CHANGES IN STEP LENGTH AND WIDTH DURING TREADMILL RUNNING

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The purpose of this study was to measure a runner's step length and width during thirty-minutes of treadmill running. The step kinematics for sixteen subjects, ten experienced and six inexperienced treadmill runners, were acquired and analyzed. Four LED markers were positioned on the front tips of the toe boxes and heel counters on both the right and left shoes at the same level. The positions of the four markers were captured by a Visualeyez system for ten seconds at the beginning of the 5 th and 30 th minutes. The results showed that the subjects seemed to increase their step length backward in their toe-off position after thirty-minutes of treadmill running. The maximum range of movement, defined as the product of the maximum step length and the maximum step width, was 66% and 30% of their height for the subjects during thirty-minutes of running.

KEYWORDS: treadmill deck, motion capture, experienced treadmill runners

INTRODUCTION: Because of poor outdoor environments, indoor treadmill exercise is becoming a popular exercise to improve the fitness. In previous studies, the treadmill has often been used as the experimental equipment to control conditions, such as speed and surface, and to acquire data for a continuous time (Verbitsky et. al., 1998; Derek et. al., 2002; White et. al., 2002 and Hardin et. al.,2004). Although the ground reaction forces were compared for experienced and inexperienced treadmill runners, the differences in the kinematical characteristics, such as changes in step length and step width, during long time treadmill running have not been determined. The purpose of this study was to measure the runner's step length and width during long time running. The maximum range of movements on the treadmill was calculated in order to give reference to the adequate area of the treadmill deck.

METHODS: Twenty-seven subjects without a history of musculoskeletal injury were recruited in this study. However, only the kinematical results of sixteen subjects, ten experienced and six inexperienced treadmill runners, were acquired and analyzed. The subjects who had done treadmill exercise at least once a week in the past six months were defined to be experienced treadmill runners. This investigation was approved by the Human Experiment and Ethics Committee of National Cheng Kung University Hospital.

At first, the subjects ran on a treadmill (MAC-7310, Tonic Fitness Technology, Inc, Tainan, Taiwan) and increased their speed gradually until their preferred speed within two minutes. Because thirty-minutes of exercise is good to improve human fitness, the subjects were asked to run on a treadmill for thirty minutes. Four LED markers were positioned on the front tips of the toe boxes and heel counters on both the right and left shoes at the same level (Figure 1). A Visualeyez system that consists of two trackers was used to capture the three dimensional positions of the markers automatically. In order to compute the coordinates of a marker, the positions of the two trackers should be adjusted before capturing the data to make sure that all three sensing eyes of the tracker can see the marker simultaneously. The positions of the four markers were captured for the ten seconds at the beginning of the 5 th and 30 th minutes. In this study, the step length was determined by the distance between the maximum forward and backward positions of the four markers and the step width was determined by the distance between the maximum right and left positions of the four markers. Then, the movement range was defined as the product of the step length and the step width. The kinematic data was collected by the VZSoft and smoothed using a 4th-order Butterworth low-pass filter at a cut frequency of 6Hz. All the data was filtered and analyzed by the Matlab 7.0 program. In order to compare the differences between the experienced and inexperienced groups, the two variables were normalized to subject's height.

Figure 1. There are two markers on the front tips of toe boxes and heel counters of each shoe. The positions of the four markers are at the same level (arrows).

RESULTS: The results of the experienced subjects (Table 1) and inexperienced subjects (Table 2) indicated that thirteen subjects (eight experienced and five inexperienced) increased their step lengths after thirty-minutes of running. By comparing the step widths at the 5th minute, nine subjects (five experienced and four inexperienced) enlarged their step width at the 30th minute. Although there was no statistical analysis in this study, the mean normalized step length increased for both the experienced (46% increase to 52% of height) and inexperienced groups (48% increase to 51% of height). The increased mean step width (17% increase to 20% of height) was only found for the inexperienced subjects. Excluding Subject 15, however, the differences in the step width are not significant for the other inexperienced subjects.

According to the results for all subjects, the maximum range of movement for the experienced group altered from 59%*23% to 66%*26% of their height, and the inexperienced group changed from 58%*22% to 60%*30% of their height. Therefore, the maximum range of movement was 66%*30% of their height for the all subjects during the thirty-minutes of running on the treadmill.

