, Sweden) at 250 Hz was used. Each subject was asked to run at the speed of 3.5±5% m/s with footwear and barefoot. Kinematic data were collected. The subjects had been trained barefoot running for 4 weeks. The post-test was done. **Results:** significant differences were found at the Rt. ankle joint ($p<0.01$) and at Rt. knee joint ($p<0.01$) with the running footwear and barefoot compared to barefoot after 4-wk BF training. The step length was found significantly different ($p<0.05$)**. Conclusion:** The angles of Rt. knee and ankle, and step length were altered significantly. An increase in knee flexion and plantarflexion, decrease in step length had been observed.

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INTRODUCTION

Running is one of the basic movements in activity daily living which is modified from walking for quick locomotion. It is the result of coordination between nervous and skeletal system. Central nervous system generates suitable motor nerve impulses which gather visual, proprioceptive and kinesthetic sensory information. Running is the series of repetitive movement to move body to the given direction. When the body moves forward, one leg bears bodyweight and the other swings forward for generating new base. Recreational running is widely used for aerobic exercise since it requires no specific place and membership. Running has several benefits such as improving cardiorespiratory and immune systems, reducing cholesterol and osteoporosis, preventing heart disease and hypertension, controlling body weight, mental health improvement and stress reduction (Dugan and Bhat, 2005; Hafstad *et al*., 2009).

Footwear is an important factor that affects the mechanics and performance of foot movement. The footwear's manufacturers have focused on research to improve technology for supporting wide variety of activities such as activities in daily living, sport activities, and footwear for special needs. Footwear is basically used for injury prevention from rough and uneven surfaces, environment, and impact force from the ground but the development of foot structure occurs in barefoot. People either ran barefoot or wore footwear that would seem to offer little protection from the ground, such as sandals or moccasins in the past (Bramble and Lieberman, 2004). Conventional athletic footwear was announced in competitive sport since 1970s without high technology (Lieberman *et al*., 2010). Since footwear has an important role in management of repetitive impact loads, the modern athletic footwear has been changed significantly over the past twenty years. Providing big cushioning system, midsole support and rigid heel counter, therefore, the stiffness and narrowness of footwear may lead to abnormality during developmental period and result directly to foot and ankle injuries such as plantar fasciitis, shin splint (Rao and Joseph, 1992). Sachithanandamm and Joseph (1995) surveyed 1846 adolescents and found that the incidence of flat foot had gradually increased in those who started wearing footwear before the age of 6. The incidence of lower extremities' injuries has gradually increased which result from gait, weight bearing and the forms of footwear (Radzimski, Mundermann and Sole, 2011). In the other hand, returning to natural way becomes more influences in the way of living, exercise and medicine. Barefoot

Corresponding Author: Onwaree Ingkatecha, Burapha University, Faculty of Sport Science, Chonburi Province, Thailand.

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running has been widely popular among recreational runners. The benefits and risks are still among the opponent's popular debate topic. It is claimed that barefoot running would change kinematic running pattern, shorter stride length and contact time (Squarone and Gallozzi, 2009). Foot strike patterns have been categorized as rearfoot strike which makes foot contact somewhere on the heel, midfoot strike which heel and ball of foot contact nearly simultaneously and forefoot strike which makes foot contact on the front half of the foot (Nunns *et al*., 2013). Most of runners (75%) are commonly rearfoot strikers (Pink *et al*., 1994; Hasegawa *et al*., 2007; Lieberman *et al*., 2010; Larson *et al*., 2011)

However, worldwide footwear manufacturers start to launch new models of athletic footwear; barefoot or minimalist footwear which imitates the barefoot movement. The reports showed that the incidence of injuries is less in barefoot than shod. Several studies stated that footwear limited the foot movement which effects all joints in lower extremities. This resulted to the change of movement pattern in both healthy people and patients (De Wit, De Clercq and Aerts, 2000; Radzimski, Mundermann and Sole, 2011).The purpose of this study was to investigate the foot strike pattern between barefoot and shod running after 4-week of barefoot running.

