P03-18 ID218

CHANGE OF MOVEMENT IN THE PELVIS DUE TO FATIGUE IN LONG-DISTANCE RUNNING- A CASE STUDY

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The purpose of this study was to clarify the three-dimensional movement of the pelvis due to fatigue in long-distance running. Four collegiate long-distance runners participated in this study as subjects and ran 4000m with a 5000m race pace. Subject D, whose running pace was significantly slowest, showed a significant decrease in stride length, stride frequency, and pelvis rotation angle at the end of the 4000m run. Furthermore, Subject D showed a significant increase in pelvis elevation. These factors suggested that to maintain the range of motion of pelvis rotation and to keep the pelvis elevation movement minimal is a very important factor in maintaining running speed and attaining high performance in long-distance running.

KEY WORDS: long-distance running, pelvis rotation and elevation angle, on the ground.

INTRODUCTION: In long-distance running, it is very important to maintain speed when becoming fatigued. Therefore, improving running motion is important to improve running performance.

Although many researchers have studied about running motion, there is little research concerning long-distance running. Williams et al.(1987) studied running motion using a treadmill. However, Nigg (1995) examined the kinematic comparison between overground and treadmill running, and showed that the running motion on a treadmill was different from movement on the ground. Therefore, it is important to study about the running motion on the ground. Enomoto (2003) compared the running motion of first-rank and collegiate long-distance runners and clarified characteristics of the movement of first-rank long-distance runners. However, it was undertaken by two-dimensional analysis, and the motion of the pelvis was not analysed.

Recently, the motion of the pelvis has been focused on in the running motion.

Kobayashi (2003) showed the importance of the motion of the waist in the running motion.

Ae (2002) also pointed out the necessity for muscle group strengthening concerning motion of hip joint and pelvis. Matsuo (2004 ,2006, and 2010) clarified the motion of the pelvis in sprinting and showed that the movement of the pelvis changed, depending on the running speed. It is important to clarify the movement of the pelvis for improvement of the running motion and to maintain speed in long-distance running. However, there is no research regarding the movement of the pelvis in long-distance running in relation to fatigue. The purpose of this study was to clarify the three-dimensional movement of the pelvis due to fatigue in long-distance running. Such motion of the pelvis will be able to be taken into consideration regarding technique in long-distance running and can be an important basis for how to improve performance.

METHODS: Four collegiate long-distance runners (height 174.9 ± 3.9 cm, body mass 61.3 ± 5.6 kg, 4000m time 13'18"0 ± 19"6) participated in this study as subjects. The subjects ran the 4000m trial at a pace that was based on their personal best time in a 5000m race. A three-dimensional motion capture system with eight MX-T40 and two MX-T10 cameras (Vicon Motion Systems, Oxford, UK) was set up on an athletic field, and used to collect 3D coordinate data from the markers for each 400m of the 4000m run at 250Hz. A total of 45 retroreflective markers with a diameter of 16mm were attached to the body surface of each participant. Among them, four marker sets were attached to the left and right anterior

superior iliac spine (ASIS) and posterior superior iliac spine (PSIS). A rigid link model of the pelvis was created from the four markers, to calculate the pelvis angle.
Fig.1 shows the definition of the angle of the pelvis. The running motion was analyzed by setting the y'-axis with respect to the runner's direction of movement. A straight line connects the last frame from the first frame of the center of the ASIS of the left and right sides of the runner. The z'-axis was the vertical direction, and the x'-axis was perpendicular to the y'-axis and z'-axis.
The pelvis forward-bend angle was calculated as the angle projected on the position x'y' of the moving reference frame. The pelvis elevation angle was calculated as the angle projected on the place x'z' of the moving reference frame. The pelvis forward/backward rotation angle was calculated as the angle projected on the position y'z' of the moving reference frame.
The coordinate data was smoothed by a fourth-order Butterworth digital filter at 5-10 Hz, which was fixed for each point by residual analysis.
The running parameters (lap time, stride length, and stride frequency) and angles of the pelvis (rotation, elevation, and forward-bend) were calculated. The 4000m run was divided into three phases. The beginning phase was the first three laps, middle phase laps 4-6 and the end phase laps 7-9. All subjects showed improvement of their lap times in the final lap, so it was excluded.
In this study, the subjects were very few and as such could not be compared statistically. Therefore, we analyzed every person's motion as a case study.