Table 1. The Step Length and Step Width for the Experienced Subjects

	5th minute				30th minute			
	SL(cm)	SW(cm)	SL/H(%)	SW/H(%)	SL(cm)	SW(cm)	SL/H(%)	SW/H(%)
S1	78.0	26.0	46	15	96.6	25.1	57	15
S2	74.0	29.3	42	17	94.1	26.1	53	15
S3	61.9	27.5	34	15	76.6	30.4	43	17
S4	98.1	33.7	59	20	109.2	32.3	66	20
S5	92.0	29.4	52	16	98.8	30.4	55	17
S6	82.2	37.8	51	23	81.6	42.6	50	26
S7	77.9	27.4	49	17	66.2	27.9	41	17
S8	56.4	31.4	34	19	86.5	23.9	52	14
S9	74.3	38.3	45	23	91.8	41.0	55	25
S10	72.0	29.5	45	18	74.9	24.6	47	15
Mean (s.d.)	76.7 (12.4)	31.0 (4.3)	46 (8)	19 (3)	87.6 (13.0)	30.4 (6.6)	52 (7)	18 (4)

Note: SL:Step Length; SW: Step Width; SL/H: the ratio of Step Length to Height; SW/H: the ratio of Step Width to Height

Table 2. The Step Length and Step Width for the Inexperienced Subjects

	5 th minute				30 th minute			
	SL(cm)	SW(cm)	SL/H(%)	SW/H(%)	SL(cm)	SW(cm)	SL/H(%)	SW/H(%)
S11	75.1	33.2	44	19	80.3	33.4	47	19
S12	103.8	26.6	58	15	108.7	24.7	60	14
S13	86.9	31.5	52	19	88.0	32.7	52	19
S14	73.1	38.0	43	22	89.8	35.6	53	21
S15	84.3	25.1	49	15	90.2	51.5	52	30
S16	68.9	22.5	44	14	61.8	23.7	40	15
Mean	82.0	29.5	48	17	86.5	33.6	51	20
(s.d.)	(12.7)	(5.8)	(6)	(3)	(15.3)	(10.0)	(7)	(6)

Note: SL:Step Length; SW: Step Width; SL/H: the ratio of Step Length to Height; SW/H: the ratio of Step Width to Height

DISCUSSION: The purpose of this study was to investigate the changes in the step length and step width after thirty-minutes of treadmill running. Based on the results, most of the subjects' step lengths were more likely to lengthen (80% of experienced and 83% of inexperienced). The subjects seemed to take off the treadmill deck at a position farther back to increase step length, since their landing position did not change a lot (Figure 2). The increased step length would be accompanied by more ankle plantar flexion.

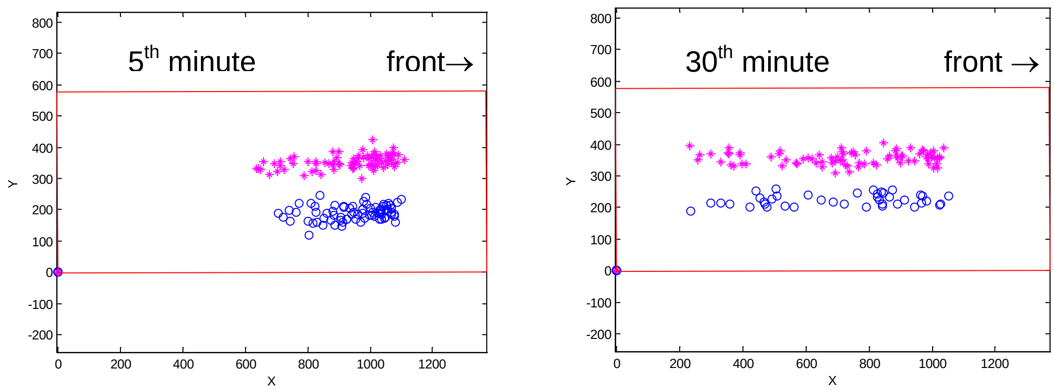

Figure 2. The changes of step length and step width after thirty-minutes of running for a subject. The red frame is the region of the treadmill deck. The right side of the figure is the frontal direction of the treadmill.

A greater percentage of inexperienced subjects (67%) had an extended step width after thirty-minutes of running than experienced subjects (50%). However, excluding subject 15, the step widths had less increase. This result showed that subject 15 had unstable steps after 30 minutes of treadmill running. However, from the evidence it was not obvious to infer that the inexperienced treadmill runners would extend their step width after thirty-minutes of running because of the fewer inexperienced subjects that were included in this study.

CONCLUSION: In this study, the range of the movement on the treadmill increased after thirty-minutes of running for both the experienced and inexperienced subjects. The subjects seemed to increase their step length backward in their toe-off position. An inexperienced subject was found to have a significantly increased step width after thirty-minutes of running. More investigations need to be done to identify whether the inexperienced treadmill runners have unstable steps after a long period of running. Based on the results of this study, the maximum range of movement was 66%*30% of their height for the subjects after thirty-minutes of running. The data will be a good reference in order to produce a treadmill that has an adequate area of its deck for the safety of leisurely users.

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