MATERIALS AND METHODS

Fifteen male (mean age 20.80$\pm$1.03 years; mean bodyweight 73.58$\pm$4.26 Kg.; mean height 170.55$\pm$8.97 cm.) and fifteen female (mean age 20.87$\pm$1.36 years; mean bodyweight 53.23$\pm$3.63 Kg.; mean height 160.43$\pm$6.87 cm.) collegiate students participated in the study. They were healthy, regularly runners and no history of serious lower extremity's injury at least 6 months prior to testing. All subjects were informed about the purposes, procedures and advantage of the study. Ethical approval for this study was obtained from the Burapha University Human Ethics Committee. Informed consent was obtained from all subjects prior to testing.

Anthropometrics are measured and recorded for each subject, including age, body weight, and height. Short warm-up was performed, consisting of continuous aerobic running at a self-selected comfortable speed along the walkway for 5 minutes to familiar with the data collection. Following the warm-up, 17 reflective markers were attached over the landmarks according to Helen Hayes' marker model (Kadaba *et al*., 1990). All markers were placed on the subjects by the same examiner. Motion capture system with six infrared cameras (Qualisys AB, Sweden) at 250 Hz was used in the study. The static and dynamic calibrations were performed before collecting data. Each subject was asked to run at the speed of 3.5$\pm$5% m/s with running footwear in the first bout and barefoot in the latter. A rest period of 5 minutes separated the bouts. Three successful trials were recorded. Four-week of barefoot running was trained. Then, the post-test was done. All statistical analyses were conducted using SPSS statistical software version 17 (SPSS Inc., Chicago, USA). The comparisons of range of motion of lower extremities were assessed using one-way analysis of variance (ANOVA) with statistical significance accepted at the $p < 0.05$ level.

Results:

The results of joint angles at touchdown, significant differences were found at the Rt. ankle joint ($p<0.01$) and at Rt. knee joint ($p<0.01$) with the standard running footwear compared to barefoot after 4-wk BF training, and barefoot compared to barefoot after 4-wk BF training. No significant differences were observed at the hip joint, Lt. knee joint and Lt. ankle joint. The step length was found significantly different ($p<0.05$) (Table 1). The subjects landed more ankle plantarflexion and shorter step length with barefoot after 4-week training. The changes in kinematics varying the lower extremity touchdown showed that when running barefoot the subjects adopted a flatter foot placement after 4-week of barefoot training compare to running in standard footwear and barefoot.

Table 1: Mean (standard deviation) values of range of motion compare between groups at touchdown.

Kinematic parameters	Footwear	Barefoot	Barefoot after 4-wk training
Lt. Hip ROM (deg)	110.75 (14.41)	106.64 (15.07)	112.01 (15.71)
Rt. Hip ROM (deg)	113.23 (15.05)	111.16 (15.36)	115.77 (17.73)
Lt. Knee ROM (deg)	160.83 (17.47)	163.60 (5.68)	160.45 (6.49)
Rt. Knee ROM (deg)	164.06 (7.25)	165.42 (5.73)**	162.54 (8.84)*
Lt Ankle ROM (deg)	92.78 (7.02)	88.93 (7.31)	88.64 (0.92)
Rt. Ankle ROM (deg)	93.12 (10.83)	90.03 (7.92) **	89.52 (6.58)*
Step length (m)	1.33 (0.16)	1.28 (0.15)	1.25 (0.10)*

*Statistical difference between footwear and barefoot after 4-wk training
** Statistical difference between barefoot and barefoot after 4-wk training

Figure 1 showed the range of motion of Lt. and Rt. lower extremities compared between athletic footwear, barefoot and barefoot after 4-week of barefoot training. The hip flexion and the ankle plantarflexion tended to increase after 4-week of barefoot training. For the variable of step length, there was significantly different between running with footwear and barefoot running after 4-week of barefoot training (Figure 2).

