RELATIONSHIP BETWEEN GROUND REACTION FORCE AND STABILITY LEVEL OF THE LOWER EXTREMITY IN YOUNG ACTIVE ADULTS

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The purpose of this study was to identify the relationship between GRF and the stability level of the lower extremity to define the risk of running-related injuries. 13 participants were divided to two groups (previous running injury; no previous running injury) and performed a Single-leg Excursion Test (SET), and ran across a force plate to measure GRFs. Results showed a moderate negative correlation, ($r(10) = -0.620$, $p < 0.05$). The injury group had higher GRF and lower SET scores as compared to the no injury group. Runners that can reduce the GRF and improve their stability level in the lower extremity by performing proper strength and stability training may reduce the risk of injuries from running activities.

KEY WORDS: stability, running, ground reaction force, injury risk

INTRODUCTION: As the number of recreational runners have increased over the last decade, running-related injuries have been reported dramatically larger than ever (Taunton, Ryan, Clement, McKenzi, Lloyd-Smith, & Zumbo, 2002). Williams, McClay, and Hamill (2001) stated that those common running-related injuries are stress fractures, shin splints, plantar faciitus, and IT band syndrome. Many of these syndromes occur from excessive running distance or intensity, or types of ground surface which stress muscles and joints in the lower extremity (Novacheck, 1998). Moreover, there are also different causes of these injuries, such as anatomical structures and running mechanics (Karamanidis, Arampatzis & Bruggemann, 2004; Wilks, 2005). The biomechanical analysis of running mechanics started over 30 years ago, and since observational study was not reliable enough to identify probable causes of injuries, the force plate has become one of the most popular instruments to measure the impact force and collect reliable data to identify the amount of force the body produces during an impact. Novacheck (1998) estimated the ideal GRF during running is from 1.6 to 1.8 times of body weight. Recent studies showed that higher GRF is typically found in older runners, runners with longer stride length, and running downhill (Bus, 2003; Karamanidis et al. 2004; Gottschall & Kran, 2005). Excessive running distance and intensity may have major contributions to running-related injuries. Macera and colleagues (1989) showed that more than half of runners have experienced running-related injuries during their first year of committed running training. These data indicate that novice runners may lack knowledge on running routines and proper progression as compared to experienced runners. Moreover, this may also indicate that novice runners' muscles in the lower extremity are not adapted properly to run the distance or handle the intensity repetitively. Lysholm & Wiklander (1987) stated that novice runners are increasing distance too rapidly and, they also tend to overly engage high intensity training.
Anatomical structure has a major role in running mechanics (Wilks, 2005), especially when differentiating mechanics and injury risk between male and female runners. Female runners reported twice as many as running-related injuries as male runners (Taunton et al., 2002). Women have wider hip which causes femoris to be structurally V-shaped, in an angle from hip to knees, and this anatomical structure affects the running pattern for female runners (Horton & Hall, 1989). Wilks (2005) also stated that this may cause higher stress to the lower extremity for female runners, since it lacks shock absorption due to the fact that the lower extremity in women is not aligned straight as much as the lower extremity of the male anatomical structure. Finally, Ferber et al. (2003) found that female runners actually engaged more overall muscle activities to run, as compared to male runners because of the significant difference in anatomical structure of the lower extremities. There were no studies about the direct relationship between the anatomical structures and muscle functionality, or comparison of the muscle strength between female and male runners.

If there is a difference in the stability levels between male and female runners, muscle stability may influence why female runners have more running-related injuries. While muscular strength has been shown to influence running-related injuries, stability has not been fully examined.

