Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(2):554-558

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

The influence of forefoot binding force change on vertical jump kinematics variation

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ABSTRACT

Sports equipment is able to stimulate the human body for some related performance improving. The aim of this study is to explore the influence of metatarsal binding force variety on the lower limb kinematic changing. 7 healthy male volunteers were recruited, and every subject complete three types of vertical jump with different binding force on metatarsal area. The results showed that foot dorsiflexion angle was increased significantly after binding force enforced. It may have other effect when the binding position changed to other parts of the foot, further study shall paid to the lower limb muscles stimulation when the extra tension force exerted.

Key words: Vertical jump; Metatarsal; Binding force

INTRODUCTION

Competitive sports have always been concerned, which not only brings the audience brilliant games, but also attains glory for the country with victory. As the principle part of the competition, athletics ability determines the extent of excellence and the result of the contest, therefore, the development of athletic ability is becoming a main point of competitive sports for researches.

Generally, the increasing of internal factors of athletes were more significant than that of external ones. However, achievements in sports demand the advance of technical capacity as well as the improvement of the external environment, such as ambient that helps to improve athletic performance to some extent and sport equipment and so on. Previous studies demonstrated mirroring environment contributed to aerobics exercises [1]. Favorable sport equipment are the basis of completing the technical movements. It has been proved that training and racing with appropriate sport equipment can influence the training effects and competence in competition [2]. Researchers tested the height of vertical jump, ground reaction forces and lower limb muscle EMG changes of the subjects whose triceps surae were tied with elastic bandages while vertical jump, resulting in the distinct increases of ground reaction forces and no significant changes in EMG [3]. It indicated that a certain stimulus imposed externally can effectively promote the constructional ability of triceps surae, but there is no further explanation of the reasons for increased ground reaction forces. Studies show that proximal portion of the limb have a higher rotational inertia ,one completing the technical movements of vertical jump, the proximal joints generate higher energy consumption in in completing reverse movements before stretch, for completing submaximal vertical jump action. The distal portion of the limb achieves the maximized contribution while the proximal part presents the minimized one [4]. Inspired by previous studies, whether imposing certain binding forces on foot which is located in the most remote part of the body will produce effective stimulus similarly to change the kinematics changes of vertical jump is still unknown. However, the performance of vertical jump is mainly constrained by three aspects of physiological structural characteristics, joint angles and gravity [5]. Therefore, the analysis of vertical jump should proceed from physiological structural characteristics, joint angles and gravity.

In this study, the joint angle changes are the research priorities, and we explore select forefoot to be applied to a certain stimulation to verify whether binding force changes in metatarsal regional affect changes in lower extremity joint angle.

EXPERIMENTAL SECTION

Seven healthy male subjects (age 20.71±1.4 years, height 1.74±0.04m, body mass 66.26±2.84kg, engaged in aerobics exercise 4.14±1.3 years) volunteered to participate in this study. All subjects were excellent athletes of Ningbo University. All subjects were physically active and had no recent lower extremity injury or pain at the time of the study.

Preceding the data collection, each subject was screened by an aerobic coach, and any subject who motion instability was excluded from the study. The subjects were tested while on three shoe conditions: ordinary aerobic shoe (*N*) provided for the study by Double star Corporation and a prototype binding two elastics (*T*) and a prototype binding four elastics (*F*). The position of elastics situate middle of 1-5 metatarsal, the position away from the metatarsal joins, it will not produce intervention on metatarsal joint movement. In order to guarantee the accuracy of experimental conditions, make sure the bound location of shoe were in accordance with constraints position of anatomy, while we found the bound location we made a mark on shoe upper. The shoes of this study were simple aerobics shoes, and the vamp was lightweight fabric quality, the sole was rubber material. The elastics was made of rubber.

According to information in previous literature reported has not similar study, so the choice of binding force was lack of theoretical basis, hence this study investigative selected two and four elastics emanating force as stimulus variables（if the elastics selected too lack, then may not generate enough stimulation. If the elastics selected too much that will lead to discomfort, and even cause damage to the athletes. The modulus of elasticity was 176N/cm, by measuring the elasticity value of two and four elastics respectively 49.3N and 98.6N.

