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Original Article

Reliability of lower leg proximal end and forefoot kinematics during different paces of barefoot racewalking on a treadmill using a motion recorder (MVP-RF8-BC)

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Abstract. [Purpose] This study was performed to investigate the changes in lower leg proximal end and forefoot kinematics, and reliability of measurement during different paces of barefoot racewalking on treadmill. [Subjects] Eleven junior racewalking men participated in this study. [Methods] To identify changes in lower leg proximal end and forefoot kinematics, during different paces of barefoot racewalking on a treadmill, a wireless motion recorder (MVP-RF8-BC) was used. Interclass correlation coefficients (ICC 1, 2) were used to estimate reliability. [Results] There were significant differences in the lower leg proximal end and forefoot maximum medial/lateral rotations at a pace of 9 km/h compared with those at a pace of 5 km/h pace. The intra-examiner reliability estimates ranged from 0.82 and 0.89 to 0.87 and 0.93 for lower leg proximal end inversion/eversion rotation and medial/lateral rotation, and from 0.92 and 0.84 to 0.93 and 0.91 for forefoot inversion/eversion rotation and medial/lateral rotation. [Conclusion] We conclude that the lower leg proximal end and forefoot kinematics of barefoot racewalking on a treadmill are influenced by different paces and that assessment of lower leg proximal end and forefoot kinematics by means of the wireless motion recorder (MVP-RF8-BC) is adequately reliable. This information may be useful for determining exercise prescriptions.

Key words: Motion recorder, Kinematics, Reliability

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INTRODUCTION

The 8ch Wireless Motion Recorder (MVP-RF8 Series) is an inertial measurement unit made by MicroStone Inc., Saku Japan. It is an electronic device that uses the combination of an accelerometer, gyroscope, and magnet attachment (option that provides a reference frame) to record the location and orientation of the device in 3D space. The location and orientation are detected by calculating linear displacement (using accelerometer data) and rotational displacement (using gyroscope data) of the device from a reference point. The MVP-RF8 Series can be used to record behavior, rehabilitation and sports for motion analysis. Tao Zheng et al. reported use of a miniature wireless motion recorder (MVP-RF8-GC) to record the maximum cervical range of motion (ROM) and joint position error before and after interventions[1)].

Walking is an essential movement and is the most frequently performed action by human beings[2)]. Racewalking is an

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Olympic event, and the popularity of racewalking has increased steadily. It has not yet attracted large numbers of adolescents in China, but there appear to be indications that the event is growing in popularity. Racewalking events of 5 and 10 km are becoming increasingly popular for amateur athletes, and successes in these relatively short events have inspired some teenagers to attempt longer distance races. A number of walking enthusiasts have attributed the rising popularity of racewalking to decline in the popularity of jogging and this trend has been influenced by widespread belief that racewalking is a sport providing opportunities for competitions, as well as valuable health and fitness benefits, without significant risk of injury[3].

Previous research has shown that success in race walking is related more to the efficiency of technique rather than physiological factors[4]. The kinematics of the forefoot in racewalking are triplanar motions. Since the axis of the subtalar joint is not in any cardinal plane, the motions occurring in the subtalar joint present a triplanar motion pattern. The triplanar motions of the forefoot are as follows: transverse motion, frontal motion and sagittal motion. The transverse motions occurring primarily in the subtalar joint are composed of medial rotation (adduction), which is movement of the forefoot or part of the foot medially in horizontal plane and lateral rotation (abduction), which is movement of the forefoot or part of the foot laterally in the horizontal rotation. Rotations in the coronal plane were defined as inversion and eversion rotation. During running, both medial and lateral rotation were observed in the footprints of the rearfoot and forefoot in the horizontal plane[5]. There are significant differences between racewalking and normal walking or jogging during the stance phase (closed kinematic chain motions) of the gait cycle. This is because two simple rules govern racewalking: The first rule of racewalking demands that at least one foot is in contact with the ground at all times. This rule defines racewalking as opposed to jogging. The second rule of racewalking demands a straight leg from contact with the ground until the leg reaches the vertical upright position relative to the ground, which distinguishes racewalking from normal walking. Keeping the leg straight with foot introversion increases torque at the knee, and this may be a potential factor for lower extremity injuries.

In fact, although treadmills may not be suitable for everyone, they offer walkers many more options for more efficient workouts. One of their best features is that they can be set at various paces. Racewalkers often use treadmills because of the benefits of having a flat unchanging surface allowing pace judgment to be learned[6]. The purpose of this study was to investigate the changes in proximal lower leg and forefoot kinematics, and reliability of measurement during different paces of barefoot racewalking on treadmill.

SUBJECTS AND METHODS

This study was conducted with 11 healthy young amateur racewalkers. The participants were students of the Huaian Sports School of Huaian City, China. To be included in the study, each participant was required to have been trained at the school for at least 3 years. The participants' characteristics are detailed in Table 1.