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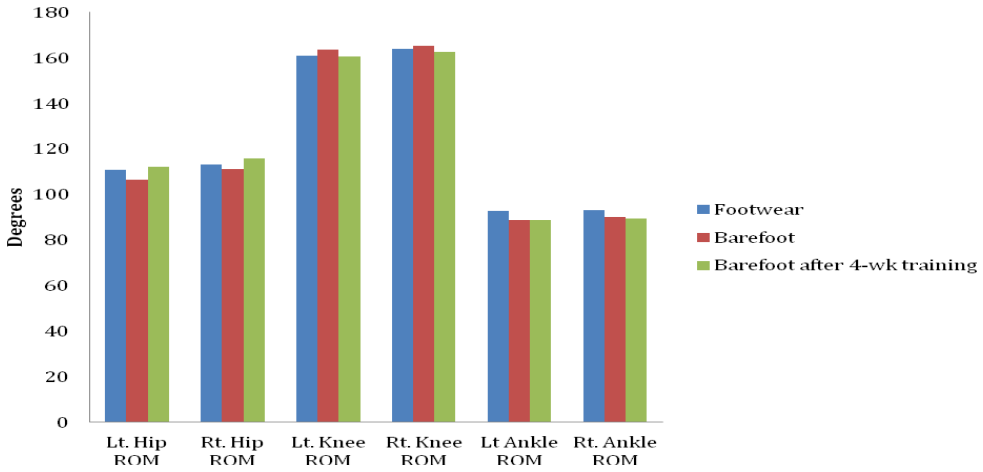

Fig. 1: The range of motion of lower extremities compared between groups.

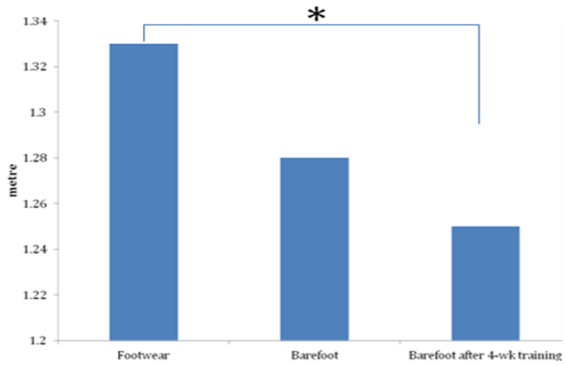

Fig. 2: The step length compared between groups.

Discussion:

The present study was to investigate the kinematic changes of barefoot running after 4-week of barefoot training. The range of motion of lower extremities after 4-week of barefoot training showed that no change in the knee angles, the hip flexion and the Lt. ankle plantarflexion tended to increase but no significantly different while the Rt. ankle plantarflexion increased significantly which corresponded with several studies. The barefoot running resulted in altering foot strike pattern at touchdown such as more hip and knee flexion, plantarflexion (Bramble and Lieberman, 2004; Hasegawa *et al*., 2007; Lieberman *et al*., 2010). Since the structures of the foot, especially midfoot and forefoot, there are a lot of bones articulated. The important role of synovial articulation is to absorb shock or impact that penetrates through it. Therefore, the ground reaction forces transfers through articulations in the foot at touchdown would be reduced. In addition, one of the most important structures in the foot, the medial longitudinal arch of foot (MLA) with large spring-like ligament, helps absorbing shock effectively (Divert *et al*., 2005; Squarone and Gallozzi, 2009; Lieberman *et al*., 2010). Although, several studies reported greater knee flexion angles at initial contact during barefoot running (De Wit *et al*.,2000; Lieberman *et al*., 2010), the knee angles in our study had no changed. One study reported that barefoot runners demonstrated greater leg stiffness as compared to shod runners throughout the stance phase of running. (Divert *et al*., 2005). The shorter step length was observed in barefoot compared with shod conditions, corresponding to the previous studies since the sagittal plane of joint angles altered (Squadrone and Gallozzi, 2009; Thompson *et al*., 2014).

The attenuation of impact forces plays an important role in the selection of foot strike patterns. The modern athletic footwear with large, elevated cushioning heels, and arch supports would promote rearfoot striking pattern (Lieberman *et al*., 2010). People who are accustomed to regularly wear shoes have heel-to-toe or rearfoot strike pattern and result in increasing impact forces of 1-1.2 times per bodyweight (Lieberman *et al*., 2010; Daoud *et al*., 2012; Milner *et al*., 2006). This would be the reason why the huge cushioning system with high technological materials has been added to the heel. As the barefoot running promotes the movement of foot structures (De Wit *et al*., 2000). According to Robbins *et al*. (1987, 1993), barefoot running style needs the adaptation for several weeks. The 4-week of barefoot training is for skill learning to avoid any processes that lead to injury. This is the basic learning process of human by using several physiological systems such as nervous, musculoskeletal systems. The learning process has completed by receiving the information through the sensory input from other receptors at organs, for example, mechanoreceptors, photoreceptors, golgi tendon organs. The sensory information would be gathered from several resources to interpret and memorize as