Each subjects performed submaximal vertical jump with three kinds of experimental conditions. In the process of vertical jump subjects put hands on hips, and both feet close up. Each experimental condition was randomly selected. Before testing, subjects were allowed to familiarize the testing conditions. A successful trial was both feet jump at same time and land at same time. In the process of vertical jump the position of body center on significant deviation in the sagittal plane and frontal plane.

Figure. 1 Reflective markers placed on the one side of the lower limb.

Three-dimensional kinematic data were obtained with eight high-speed cameras at 250 Hz (vicon Oxford Metrics Limited UK) system was calibrated allowing a three-dimensional residual error 0.5mm. Before testing, three retro-reflective markers were attached each segment of lower limbs. The markers attached with a divided into two groups. A group of makers attached with pelvis (four)：lift and right anterior superior spine, lift and right posterior superior iliac spine; another group of markers attached with lower limb (twelve): lift and right knee, lift and right thigh, lift and right shank, lift and right ankle, lift and right toe, lift and right heel. In order to distinguish between left and right sides, the markers of right thigh was slightly lower than lift thigh (Figure 1)

The markers had been attached. A standing calibration for each shoe condition was obtained with the subjects standing in an upright reference position, where the long axis of the right foot was parallel to the anterior-posterior axis of the laboratory coordinate system. This position was require to determine the locations of the joint centers relative to the segment markers. After static calibration, subjects performed submaximal vertical jump with hands on hips in the experimental area. Three groups maximum vertical jump was performed in each condition and each group of three times. Each group vertical jump was completed, subjects have a rest for 5 minutes to avoid fatigue. The joint markers were then removed and the walking trials were performed. The data were smoothed with a low-pass fourth-order Butterworth filter with 20 Hz and 100 Hz cut-off frequencies for kinematic data. Vicon system collection angular variation of knee and ankle joints in sagittal, frontal plane and horizontal plane. Statistical analysis use spss17.0 software, paired sample t-test was used to analysis significance of angular variation peak value of knee and ankle. The level of significance was set at $\alpha=0.05$ to identify statistically significant differences between the three shoe conditions.

RESULTS

In the take off stage of vertical jump, the binding two (*T*) and four(*F*) elastics shoes both showed angular variation peak value of the ankle in sagittal plane that was significantly different from the ordinary aerobic shoe (*N*) (Figure 2) ($p<0.05$). None of variables calculated for angular variation peak value of the ankle in frontal plane as well as horizontal plane, showed any significant differences between the ordinary aerobic shoes.