The participants were excluded if they had a lower limb or foot injury, visual problems, or vestibular problems. The exclusion criteria were assessed by using a questionnaire and through physical tests. The participants signed an informed document approved by the ethics committee of Jangsu Province Huaian Sports School, which also approved the study. Before the testing session, all of the participants were supervised while they performed a 10-minute conventional routine warm-up. The participants were asked to refrain from any exercise for 2 hours before testing.

Participants walked barefoot on an instrumented treadmill. The lower leg proximal end and forefoot maximum inversion/eversion (I/E) rotation and medial/lateral (M/L) rotation were measured with an 8ch Wireless Motion Recorder (MVP-RF8-BC, MicroStone Inc., Saku, Japan) during racewalking at pace of 5 and 9 km/h. The wireless motion recorder was attached to the third and forth metatarsal of the right foot in order to record forefoot kinematics and to the proximal end of the right lower leg and just below the proximal end of the fibula to record lower leg proximal end kinematics . The sampling rate of the wireless motion recorder was 200 Hz, and the data were transmitted by bluetooth to a computer. The data were collected for 6 seconds in two capture stages and approximately 30 seconds plateau was reached in each stage. The participants' motion characteristics in 3 consecutive gait cycles at each of the 2 speeds were recorded and analyzed with the MVP-RF8-BC analysis software system. The means of 2 measurements were adopted as representative values. A video camera (200 fps) was simultaneously used to record the cycle phases and racewalking technique. The measurement sequence was completely random for each participant.

The PASW Statistics 18.0 statistical package was used for statistical analysis. Differences in lower leg proximal end and forefoot kinematics were compared by employing the independent t-test. The level of statistical significant was set as $p = 0.5$. The intra-class correlation coefficient (ICC1, 2) was also calculated to investigate the within-subject reliability of proximal lower leg and forefoot kinematics.

RESULTS

The lower leg proximal end and forefoot maximum inversion/eversion (I/E) rotation and medial/lateral (M/L) rotation during barefoot racewalking at the 5 km/h and 9 km/h paces on the treadmill are shown in Table 2. The independent t-test showed that there were significant differences in the lower leg proximal end and forefoot maximum medial/lateral (M/L) rotations at the 9 km/h pace compared with those at the 5 km/h pace. The ICC values (1,2) are shown in Table 3. The values of lower leg proximal end and forefoot maximum inversion/eversion (I/E) rotation and medial/lateral (M/L) rotation at the

Table 1. Characteristics of the subjects (n=11)

Age (years)	16.3±1.9
Weight (kg)	58.4±10.1
Height (cm)	177.8±10.7

Data are presented as the mean ± standard deviation

Table 2. Comparison values of LL I/E, LL M/L, F I/E and F M/L at different paces (n=11)

	Pace	
	5 km/h	9 km/h
LL I/E	3.7±0.5	3.5±0.6
LL M/L	3.6±0.7	4.2±0.6*
F I/E	12.3±2.2	11.6±4.1
F M/L	5.1±1.2	6.7±0.7**

Data are presented as the mean ± standard deviation.
Significant differences at different paces: *p<0.05; **p<0.01.
LL I/E and LL M/L: lower leg proximal end maximum inversion/eversion and medial/lateral rotation.
F I/E and F M/L: forefoot maximum inversion/eversion and medial/lateral rotation.

Table 3. Interexamer reliability of LL I/E, LL M/L, F I/E and F M/L at different paces (n=11)

	Pace	
	5 km/h	9 km/h
LL I/E	0.82	0.87
LL M/L	0.89	0.93
F I/E	0.92	0.93
F M/L	0.84	0.91

LL I/E and LL M/L: lower leg's proximal end maximum inversion/eversion and medial/lateral rotation.
F I/E and F M/L: forefoot maximum inveesion/eversion and medial/lateral rotation.

5 km/h and 9 km/h paces showed a high level of reliability. The intra-examiner reliability estimates ranged from 0.82 and 0.89 to 0.87 and 0.93 for lower leg proximal end inversion/eversion (I/E) rotation and medial/lateral (M/L) rotation, and from 0.92 and 0.84 to 0.93 and 0.91 for forefoot inversion/eversion (I/E) rotation and medial/lateral (M/L) rotation.

DISCUSSION

Using a wireless motion recorder (MVP-RF8-BC), the lower leg proximal end and forefoot kinematics were measured during racewalking at 5 km/h and 9 km/h paces and their measurement reliabilities were investigated. There were significant differences in the lower leg proximal end and forefoot maximum medial/lateral (M/L) rotations at the 9 km/h pace compared with those at the 5 km/h pace. This may indicate that the lower leg proximal end and forefoot kinematics of barefoot racewalking on a treadmill are influenced by different paces and that assessment of lower leg proximal end and forefoot kinematics by means of the wireless motion recorder (MVP-RF8-BC) is adequately reliable. This information may be useful for determining exercise prescriptions.

Motion capture is usually used in the medical science field for analyzing the physics of human motion, especially in biomechanics studies related to sports and rehabilitation. All these applications involve examination of kinematics and kinetics. In this study the wireless motion recorder (MVP-RF8-BC) was used to record the parameters of the moving body's trajectory.

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