Mechanics of Pole Running in Subjects with Chronic Knee Problems

Young-Hoo Kwon, Lori R. Bolt, and Jaekun Shim
Ball State University, Muncie, Indiana, USA

The purpose of this study was to examine the effects of the telescope-style running poles on the lower-extremity running mechanics of the subjects with chronic knee problems. Ten male recreational runners (age = 55.2 ± 9.0 yr) with chronic knee problems participated in this study. Each subject was individually fitted with a pair of specially-designed telescope-style running poles. The pole-running trials of the subjects were compared with their normal running trials after a 4-week familiarization period. The maximum knee flexion angle during the swing phase significantly decreased by 12.2° due to the use of the running poles. The ground reaction force data revealed a consistent trend of decrease with significant decreases in the peak vertical propulsive force (11.4%) and the vertical impulse (11.4%) due to the use of the poles. It was concluded that (a) the telescope-style running poles significantly altered the lower-extremity kinematics by decreasing the knee flexion during the swing phase, and (b) the running poles generally reduced the foot-ground interaction and provided a source of propulsion during the push-off phase of the running gait.

Introduction

Running has become a very popular physical activity among people who are trying to maintain a healthy body weight, increase aerobic fitness, and reduce the risk of cardiovascular disease. However, the repetitive nature of running can lead to overuse injuries. The impact force at foot-strike can be 2 to 3 times the body weight of the individual (Cavanagh & LaFortune, 1980; Clarke, Frederick & Cooper, 1983; Munro, Miller & Fuglevand, 1987). Chronic knee injuries, alone, account for nearly half of the injuries from which runners suffer (Fredericson, 1996; Gudas, 1980; James, Bates & Osternig, 1978; Scott & Winter, 1990; Van Mechelen, 1992). While the exact mechanism responsible for overuse injury is yet to be determined, a method is worthy of investigation which might protect runners from the harm caused by repetitive overloading of the lower leg.

Although previous studies have focused on altering impact forces via shoe design in hope of reducing the risk of injury, the results from such shoe studies are contradictory. Recent research has studied the effect of ski poles on walking, skiing, and running (Bilodeau, Boulay & Roy, 1992; Bilodeau, Rundell, Roy & Boulay, 1996; Millet, Hoffman, Candau & Clifford, 1998; Millet, Hoffman, Candau & Clifford, 1998; Hoffman & Clifford, 1990; Hoffman, Clifford, Foley & Brice, 1990; Porcari, Hendrickson, Walter, Terry & Walsko, 1997; Rogers, VanHeest & Schachter, 1995; Street & Frederick, 1995), but the main emphasis has been on energy expenditure, cycle rate, cycle length, and velocity. Use of specially-designed running poles has the potential to substantially alter the lower-extremity kinematics and kinetics of running. The purpose of this study was to examine the effects of the new telescope-style running poles on the running mechanics of the subjects with chronic knee problems. It was hypothesized that the use of the running poles would alter the lower-limb kinematics and reduce the foot-ground interaction during running.

Methods

Ten male recreational distance runners were recruited for this study (age = 55.2 ± 9.0 yr, height = 176.9 ± 4.2 cm, mass = 77.5 ± 12.2 kg). Subject had history of anterior knee problems including malalignment, bursitis, tendonitis, and arthritis. Each subject was individually fitted with a pair of telescope-style running poles (FX 190, Martin Van Breems, Inc.) prior to a 4-week familiarization period.

The light-weight (488 g) aluminium main poles freely slide over plastic upper poles that attach to a close-fitting mesh vest (telescoping motion) through hinge structures located under the armpits. Pole length (63.9 ± 1.6% of the height) and handle height were fitted individually with the arm at 140° elbow angle. The pole handle is at a 75° to the main pole. Subjects were required to run with the poles for a minimum of one hour per week.

The data collection was performed at the end of the training period. Three good trials with correct velocity (3.5-3.7 m/s), and footstrike on the force plate were collected for each condition (normal running vs. pole running). Two-dimensional motion analysis was performed with one 60-Hz video camera based on the 2-D DLT method (Kwon, 1994). The ground reaction force was measured with a force-plate (Kistler 9281B) at 500 Hz. For each joint motion and ground reaction force variable, the means of the three successful trials in both conditions were computed and the paired T-test (two-tailed) was performed to monitor any significant changes due to the use of the running poles ($p < .05$).

Results

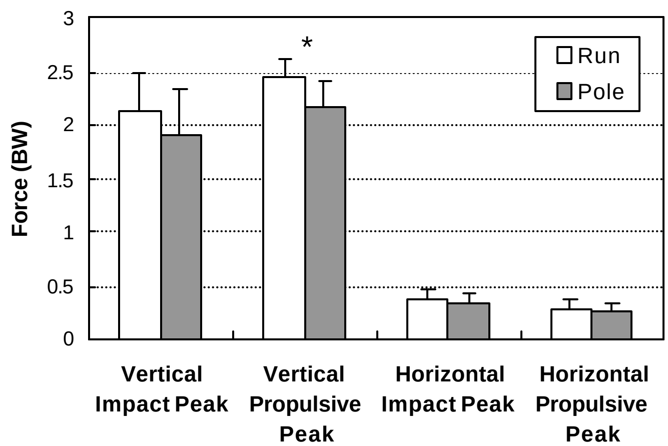
Among the joints, the knee joint range of motion decreased significantly (12.2°) during the swing phase due to the use of the running poles (Table 1), mainly caused by the decrease in the maximum knee flexion angle during the swing phase (10.9°). The maximum hip hyperextension angle was also significantly different between the conditions.