experiences, memory or skills (Leiberman, 2012). Therefore, the ability of sensory receptors may affect the alteration of foot strike pattern of lower extremities for responding to ground impact and help improving the coordination of proprioceptive receptors (Kurz and Stergiou, 2003). The results of 4-week of barefoot training showed that subjects tended to change their foot strike pattern by increasing hip flexion and ankle plantarflexion, and reducing step length. The changes corresponds with the previous studies which stated that when running barefoot the flatter foot placement was adopted the same as Squarone and Gallozzi (2009), De Wit *et al*. (2000) and Hennig *et al*. (1996) in an attempt to reduce pressure under the heel. In addition, Leiberman *et al*. (2010) reported the habitually barefoot runners contacted the ground with flatter foot the same as the study of Hamill *et al*. (2011) which stated that participants altered their rearfoot strike pattern to midfoot strike pattern when the footwear was removed.

It is believed that the barefoot running helps improve sensory input, alter the pattern of movement, especially ankle joint to reduce impact forces, and improve position sense (Robbins & Gouw, 1991; Robbins & Waked, 1997). Visual sensation helps the perception of the surface characteristics, either hard or soft, where the foot contacts. Runners tend to alter their foot strike pattern to reduce the ground impact when running barefoot on the hard surface (Hennig *et al*., 1996; Dixon *et al*., 2005; Lieberman, 2012; Gruber *et al*., 2013). The cushioning system and midsole support have been added to the running footwear to protect the impact force and provide stability for the gait. This is the concept that the footwear manufacturers have widely produced the advertisement of the models of running footwear which reduce injuries (Williams *et al*., 2001; Butler *et al*., 2007). These would make the footwear as a rigid cradle which limits proprioception (Robbins & Waked, 1997; Lieberman *et al*., 2010). Due to this reason, the foot strike patterns have been modified depending on the footwear models (Kong *et al*., 2009).

Conclusion:

The current concept of barefoot running are still under the debate. The foot strike pattern has been altered with type of footwear and training through learning process. This study found that The angles of Rt. knee and ankle, and step length were altered significantly. An increase in knee flexion and plantarflexion, decrease in step length had been observed.

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REFERENCES

Bramble, D.M. and D.E. Lieberman, 2004. Endurance running and the evolution of Homo. Nature, 432(7015): 345-352.

Butler, R.J., J. Hamill and I. Davis, 2007. Effect of footwear on high and low arched runners' mechanics during a prolonged run. Gait Posture, 26: 219-225.

Daoud, A.I., G.I., Geissler, F. Wang, J. Saretsky, Y.A. Daoud and D.E. Leiberman, 2012. Foot strike and injury rates in endurance runners: A retrospective study. Med Sci Sports Exerc., 44(7): 1325-1334.

De Wit, B., D. De Clercq and P. Aerts, 2000. Biomechanical analysis of the stance phase during barefoot and shod running. J Biomech., 33: 269-278.

Dixon, S., A. Collop and M. Batt, 2005. Compensatory adjustment in lower extremity kinematics in response to a reduced cushioning of the impact interface in heel-toe running. Sports Engineering, 8: 47-55.

Divert, C., G. Mornieux, H. Baur, F. Mayer and A. Belli, 2005. Mechanical comparison of barefoot and shod running. Int J Sports Med., 26(7): 593-598.

Dugan, S.A. and K.P. Bhat, 2005. Biomechanics and analysis of running gait. Phys Med Rehabil Clin., 16(3): 603-621.

Gruber, A.H., J.F. Silvernail, P. Brueggemann, E. Rohr and J. Hamill, 2013. Footfall patterns during barefoot running on harder and softer surfaces. Footwear Science, 5: 39-44.

Hafstad, A.D., N. Boardman, J. Lund, M. Hagve, U. Wisloff, T.S. Larsen and A. Ellen, 2009. Exercise-induced increade in Cardiac efficiency: the impact of intensity. Circulation, 120(18): S880.

Hamill, J., E.M. Russell, A.H. Gruber and R. Miller, 2011. Impact characteristics in shod and barefoot running. Footwear Science, 3: 33-40.

