Acta Technica 62 No. 3A/2017, 29–36

Effects of friction property on biomechanics of lower limbs of table tennis players

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Abstract. Friction property is an important property of sports shoes. In this paper, we studied the changes of lower limbs biomechanical characteristics of athletes between the soles and the surface of the site under different friction property conditions. Eight college students who majored in table tennis were selected as the subjects. Subjects were wearing two pairs of table tennis shoes respectively and completed the stepping forward and hitting the ball action under two angles on the surface of the three sites. The joint and kinematics data of the lower limbs were collected to analyze the effects of the friction property between the athletic shoes and the surface of the site on the biomechanical characteristics of the lower limb. The results showed that with the increase of the friction coefficient, the knee flexion angle at the peak of the ground vertical force decreases and the minimum value of the knee joint flexion angle during batting tended to decrease.

Key words. Sports shoes, friction property, table tennis, biomechanics.

1. Introduction

Table tennis players always suddenly start, stop, move and twist when they are in the squat state in the training and competition, and the knee and ankle loads are great. For different levels of athletes, the risk of injury also increases with the increase of exercise intensity and requirements, as well as the growth of training life [1]. In addition to the training and competition, the venue and equipment are parts of the factors causing the sports injury. Some studies think that the complex structure and function of foot and ankle make the footwork of table tennis players more important. And the high injury rate of the ankle and foot shows that players need to pay more attention in training, but also need to choose the right sports shoes carefully.

At present, there is no standard instrument and test method to measure the coefficient of friction. The research on friction performance of sports shoes is not

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deep enough. It mainly focuses on the comparison of the friction coefficient between different soles and surfaces of the ground. The study on the effect of the friction property on the movement is relatively lacking. The effect of the friction property between the sports shoes and the surface of the ground will affect the biomechanical characteristics of the lower limbs of the table tennis players and this effect is a potential factor to increase the injury of the lower limbs of the players, which need to be verified experimentally. In this paper, we mainly aim at the effect of friction property on the knee joint of table tennis players [2].

2. Subjects and methods

2.1. Research objects and equipment

Eight male college students who are the table tennis players are selected as experimental subjects. They are all right-handed and have taken the second grade. Subjects have no history of serious injury to the lower limbs and did not engage in vigorous exercise 24 hours before the experiment [3]. The basic information of the subjects is shown in Table 1.

Table 1. Basic information of subjects ($n = 8$)

Height (cm)	Weight(kg)	Age (year)	Sports level
173.1±4.2	62.8±2.7	21.9±1.1	Second

The Kistler three-dimensional force platform (Model 9281CA) made in Switzerland was used to collect the ground reaction force and related parameters during the stroke. The frequency of collecting was 1000 Hz. The kinematic data of the lower limbs of the subjects were collected by the Motion infrared high speed motion capture system made in US.

The two pairs of shoes used in experimental test were table tennis shoes of two sports brands respectively, which were new N table tennis shoes and the used O table tennis shoes. The upper structure is basically the same. Subjects were wearing two pairs of shoes and uniform socks for testing.

2.2. Definition and calculation of kinematic index

The kinematic parameters are buffer time, COMx, COMy, the three-dimensional angle of the right-sided knee joint at the peak of the ground vertical impact force and the three-dimensional angle extremum of the right knee joint during the whole stroke [4]. The COMx refers to the distance between the center of gravity at the peak of the ground vertical impact and the heel in the sagittal plane, that is, the X-coordinate of the heel point minus the X-coordinate of the center of gravity [5]. The COMy refers to the distance between the center of gravity at the peak of the ground vertical impact and the heel in the frontal plane. COMx and COMy are divided by height, standardized as the multiple of the height [6]. The right pelvic coordinate system is:

$$j = \frac{r_{\mathrm{RASIS/MIDASIS}}}{\left|r_{\mathrm{RASIS/MIDASIS}}\right|}, \quad k = \frac{r_{\mathrm{MIDASIS/MIDPSIS}}}{\left|r_{\mathrm{MIDASIS/MIDPSIS}}\right|}, \quad i = j \times k\,, \tag{1}$$

where $r_{\mathrm{RASIS/MIDASIS}}$ is the vector quantity of the midpoint of the left and right anterior superior iliac spine pointing to the right anterior superior iliac spine, and the $r_{\mathrm{MIDASIS/MIDPSIS}}$ is the vector of the posterior superior iliac spine pointing to the midpoint of the left and right anterior superior iliac spine.