The Single-leg Excursion Test (SET) is a functional test that has been used to assess lower body stability and dynamic balance in recent years (Hertel, Miller & Denegar, 2000; Olmsted, Carcia, Hertel, & Shultz, 2002). Its reliability is 0.67 to 0.87, (Kinzey & Armstrong,1998). Olmsted et al. (2002) reported that when instability of the lower extremity is diagnosed by using the Excursion Test, those participants generally possess weaker muscular functionality, and may experience a higher risk of injuries from physical activities by possessing less balance and body control. Thus, poor stability may be associated with running-related injuries. As a result from ineffective muscle functions, it may cause overload muscle activities, fatigue, and faulty movement pattern. These reviewed studies discuss GRF and its relation to running-related injuries. However, the direct relationship between the GRF and the functionality of the lower extremity muscles has not been studied to identify its correlation to a risk of running-related injuries. Therefore, the purpose of this study was to define the relationship between the GRF and the stability level of the lower extremity to identify risk of running-related injuries.

METHODS: A total of 13 physically active, young adults (9 males, 4 females) volunteered for this study (age: M = 21.5, SD = 3 yrs, height: M = 174.6, SD = 9.5 cm, weight: M = 73.9, SD = 13.4 kg). They answered specific questions about their daily activity levels and past history of their lower extremity injuries to identify their risk of running-related injuries. Based on their answers, the participants were divided to two groups to be categorized as a high risk or a low risk prior to the test. All participants met minimum amount of physical activities respectively followed by the ACSM guideline (ACSM, 2000). One participant was eliminated from the study because of current lower back pain. This study simulated the real running speed of active young adults. Participants made left foot contact on the force plate at a comfortable running speed (2.65-3.35 m/s = 10-8 minutes per mile pace) after having warmed up for 1 mile outdoors. During the total of 3 trials, if participants had abnormal steps prior to reaching the force plate, the trial was not recorded, and they were asked to perform another trial. The GRFs were measured by an AMTI force plate (Advanced Medical Technologies, Inc., Watertown, MA) that sampled at 600 Hz. The Peak Motus software (ver. 8.2, ViconPeak, Centennial, CO) was used to reduce the data. Peak GRFs were obtained at the instant of contact, converted from Newtons to Newtons/body weights (N/BW), and averaged for the group.

The SET measured an amount of control in the lower extremity. Since verbal instruction and visual demonstration increases the reliability of the SET (Kinzey & Armstrong, 1998), each participant was given these along with 3-5 practice trials. Eight lines had 30 inches of length which was placed on 45 degree angles apart. See Figure 1. The test was done without shoes to eliminate influence from shoes. Each participant placed his or her left foot on the center of 0-180 degree line. Then, participants reached for their toes as far as possible to the directions of 0, 90, and 180 degree lines while maintaining balance. Then participants performed the same sequence with their right foot. Each participant received 3 trials in each foot to reach their toes to the guided directions. Participants must be in static position for at least 3 seconds to ensure their ability to stabilize their bodies before recording the data. The lengths of the reaching toes and the heel of opposite foot were measured manually. The scores of the SET were recorded with the longest lengths of all 3 directions added to be the total score. Peak GRF and SET results were input into SPSS (SPSS Inc. Chicago, IL) and reduced using Pearson correlation coefficients, $p < 0.05$. A simple linear regression was employed to identify the meaningfulness among those criterion variables.

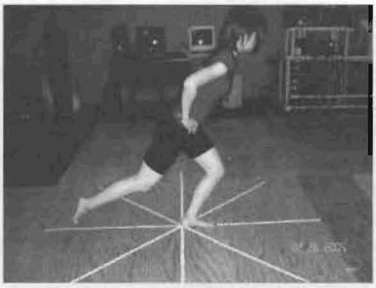

Figure 1 A participant performing the SET.