Table 1 Summary of the Lower-Limb Kinematics during the Swing Phase (Mean ± SD)

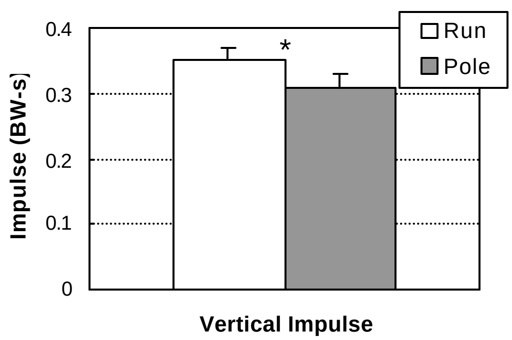
	Running	Pole-Running
Hip ROM	40.5 ± 5.1°	43.9 ± 10.2°
Max. hip hyperextension*	3.3 ± 6.3°	6.8 ± 4.2°
Max. hip flexion	37.2 ± 7.7°	37.1 ± 11.0°
Knee ROM*	91.8 ± 7.4°	79.6 ± 9.4°
Max. knee flexion*	101.9 ± 8.3°	91.0 ± 11.7°
Min. knee flexion	10.1 ± 5.9°	11.4 ± 5.7°
Max. stance-phase knee flexion	44.1 ± 5.7°	46.5 ± 6.6°
Ankle ROM	50.2 ± 5.6°	47.2 ± 5.8°

*$p < .05$

Among the ground reaction force variables only the peak vertical propulsive force was found to show a significant difference between the two running conditions (Figure 1a). The peak vertical propulsive force decreased by 11.4% (2.46 ± 0.17 BW in running to 2.18 ± 0.23 BW in pole-running) due to the use of the telescoping running poles. The peak vertical impact force showed a non-significant mean decrease of 9.4% (2.12 ± 0.37 BW in running vs. 1.92 ± 0.41 BW in pole-running). The vertical impulse (Figure 1b) also showed a significant difference between the running conditions (0.35 ± 0.02 BW·s in running vs. 0.31 ± 0.02 BW·s in pole-running) with an average decrease of 11.4% due to the use of the poles.



(a)



(b)

Figure 1 ¾ Comparison of the selected ground reaction force variables between the running conditions: peak forces (a), and vertical impulse (b) (*p < .05).

Discussion

The data from the present study demonstrated that the use of the telescope-style poles significantly reduced the knee flexion during the swing phase and significantly increased maximum hyperextension of the hip. The motion of the upper body in one unit in this process, including the stretched arm-pole complex, causes an increased moment of inertia of the upper body. It could be that in order to keep the balance, subjects needed to increase the moment of inertia of the lower limb by reducing the knee flexion. The counter-rotation of the pelvis against the upper trunk in this process could contribute to a more trailing position of the pushoff leg, causing increased maximum hip hyperextension angle at toeoff.

The ground reaction force variables in fact showed a consistent trend of decrease due to the use of the poles with the changes in the peak vertical propulsive force and the vertical impulse being statistically significant since the running poles can directly contribute to the propulsive phase of the pole-running cycle. From the toe-off to pole-off the pole is pointing rearward and runners can generate a propulsive force by pushing off the ground using the pole through trunk rotation, elbow flexion, and forearm pronation.

Although the peak impact force has been historically linked to injury (Cavanagh & LaFortune, 1980; Clarke et al., 1983; DeWit et al., 1995; Nigg, Cole & Bruggemann, 1995), reduction of the peak propulsive force is more important than the reduction of the peak impact force in subjects with problems that involve the patellofemoral joint and the patellar tendon. Scott and Winter (1990) estimated the patellar tendon force and the patellofemoral joint force in running by using a knee model and showed that the peak internal forces were closely related to the peak propulsive force. Reduction of the propulsive ground reaction force by using the telescope-style running poles is thus meaningful and the significant reduction in impulse indicates an overall decrease in the interaction between the leg and the ground. An average reduction of 11.4% in the propulsive peak and impulse alike could allow the patients with knee problems to continue running without pain.

From the data analysis, it was concluded that (a) the telescope-style running poles altered the lower-extremity running kinematics by decreasing the knee flexion during the swing phase and increasing the maximum hip hyperextension, and (b) the running poles generally reduced the foot-ground interaction and provided a source of propulsion during the push-off phase of the running gait, decreasing the amount of force and impulse imposed upon the foot in subjects with chronic knee problems.

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