The right foot coordinate system is:

$$k = \frac{r_{\mathrm{RTOE/RCANKLE}}}{\left|r_{\mathrm{RTOE/RCANKLE}}\right|}, \quad j = k \times \frac{r_{\mathrm{RCANKLE/ROANKLE}}}{\left|r_{\mathrm{RCANKLE/ROANKLE}}\right|}, \quad i = j \times k\,, \tag{2}$$

where $r_{\mathrm{RTOE/RCANKLE}}$ is the vector of the right ankle joint pointing to the head point of the right foot, and $r_{\mathrm{RCANKLE/ROANKLE}}$ is the vector of the right lateral malleolus pointing to the center of the right ankle joint.

3. Results and analysis

3.1. Division of the action

The two movements selected in this paper are the common stepping and batting movements in table tennis. Like tennis, table tennis batting action is generally divided into: backswing stage, batting stage, waving stage and the reduction phase. The Motion system and the force platform collect the data simultaneously, so the data collected by the two systems is the corresponding. Figure 1 shows the curves of the vertical force during the movement of a subject [7].

3.2. Kinematics time-space parameters analysis

The interaction of the friction coefficients and movement on the buffer time, COMx and COMx was no significant difference, and there was no significant difference in the three friction coefficients between the three variables. COMx had a significant difference between the two actions (as shown in Figure 2), COMx is positive at 180 ° step, and negative at 45 ° step. The time-space parameters analysis results are shown in Table 2.

3.3. Analysis of three-dimensional angles of knee joint

Statistical methods were analyzed by repeated measures of variance analysis. The results of the knee flexion angle at the peak of the ground vertical impact showed that there was no interaction between the action and the friction coefficient, the action had no significant effect on the flexion angle, and the single factor of friction coefficient was significant. The results showed that the knee flexion angle under the friction coefficient H was significantly smaller than the knee joint flexion angle under friction coefficients L and M. The adduction/abduction angle and medial rotation/external rotation angle of the knee joint were not affected by the action and friction coefficient at the peak of the ground impact force. Table 3 showed the results of the three-dimensional angle of the knee joint at the peak of the impact.

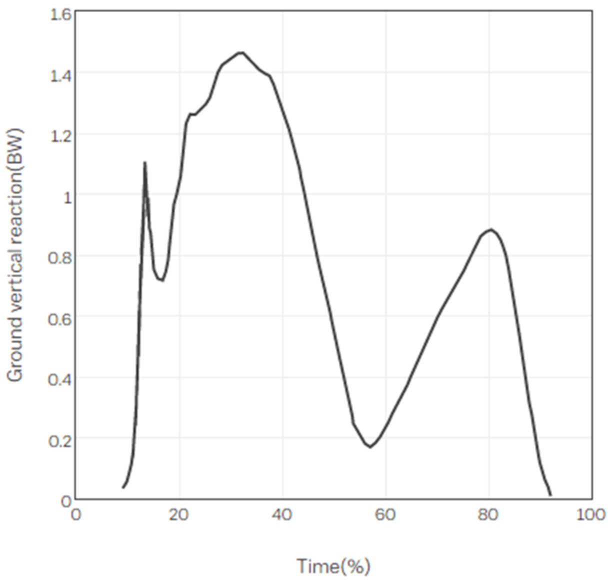

Fig. 1. Ground vertical reaction force curve of stepping and batting movement

Table 2. Time-space parameter analysis results ($n = 8$)

		Buffer time (s)	COMs (HT)	COMy (HT)
180 ° step	Friction coefficient L	0.043±0.019	0.48±0.20	2.56±0.35
	Friction coefficient M	0.057±0.029	0.55±0.24	2.70±0.24
	Friction coefficient H	0.047±0.022	0.49±0.32	2.77±0.24
45 ° step	Friction coefficient L	0.040±0.018	-0.61±0.24	2.55±0.34
	Friction coefficient M	0.043±0.010	-0.53±0.47	2.61±0.32
	Friction coefficient H	0.037±0.008	-0.62±0.35	2.59±0.30
P		0.352	0.796	0.327
Friction coefficient	*action	0.560	0.982	0.467

In the table, symbol P denotes the difference of the same index of the two movements in the three kinds of friction coefficient. Friction coefficient *action is the P value under the interaction of the friction coefficient and the action. Symbol * indicates that the significant level $P < 0.05$.