Hasegawa, H., T. Yamauchi and W.J. Kraemer, 2007. Foot strike patterns of runners at the 15-km point during and elite-level half marathon. J Strength Condit Res., 21(3): 888-893.

Hennig, E.F., G.A. Valiant, Q. Liu, 1996. Biomechanical variables and perception of cushioning for running in various types of footwear. J Appl Biomech., 12: 143-150.

Kadaba, M.P., H.K. Ramakrishnan, M.E. Wooten, J. Gainey, G. Gorton and G.V.B. Cochran, 1990. Repeatability of kinematic, kinetic, and electromyographic data in normal adult gait. J Orthop Res., 7(6): 849-860.

Kong, P.W., N.G. Candelaria and D.R. Smith, 2009. Running in new and worn shoes: a comparison of three types of cushioning footwear. Br J Sports Med., 43: 745-749.

Kurz, M.J. and N. Stergiou, 2003. The spanning set indicates that variability during the stance period of running is affected by footwear. Gait Posture, 17: 132-135.

Larson, P.M., E. Higgins, J. Kaminski, T. Decker, J. Preble, D. Lyons, K. McIntyre and A. Normile, 2011. Foot strike patterns of recreational and sub-elite runners in a long-distance road race. J Sports Sci., 29(15): 1665-1673.

Lieberman, D.E., 2012. Human Learning and Memory. NY; Cambridge University Press.

Lieberman, D.E., 2012. What can we learn about running from barefoot running: an evolutionary medical perspective. Exerc Sports Sci Rev., 40: 63-72.

Lieberman, D.E., M. Venkadesan, W.A. Werbel, A.I. Daoud, S. D'Andrea, I.S. Davis, R.O. Mang'Eni and Y. Pitsiladis, 2010. Foot strike patterns and collision forces in habitually barefoot versus shod runners. Nature, 463(7280): 531-535.

Milner, C.E., R. Ferber, C.D. Pollard, J. Hamill and I.S. Davis, 2006. Biomechanical factors associated with tibial stress fracture in female runners. Med Sci Sports Exerc., 38: 323-328.

Nunns, M., C. House, J. Fallowfield, A. Allsopp and S. Dixon, 2013. Biomechanical characteristics of barefoot footstrike modalities. J Biomech., 46: 2603-2610.

Pink, M., J. Perry, P.A. Houglum and D.J. Devine, 1994. Lower extremity range of motion in recreational sport runner. Am J Sports Med., 22(4): 541-549.

Radzimski, A.D., A. Mundermann and G. Sole, 2012. Effect of footwear on the external knee adduction moment – A systematic review. The Knee, 19(3): 163-175.

Rao, U.B. and B. Joseph, 1992. The influence of footwear on the prevalence of flat foot, A survey of 2300 children. J Bone Joint Surg., 74(4): 525-527.

Robbins, S.E., A.M. Hanna, 1987. Running-related injury prevention through barefoot adaptations. Med Sci Sports Exerc., 19: 148-156.

Robbins, S.E. and G.J. Gouw, 1991. Athletic footwear: unsafe due to perceptual illusions. Med Sci Sports Exerc., 23: 217-224.

Robbins, S.E., G. Gown, J. McClaran, E. Waked, 1993. Protective sensation of the plantar aspect of the foot. Foot Ankle, 14: 347-352.

Robbins, S.E. and E. Waked, 1997. Hazard of deceptive advertising of athletic footwear. Brit J Sports Med., 31: 299-303.

Sachithanandam, V. and B. Joseph, 1995. The influence of footwear on the prevalence of flat foot; A survey of 1846 skeletally mature persons. J Bone Joint Surg., 77(2): 254-257.

Squadrone, R. and C. Gallozzi, 2009. Biomechanical and physiological comparison of barefoot and two shod conditions in experienced barefoot runners. J Sports Med Phys Fitness, 49: 6-13.

Thompson, M.A., A. Gutmann, J. Seegmiller, C.P. McGowan, 2014. The effect of stride length on the dynamics of barefoot and shod running. J Biomech., 47(11): 2745-2750.

Williams, D.S., I.S. McClay, J. Hamill and T.S. Buchanan, 2001. Lower extremity kinematic and kinetic differences in runners with high and low arches. J Appl Biomech., 17: 153-63.