GROUND REACTION FORCES AND PLANTAR KINETICS OF ROPE SKIPPING IN DIFFERENT SPORT SHOES – A PILOT STUDY

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The purpose of this study was to investigate the ground reaction forces and plantar kinetics of different rope skipping skills with different sports shoes. One male elite rope skipper was instructed to skip rope with four skills and with four shoes. The skills included single bounce, double under, triple under and alternative step. The Pedar Mobile system was used to collect plantar pressure information beneath the foot inside the sports shoes. Vertical ground reaction forces (VGRF) of each skip were measured on a force platform. The mean values of each group were calculated for comparison. It was found that the VGRF is greater for triple under (~2.8 times BW on right leg), moderate for double under (~2.5 times BW on right leg), and lower for single bounce (~2.0 times BW on right leg). During landing, the peak pressure mainly occurred at the metatarsal heads and hallux.

KEY WORDS: Biomechanics, jump rope, landing, physical activity

INTRODUCTION: Rope skipping, a new kind of trend-sport, is becoming popular in schools. According to the Hong Kong Rope Skipping Association, there are 153 school members in Hong Kong and most of them have developed their own school team. Rope skipping training can significantly improve the neuromuscular coordination (Hong,1999). It is also a common activity to improve the muscle endurance and cardiovascular fitness of students during physical education lesson. Previous studies showed that regular rope skipping training increases the bone density in post-pubescent girls (Arnett and Lutz, 2002). Jumping and landing activities form a major component of sports such as volleyball, basketball, and also rope skipping. Many injuries associated with there sports occur during landing.
However, the jumping and landing techniques in rope skipping are quite different from other sports. In order to make the skipping movement efficient, it should be subtle and controlled ballistic action that propels the body in a vertical direction such that the height attained is just enough to allow the rope to pass under the feet while maintaining continuous fluid motion. During the landing phase, the skipper braces for shock absorption and weight bearing (Pitreli and O'shea, 1986). The movement is primarily eccentric with flexion of ankles and knees. The ground reaction force from rope skipping was approximately 3.2 times the body weight (Arnett & Lutz, 2002). However, few data are available regarding to the plantar pressure distribution. In order to design specific shoes for rope skipping, plantar pressure analysis is necessary. The aim of this study is to study the ground reaction forces and the plantar pressure patterns uring rope skipping in elite athlete.

METHODS: One male elite rope skipper (age: 23.0 years, body mass: 70.8kg, height: 178.3cm) and with right leg dominated participated in this study. He was currently a member of Hong Kong National Rope Skipping Team and he participated in regular rope skipping training for at least 3 hours per week. Informed consent was obtained prior the study. VGRF for each skip were measured by a force platform (Kistler, 9281CA, Switzerland) with the sampling rate of 1000Hz. The subject was instructed to skip his right leg landing on the force platform. He performed four skills

Figure 1 Four sports shoes in this study.

(single bounce, double under, triple under, and alternative step) with four popular sport shoes (running shoes, volleyball shoes, basketball shoes, clothe shoes) (Figure 1) in his own pace. For each combination, a minimum of 10 successive skipping were performed. The sequence of shoes and skills was randomized. The Pedar Mobile system (Novel GmbH, Germany) was used to collect plantar pressure data. The system consisted of two flexible insoles and each containing 99 sensors in a matrix design. The insoles were fitted into the shoes and the sampling frequency was 50Hz. The data collected was divided into nine districts for further analysis. Figure 2 shows the nine districts of insole data in left foot (M1 - medial heel, M2 - lateral heel, M3 – medial mid-foot, M4 - lateral mid-foot, M5 – metatarsal head I, M6 - metatarsal head II, M7 - metatarsal head III-V, M8 - hallux, M9 - lateral toes). For both data collected from force perform and Pedar Mobile systems, mean values of each group were calculated for comparison.

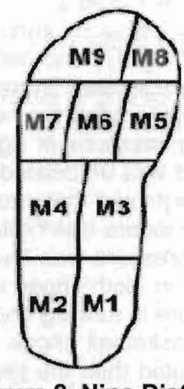


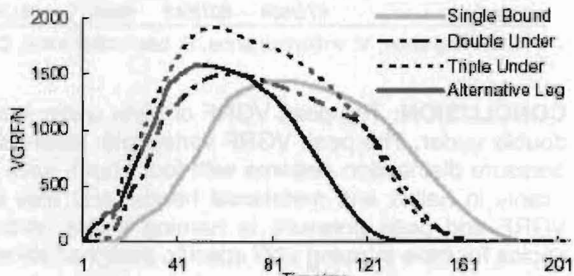
Figure 2 Nine Districts of insole data.

RESULTS AND DISCUSSION: Result showed that the peak vertical ground reaction force (VGRF) of triple under with four shoes were greatest (Table 1), which was approximately 2.72-2.99 times of his body weight (BW) on right foot. VGRF of double under was moderate, which were approximately 2.36-2.66 times of BW on right foot. The lowest VGRF occur in the single bound, which were approximately 1.84-2.91 times of BW on right foot. For the triple under skill, it is necessary for the rope to pass under the feet for three times in each skip. The skipper has to skip higher than performing single bounce and double under to allow more time for the rope to pass through. Also, immediate rebound after each landing was essential to maintain the continuous fluid motion, it limited the time for reducing impact force by ankles and knees flexion. Due to greater jumping height and shorter touch down period, greater VGRF was resulted. On the other hand, the alternative step skill is unlike the standard two-footed jump in that the performer pushes off on one leg and lands on the opposite leg. In order to perform this step, the performer must shift his weight alternately from one leg to the other. Since the leg is responsible for single support, it bears the most weight of the landing. The peak VGRF of alternative step was approximately 2.50-2.91 times of BW on right foot. These low VGRF were mainly caused by the low skipping height.