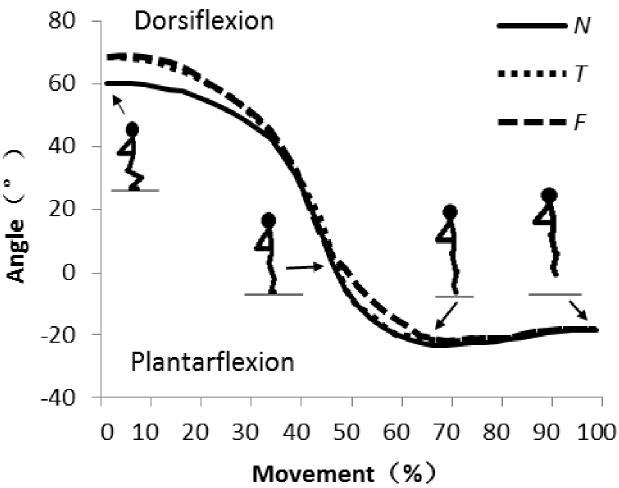

Figure. 2 Mean ankle angular variation in sagittal plane

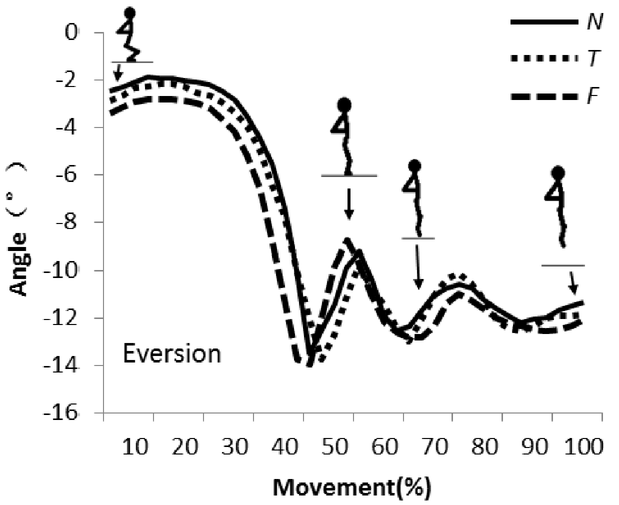

Figure. 3 Mean ankle angular variation in frontal plane

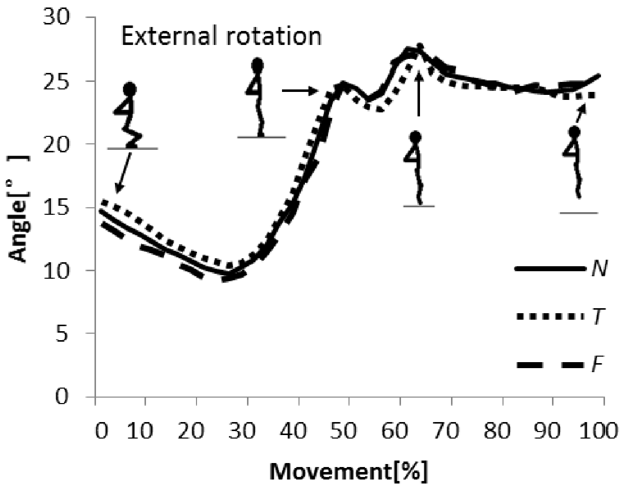

Figure. 4 Mean ankle angular variation in horizontal plane

DISCUSSION

The purpose of the study is to explore the effect of forefoot, metatarsal area, binding force changes on the vertical jump kinematics of human. The assumption of the experiment is that the increased binding force in the forefoot, metatarsal bones lead to an obvious change of lower extremity angle. The results show that in the initial taking-off stage, the forefoot, metatarsal area, with binding rubber band greatly increased in the sagittal plane of crest compared to that without binding rubber.

Experiments collected the ankle and knee's joints' angle changes in the sagittal plane, coronal plane and horizontal plane from the beginning of vertical jump to the highest point (Figure 2-4). In the graph, four movements were labeled, center of gravity to the lowest before taking-off, feet still on the ground after jump, the point feet leaving ground after jump and the highest point. In this study, angle change of left lower extremity was measured as the standard, to research the angle changes from the initial stage of jump to the highest point. According to all the angle change data, only in the initial phase of taking-off the ankle's peak angle change in the sagittal plane showed a significant increase (Figure 2). It depicted that foot dorsiflexion angle increased in the initial stage of taking-off. The reason may be some of the rubber band around the sole elevated the forefoot region, resulting in the increase of peak dorsiflexion angle in the initial stage of vertical jumps. The study of Clifford Larkins et al showed that when people standing on the slopes of a negative tilt angle completed vertical jump, the height increased. While standing on the slope of a positive tilt angle, the vertical jump height slightly reduced [6].

The reason of a slight knee change may be foot tied with rubber band which changed the proprioceptive system of lower limb. The proprioceptive system included sensory and some other features, which relate to the feeling of space consciousness and musculoskeletal mechanical state, including the location of sensory, motor and balance [7]. In general, the proprioception perceived the sense of joint displacement and vibration and joint position sense. It is a complicated neuromuscular reflex activity, to increase the stiffness of the muscles and decrease their displacement [8], to maintain a stable posture [9] and joint stability [10]. The metatarsal region with rubber band may become more stable, and metatarsal muscles and ligaments around the joint may become stiff, which increased the spatiality of lower limbs.

The study conducted a preliminary analysis of the angle changes in the lower extremity and didn't make any further research on the EMG of the lower limb muscle and ground reaction force changes. Similar studies tested the change of EMG and ground reaction forces with binding elastic bandage on the triceps surae. And the result showed the change of EMG is not distinctively obvious but the ground reaction force greatly increased [3]. In future studies, it is necessary to probe into the changes of EMG and ground reaction force of the lower extremity.

CONCLUSION

The experiment was performed with two feet jump, but the study selected the angle change of the left lower limb as reference. The experiment did not prove whether there would be any obvious angle change in the right lower extremity. Therefore, the analysis angle changes of both lower limbs are essential in the future studies.

Acknowledgement
This work was financially supported by Ningbo Natural Science Foundation (2013A610262), SRF for ROCS, SEM,

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