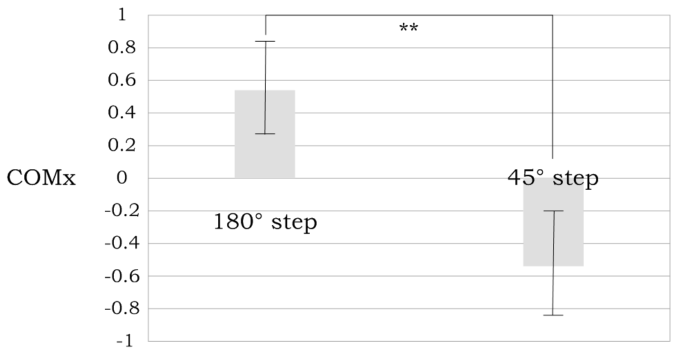

Fig. 2. Differences of COMx between the different actions (** represents $P < 0.01$, and the difference is significant)

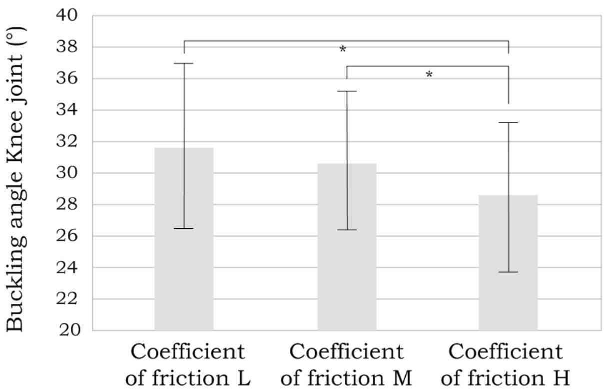

Fig. 3. Difference of the knee flexion angle at the peak of vertical impact force in the different friction coefficient (* represents $P < 0.05$, and the difference is significant)

4. Conclusion

In this paper, we aimed at the effect of friction property on the lower limbs biomechanics of the table tennis players, mainly studied the kinematic index of the athletes' lower limb. In this experiment, we took 8 table tennis students in a university as test objects. The participants completed the step and batting action under two angle with two pairs of table tennis shoes respectively on three kinds of site surfaces. The kinematic data of the knee joints of the lower limbs was collected by the Kistler three-dimensional force platform and Motion infrared motion capture system. The following conclusions were obtained: the friction coefficient affected the kinematic characteristics of the knee joint during step and batting. With the increase of the friction coefficient, the knee flexion angle at the peak of the impact force and the minimum value of the knee joint flexion angle during batting tended to decrease.

Table 3. Analysis results of the three-dimensional angle of the knee joint at the peak of the impact ($n = 8$, unit: degrees)

		Flexion angle	adduction/ abduction angle	Medial rotation/ external rotation angle
180 ° step	Friction coefficient L	33.6±6.0	-0.02±4.07	7.5±6.5
	Friction coefficient M	32.8±4.9	-0.02±4.22	9.2±8.0
	Friction coefficient H	30.2±6.2	-0.38±4.73	10.3±6.4
45 ° step	Friction coefficient L	29.9±4.8	-1.06±3.96	5.7±7.2
	Friction coefficient M	29.6±3.8	-0.07±4.34	6.7±5.9
	Friction coefficient H	27.3±3.2	0.01±4.31	10.3±9.1
P		0.026*	0.602	0.292
Friction coefficient	*action	0.949	0.078	0.517

In the table, symbol P denotes the difference of the same index of the two movements in the three kinds of friction coefficient. Friction coefficient *action is the P value under the interaction of the friction coefficient and the action. Symbol * indicates that the significant level $P < 0.05$.

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Received May 7, 2017