Table 1 Peak VGRF (N/BW) on right foot of different skills in different shoes.

	Single Bounce	Double Under	Triple Under	Alternative Step
Running Shoes	1348 / 1.94	1640 / 2.36	1887 / 2.72	1759 / 2.53
Volleyball Shoes	1520 / 2.19	1845 / 2.66	2072 / 2.99	1810 / 2.61
Basketball Shoes	1331 / 1.92	1710 / 2.46	1891 / 2.72	2018 / 2.91
Cloth Shoes	1279 / 1.84	1771 / 2.55	2033 / 2.93	1734 / 2.50

Among these four shoes, the mean peak VGRF with cloth shoes were lowest when performing single bound and alternative step skill, which were approximately 1.84 times of BW (Table 1). The mean peak VGRFs with running shoes were lowest when performing double and triple under. Mean peak VGRF with volleyball shoes were relatively higher when performing both four skills. The trends of the VGRF of four skills from foot strike to 200ms after foot strike are



Fiqure 3 Trend of VGRF of fore skills with time.

shown in Figure 3.
Plantar pressure during landing of rope skipping (Table 2) occurred mainly at metatarsal head (M5-M7) and hallux. The mid-foot (M3-M4) and lateral toes (M9) shared some of the pressure as well. In most case of standard two-footed jump, such as single bounce, double and triple under, the heel regions (M1-M2) were free from pressure. Result showed that the plantar pressure of right foot was relatively higher than left foot in most case. Since the subject was dominated with his right foot, he tended to use his dominant leg to bear more of his weight and then resulted in higher value.
The pressure distribution patterns among four shoes were similar. Table 2 showed that the peak pressure was lower in running shoes with same skill, whereas the peak pressure was higher in cloth shoes with same skill. There were about 30% difference between the peak pressure in running shoes and cloth shoes. Moderate pressure was found in volleyball shoes and basketball shoes. For the alternative step skill, the peak pressure was more evenly distributed than the two-footed jump. Unlike single bounce, the rear foot (M1-M2) also bore part of the pressure when performing alternative step skill. On the other hand, pressure was significantly reduced in hallux (M8) when compared with two-foot jump.

Table 2 Peak pressure (kPa) of the four skills with different shoes (L/R).

Skill	Single Bounce				Double Under			
Shoe	R	V	B	C	R	V	B	C
Medial heel	0/0	0/0	33/26	0/0	0/0	0/6	5/20	0/5
Lateral heel	0/0	0/0	6/0	0/0	3/0	0/0	0/0	0/2
Medial mid-foot	44/70	32/51	80/74	0/59	91/107	50/117	99/121	37/112
Lateral mid-foot	45/79	38/63	80/72	40/94	152/119	80/102	113/124	164/152
Metatarsal head I	199/263	277/322	209/256	362/353	366/485	471/422	443/420	601/602
Metatarsal head II	192/250	271/323	196/231	362/365	395/484	474/423	445/429	619/611
Metatarsal head III-V	139/160	190/232	164/153	238/235	308/251	348/272	342/295	510/400
Hallux	223/279	293/297	225/232	217/195	245/414	309/452	279/318	274/366
Lateral toes	59/74	81/82	106/108	59/89	120/175	81/128	136/144	94/152
Total	227/289	297/330	225/257	362/365	395/485	474/454	445/431	619/610
Skill	Triple Under				Alternative Step			
Shoe	R	V	B	C	R	V	B	C
Medial heel	6/33	13/24	20/57	0/12	97/56	109/49	113/76	100/15
Lateral heel	4/18	5/0	0/17	0/12	117/55	128/47	128/49	110/16
Medial mid-foot	120/168	133/179	145/202	88/177	160/147	166/138	159/144	199/155
Lateral mid-foot	162/177	161/147	157/194	186/197	253/160	257/164	270/167	457/223
Metatarsal head I	552/528	601/516	535/447	616/612	220/243	252/269	182/198	271/322
Metatarsal head II	557/534	607/523	556/470	631/622	254/254	310/306	212/216	344/407
Metatarsal head III-V	381/290	424/330	429/339	532/417	236/193	261/253	217/191	333/308
Hallux	449/392	497/530	339/322	360/355	121/130	236/240	204/148	142/138
Lateral toes	135/186	105/149	163/158	98/153	66/78	71/70	54/60	62/61
Total	575/534	607/543	556/471	631/622	263/254	312/306	271/216	457/407

R: running shoe, V: volleyball shoe, B: basketball shoe, C: cloth shoe

CONCLUSION: The peak VGRF of triple under was higher than those of single bounce and double under. The peak VGRF varied with different shoes and different skill performed. The pressure distribution patterns with four shoes were quite similar. Higher pressure was found mainly in hallux and metatarsal heads, and also in dominant leg. There were lower peak VGRF and peak pressure in running shoes, which suggested that it is probably a good choice for rope skipping until specific designed shoes are investigated.

REFERENCES:
Arnett MG & Lutz B (2002). Effect of rope-jump on the os calcis stiffness index of

postpubescent girls. *Medicine and Science in Sports and Exercise*. 1913-1919.
Hong Y (1999). Neuromuscular coordination to rope skipping training: Kinematics and EMG study. 5_{th} IOC World Congress on Sport Sciences.
Pitreli J & O'shea P (1986). Rope Jumping: The biomechanics, techniques of and application to athletic condition. *NSCA Journal*. 8: 5-11, 60-61.