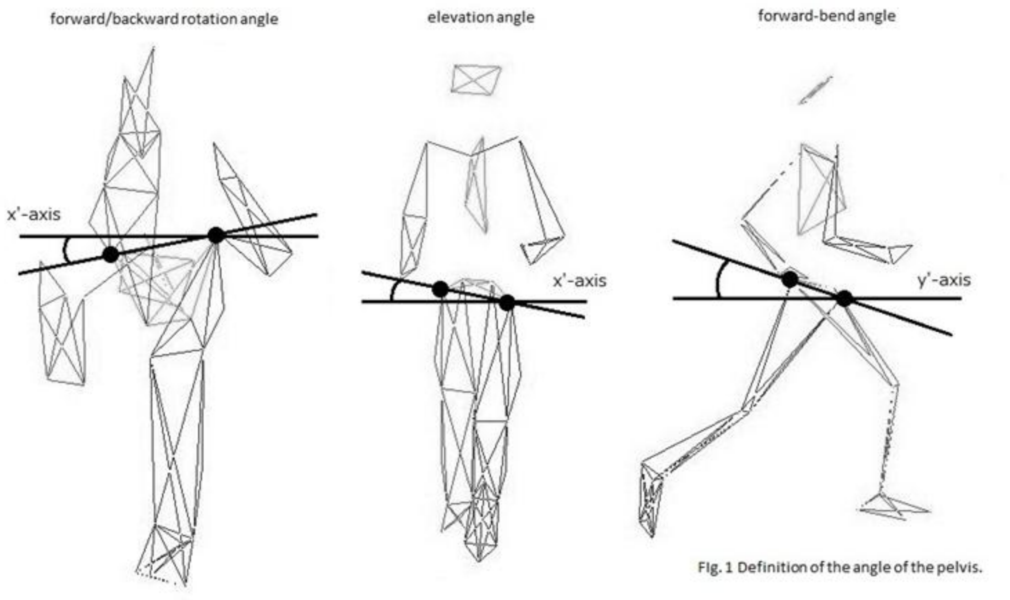

Fig. 1 Definition of the angle of the pelvis.

RESULT: Fig.2 showed the lap time for each lap in the 4000m run. Subject A, B, and C maintained their lap times better than Subject D. Subject D showed the greatest reduction in the middle and end phase compared with the beginning phase.
Fig.3 showed the stride frequency for each phase. All subjects decreased their stride lengths toward the end phase.
Fig.4 showed the stride frequency for each phase. Subject A and C maintained their stride frequency through the three phases. Subject B increased, and Subject D decreased their stride frequency toward the end phase.

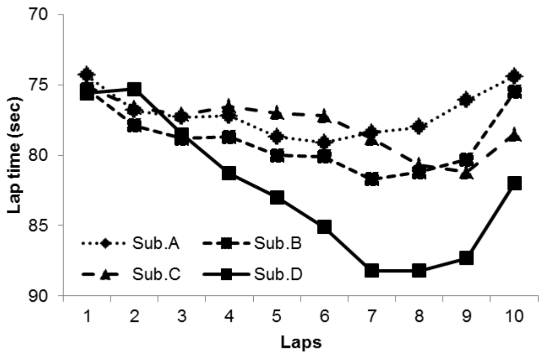

Fig. 2 The lap time of each subjects for each lap.

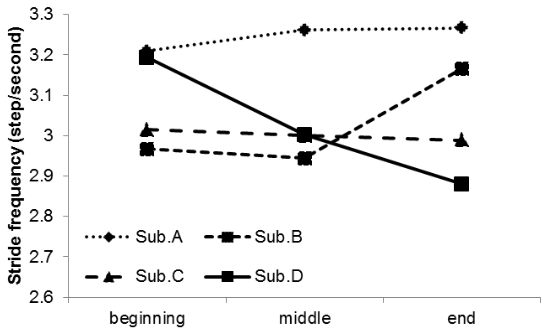

Fig. 3 The stride frequency of each subjects for each phase.

