EFFECT OF EXHAUSTIVE UPHILL RUNNING ON KNEE JOINT MOTION DURING THE STANCE PHASE OF RUNNING

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The purpose of this study was to imitate an exhaustive outdoor mountain road uphill running and investigate the effect on knee joint motion angles during the stance phase of running. Knee joint kinematical data collected from 8 male recreational runners running at 10 km/hr on a level treadmill prior to and following exhaustive uphill running revealed differences in flexion angles. These results demonstrated that exhaustive running can have an effect on knee joint running movement pattern. Due to these findings, the human natural movement control may be adjusted and the maintenance of preferred or optimal movement path costs more efforts which possibly play a role in many common lower extremity running injuries. This relevance may be applied to the future designing of assistive performance control shoes.

KEY WORDS: Knee, Kinematics, Exhaustive running

INTRODUCTION:

Mountain road racing become more and more popular recently. The numbers of recreational runners suffered from injuries also increase dramatically and the most common injured site is knee joint. The racing contains some exhaustive uphill running and may increase the knee joint loading. In addition, fatigue, either in the local muscles or the cardiovascular system, was postulated as a risk factor for running injuries which may be related to the change in running style (1). Localized muscle fatigue of either the invertors or dorsiflexors have a significant effect on the ankle joint motion during running (2), which could lead to changes in muscle's shock absorbing activities and running mechanics. Thus, muscle control ability of joint motion may be affected by general fatigue or localized muscle fatigue. Running injuries are also related to excessive lower extremity motion (3). Abnormal ankle joint motion may affect knee mechanics (4, 5), which possibly switch the normal joint coupling. Abnormal coupling of the foot and tibia during running may result in overuse injuries (6). In summary, the movement control ability may be affected and preferred movement path can not be achieved in the presence of exhaustion. Therefore, the aim of this current study was to analyze the influence of exhaustive uphill running which may on knee joint motion angles and movement pattern during stance phase of running.

METHOD:

Data collection: Eight male recreation runners (mean age: 24.9 ± 1.0 years; mean height: 174.6 ± 3.7 cm; mean weight: 69.3 ± 4.1 kg) from college participated in this study. All subjects had no history of surgical intervention, chronic pain, orthotic use or current pathology of the lower extremity.

All subjects were fitted with sport shoes. Twenty-nine retroreflective markers were positioned by using Halen Hayes Marker Sets. Kinematics data were collected using 3D Motion Analysis System (Eagle, ten cameras) at a sampling frequency of 100 Hz. Ground reaction force (GRF) data were collected using an AMTI force plate placed underneath the treadmill and the vertical GRF was used to identify heel-strike and toe-off. The first appearance of vertical force value is defined as heel-strike, and the zero is considered to be toe-off.

After standardized warm-up stretching exercises, the subjects ran on the level treadmill at a speed of 10km/h. After catching up the pace of treadmill, the kinematics data were collected for fifteen seconds. Then the participants ran on a grade: 5% inclined treadmill at a speed of 10 km/h for 10 minutes. After the uphill running, the subjects ran on the level treadmill at a speed of 10 km/h and collected the kinematics data for fifteen seconds again.

Data Analysis: For each subject, 5 strides kinematics data for pre-exhaustive and post-exhaustive level running were analyzed and then averaged to create an individual subject mean. Group means were then calculated using this individual subject means. For each subject, the standard deviation of the five steps was calculated, creating an individual within-subject variability value. A group mean of within-subject variability was then calculated using the individual subject values. The data were analyzed using paired t-test to detect difference between subject' s maximum knee flexion angle and significant level for statistical analyses were determined using $\alpha = .05$. Average knee flexion angles were time normalized to denote knee movement pattern during stance phase of running and vertical GRF were used to define the phase of heel strike and toe off.

RESULTS:

Knee Flexion Angles prior to, and following, exhaustive uphill running are shown in Table 1. It reveals that five of the eight subjects showed greater post-exhaustive max. knee flexion angles. Four had larger post-exhaustive mean knee flexion angles. Five showed greater post-exhaustive within-subject standard deviation. Group mean max. and knee flexion angles were both increased in post-exhaustive running.