RESULTS: The outcome showed that 6 participants were evaluated as a group of the high risk of running-related injuries which including the injury was directly related to running and some of those participants experienced the injury multiple times from running or running-related activities. The other six participants were evaluated as a group of the low risk of running-related injuries as they have involved in running-related activities, but no history of the running-related or none related injuries. The scores of the SET were to compare the difference between the high risk group and the low risk group. The participants who were evaluated as the high risk of running-related injuries scored lower in the SET, as compared to the low risk participants (the high risk group: M = 134.5, SD = 4.8 inches; the low risk group: M = 159.2, SD = 8.8 inches), which supported the hypothesis of this study. Especially, the participants who had multiple running-related injuries in their past, scored the lowest because of the lack of functionality in their lower extremities. The GRF were divided by each participant's body weight. Therefore, the final outcomes of the force impact were valid to be comparable to the different body sizes of the participants. As a result, the high risk group recorded higher GRF than the low risk group. The high risk group averaged 18.9, SD = 3.3 N/BW as compared to the low risk group which averaged 14.3, SD = 0.4 N/BW This result supported the hypothesis of this study and concluded that the high risk group possesses relatively higher impact of heel strike during running, as compared to the low risk group. A Pearson correlation coefficient was calculated for the relationship among the risk scale of injuries, the scores of the SET, and the GRFs. A moderate negative correlation was found in the relationship between the score of the SET and the GRF (r (10) = -0.620, $p < 0.05$), indicating a some linear relationship between the two variables. The relationship between the risk scale of the running-related injuries and the scores of the SET showed a strong negative correlation (r(10) = -0.885, $p < 0.05$), as well as the relationship between the risk scale of the running-related injuries and the GRF with a strong positive correlation (r(10) = 0.734, $p<0.05$). A simple linear regression was calculated predicting participants' GRF based on their scores of the SET. A low significant regression equation was found ($F(1,10) = 6.25$, $p < 0.05$), with an R squared of .385. When simple linear regression was calculated predicting participants' GRF based on their risk scale of running-related injuries, a significant regression equation was found ($F(1,10) = 10.36$, $p < 0.05$), with an R square of 0.509. Lastly, a simple linear regression was calculated predicting participants' score of the SET based on their risk scale of running-related injuries. A significant regression equation was found ($F(1,10) = 34.92$, $p<0.001$), with an R square of 0.777.

DISCUSSION AND CONCLUSION: The results supported the hypothesis that there is a moderate level of the correlation between the score of the SET and the GRF. The results also identified that the high risk group was evaluated with strong relation to both low scores of the SET and high GRF. Although the values of significance (r) among the criterion valuables were relatively moderate due to the small number of N in this study, the r values might be improved by increasing number of participants for this study. In addition, coefficient of determination (r squared) was identified relatively low (38.5%) between the score of the SET and the GRF, but found moderate between the risk scale and the GRF (50.9%) and found high between the risk scale and the score of the SET (77.7%). Therefore, the high risk group had strong relationships to both GRF and the score of the SET, whereas the direct relationship between the GRF and the score of the SET was not significantly strong based on the simple linear regression. The significant finding from this study was the gender differences and its relationships to the GRF and the score of the SET. The outcome of the study showed that female participants possessed higher GRF and lower scores in the SET, as compared to male participants. This result also related to some reviewed literatures' finding. As three out of four female participants were categorized as the high risk group due to their past injuries from running, these female participants also recorded some of the highest GRF and some of the lowest SET scores. Thus, this result may support the study of Ferber et al. (2003) by identifying the strength level of the female participants, which their study did not clearly identify. Their result found that female runners engage more muscle activities during running, as compared to male runners. Their result may become reliable data by utilizing this new finding to identify that female runners possess weaker muscle stability and higher GRF, which ultimately leads to the running-related injuries. The result of the higher GRF and the low scores of the SET among the female participants also related to Horton and Hall (1989) and Wilks' (2005) statements that female anatomical structure in the lower extremity is a disadvantage to running activities because it creates higher stress to joints and muscles by possessing wider hip with V-shaped femoris. The new finding from this study may support their statement, and provide insight as to why female runners report more running-related injuries than male runners.

Based on the results of this study, we conclude that impairments in stability are associated with higher GRF during running, and that those with previous injuries show lower stability and higher GRF than those without. Runners that can reduce the GRF and improve their stability level in the lower extremity by performing proper strength and flexibility training in the long term, it may reduce the risk of injuries from running activities.

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