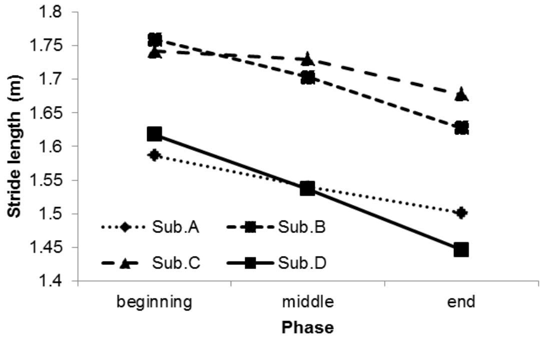

Fig. 4 The stride length of each subjects for each phase.

Fig.5 showed the pelvis forward/backward rotation angle for each of the phases. Subject A, B, and C showed no change toward the end phase, while Subject D tended to decrease the range of rotation in the middle and end phase compared with the beginning phase.
Fig.6 showed the pelvis elevation angle for each phase. Subject A, B, and C showed the tendency that the rotation angle increased from the beginning to the middle phase, and then decreased toward the end. Subject D decreased the elevation angle from the beginning to the middle phase, and then increased it toward the end phase.
Fig.7 showed the pelvis forward-bend angle for each phase. All subjects showed no significant changes.

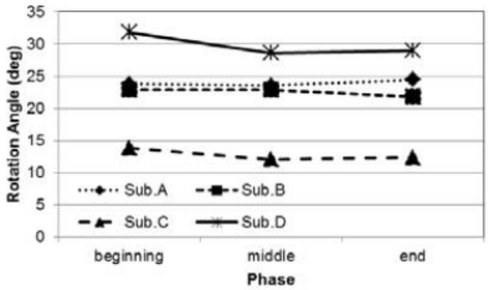

Fig. 5 The rotation angle of the pelvis for each phase.

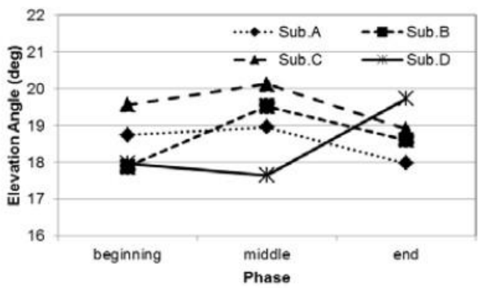

Fig. 6 The Elevation angle of the pelvis for each phase.

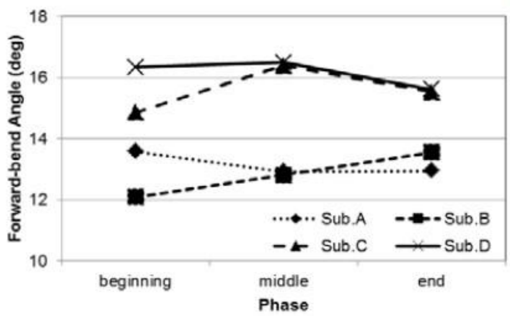

Fig. 7 The Forward-bend angle of the pelvis for each phase.

DISCUSSION: The stride frequency and stride length measurements of Subject A, B, and C showed the same changes, and tendencies as the data shown in the previous study by Enomoto (2003). Comparatively, Subject D showed different changes from the others. This subject showed a rapid decrease in lap time, stride length, stride frequency and pelvis rotation angle in the middle and end phase compared with the beginning phase. Furthermore, the elevation angle was significantly increased in the end phase (Fig.6). These factors suggested that, in Subject D, the range of motion of pelvis rotation decreased due to fatigue, and the step length also became shorter. Therefore, it was thought that Subject D elevated his pelvis greater to increase stride length. To maintain the range of motion of pelvis rotation and to keep the pelvis elevation movement minimal is a very important factor in maintaining running speed and achieving high performance in long-distance running.

CONCLUSION AND LIMITATIONS: In this study, it was observed that to improve or maintain pelvis movement is crucial in high performance long distance running. In this study, the subjects were minimal and could not be compared statistically. Therefore, it is necessary to analyse more subjects and to compare the subjects who can maintain lap times with the subjects who cannot, and to investigate the importance of the motion of the pelvis in greater depth.

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