Table 1: Knee Flexion Angles prior to, and following, exhaustive uphill running

Subject	Pre-exhaustive			Post-exhaustive		
	Max.	Mean	S.D.	Max.	Mean	S.D.
1	54.67	39.32	12.75	54.03	35.88	13.08*
2	50.41	39.70	8.21	54.03*	41.52*	9.31*
3	52.21	39.01	9.60	54.31*	39.87*	9.41
4	51.31	38.67	10.58	50.00	37.72	10.67*
5	51.14	41.73	7.05	55.20*	45.68*	7.12*
6	53.15	41.03	9.91	56.22*	43.83*	9.60
7	54.64	33.67	13.73	49.51	31.46	11.36
8	56.34	38.44	12.13	58.46*	36.55	13.41*
Average	52.98	38.96	10.49	53.97*	39.06*	10.49

* Indicates higher but not significant values from pre-exhaustive level ($\alpha = .05$)

Pre-exhaustive and post-exhaustive time-normalized knee flexion angles were summarized in Figure 1. Solid line represents pre-exhaustive and hashed line is post-exhaustive. Both line showed similar pattern but post-exhaustive line tended to slightly increase in knee flexion from heel strike to midstance and extension between foot flat and toe off.

DISCUSSION:

The aim of this study was to investigate the effect of exhaustive uphill treadmill running on the knee joint motion angle and running movement pattern. Although there was not any significant difference between pre-exhaustive and post-exhaustive running. There were still three findings in this experiment. First, not every subject showed increased knee angles in post-exhaustive run. Second, group mean max. and knee flexion angles are both increased in post-exhaustive trial. Third, post-exhaustive time normalized knee flexion angle during stance phase of running tended to slightly increase in knee flexion in support phase and extension between during propulsion phase. These trends suggest that exhaustive uphill running protocol possibly affect the knee motion pattern but the influence was individually-dependent.

There were limitations of this study. One was the numbers of subjects were too small. Another the exercise intensity was not measured objectively. The other was the unclear definition of the stance of running.

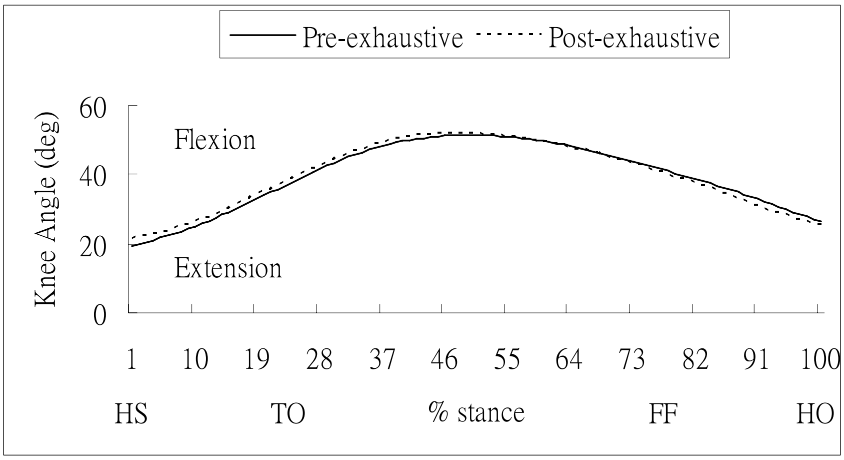

Figure 1: Knee angles during stance phase of running. HS denotes heel-strike, FF foot-flat, HR heel-raise, TO toe-off.

CONCLUSION:

In short, exhaustive uphill running protocol may influence the knee joint movement. As a result, mountain roads racing possibly have some effect on running pattern. The underlying mechanism was still uncertain and further study will be needed to clarify the relationship between joint motion and exhaustive running which may lead to general fatigue. Therefore, this relevance may be applied to the future designing of assistive performance control shoes and prevention of injuries.

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