KINEMATICS ANALYSIS OF SNOWSHOE RUNNING GAIT ON SAND

Tze Chung Luk[1], Lena Fung[1] and Youlian Hong[2]
[1]Hong Kong Baptist University, Hong Kong, China
[2]The Chinese University of Hong Kong, Hong Kong, China

The purpose of this study was to identify the kinematics characteristics of snowshoeing on sand under different running velocity in elite Hong Kong mentally handicapped athletes. Four athletes were asked to perform the snowshoe running on sand. Kinematics parameters included single leg support time, flight time, stride frequency, velocity of center of gravity (CG), vertical displacement of CG, cycle length, stride length, thigh and knee angle under different running velocities were measured. The repeated t-test was employed to examine the differences of above kinematics parameters in different velocities of snowshoeing. The results showed that there were significant differences in stride frequency, vertical displacement of CG, cycle length, and stride length between different velocities in snowshoeing on sand.

KEY WORDS: snowshoeing, running gait, sand course

INTRODUCTION: Snowshoeing (see Figure 1) has become an official event in Special Olympics since 2003. The movement of snowshoeing is similar to walking/running except the athlete uses a controlled glide called a glissade. The snowshoeing events in Special Olympics included 50 m, 100 m, 400 m, 800 m, 1600 m, 5 k, 10 k, 4x400 and 4x100 meter relay.

The idea of Special Olympics considered that snowshoe racing could help athletes enhance their fitness level during the winter months through a full body workout. In fact that snowshoeing at a self-pace for 30 minutes provides sufficient intensity to improve the cardiovascular endurance (Schneider et al., 2001). Another study showed that a six weeks of snowshoe training, 30 minutes at 75%-85% maximum heart rate and 3-4 times weekly, provides significant improvement on cardiovascular endurance (Connolly, Henkin, & Tyzbir, 2002). Furthermore, studies on the effect of snowshoe design on the energy expenditure could be found in the literature (Dalleck, DeVoe, & Karvitz, 2003; Knapil, Hickey, Ortega, & de Pontbriand, 2002). However, limited study was found to talk about the biomechanics of snowshoe running or walking gait. Such information may be useful for athletes and coaches to improve the snowshoeing technique and performance.

Another problem is the available of training venue. Snow track may difficult to find in some countries or seasons. Sometimes, grassland or sand course may be employed for training or competition purpose instead of using snow course. Therefore, the purpose of this study was to identify the kinematics characteristics of snowshoeing on sand under different running velocity in elite Hong Kong mentally handicapped athletes.

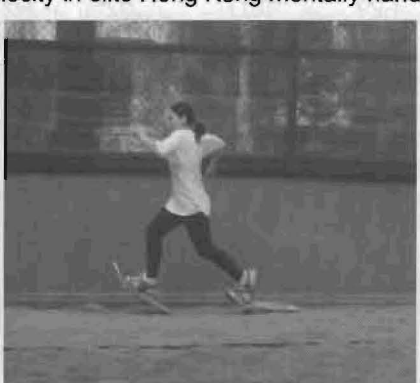
a)  b) 

Figure 1 a) Snowshoeing on sand; b) the close-up of snowshoe.

METHODS: Four athletes (2 male, 2 female) participated in this study. Age, body weight and stature of the participants were 23.50 ± 12.40 years, 56.25 ± 13.81 kg and 152.25 ± 23.39 cm respectively. Their training frequency was 3 hours per section and 3 sections weekly. All the subject were asked to perform the snowshoe running on sand with their maximal speed at a 21.9 m x 13.9 m outdoor beach volleyball court for 5 laps. A 3CCD digital camcorder with 50Hz filming rate (SONY TRV-950E PAL) was located 14 meters away from the subject and the shutter speed was set at 1000Hz (see Figure 2). A section of running motion at the first and fifth lap was video recorded. The video material was then converted into computer format for further analysis with using motion analysis system (APAS). Kinematics parameters such as single leg support time, flight time, stride frequency, velocity of CG, vertical displacement of CG, cycle length, stride length, thigh and knee angle under different running velocities were measured. The repeated t-test was employed to examine the difference of the kinematics parameters between different velocities in snowshoeing.

Figure 2 The video camcorder setting at the outdoor beach volleyball court.

RESULTS: The descriptive statistics of the parameters and the result of repeated t-test were shown in Table 1.

Table 1 Descriptive Statistics of the Kinematics Parameters.

	First lap		Fifth lap			
	Mean	SD	Mean	SD	*p* value	unit
single leg support time	0.24	0.03	0.34	0.11	.09	sec
flight time	0.10	0.03	0.07	0.05	.31	sec
stride frequency	1.53	0.23	1.29	0.17	.02*	Hz
mean velocity	3.50	0.55	2.47	0.52	.00**	m/s
max velocity	3.94	0.60	2.87	0.35	.01*	m/s
CG vertical displacement	12.81	3.57	14.54	3.22	.02*	cm
cycle length	2.38	0.37	1.87	0.31	.00**	m
stride length	1.19	0.19	0.93	0.16	.00**	m
LTO thigh angle	-22.18	7.86	-19.22	5.70	.35	deg
RTO thigh angle	-14.66	1.69	-13.27	6.29	.66	deg
L max thigh angle	56.70	9.35	47.70	7.35	.07	deg
R max thigh angle	51.24	4.91	39.69	8.00	.07	deg
LTO knee angle	-22.18	7.86	-19.22	5.70	.35	deg
RTO knee angle	-35.25	6.62	-38.12	9.74	.70	deg

Note: LTO = left heel touch down and RTO = right heel touch down. *$p < .05$; **$p < .001$.

The statistical result showed that both mean ($p < .001$) and max ($p < .05$) CG velocity within a running cycle found significant differences between first and fifth lap of snowshoeing. The mean velocity decreased from 3.50 ± 0.55 m/s at first lap to 2.47 ± 0.52 m/s at fifth lap. The maximum CG velocity also found decreasing trend from 3.94 ± 0.60 ms^{-1} to 2.87 ± 0.35 ms^{-1} at first to fifth lap respectively.

As the snowshoe running velocity decreased significantly, some of kinematics parameters found significant changes. Stride frequency was significantly decrease from 1.53 ± 0.23 to 1.29 ± 0.17 ($p < .05$) as the running velocity decreased. Moreover, stride length and cycle length also found significantly decrease from 1.19 ± 0.19 m to 0.93 ± 0.16 m ($p < .001$) and 2.38 ± 0.37 m to 1.87 ± 0.31 m ($p < .001$) respectively when the running velocity decreased. Beside this, the vertical displacement of CG within the running cycle showed significant difference at the first lap (12.81 ± 3.57 cm) and the fifth lap (14.54 ± 3.22 cm) ($p < .05$).

The maximum thigh angle within the running cycle showed marginally difference ($p = .07$) between first lap at 56.70 ± 9.35 deg (left), 51.24 ± 4.91 deg (right) and fifth lap at 47.70 ± 7.35 deg (left), 39.69 ± 8.00 (right) as the running velocity decreased.

Although single leg support time and flight time showed no significant difference between different running velocities. The mean value of single leg support time was shorter in high running speed than slow speed. The longer flight time was found in high running speed than the slow speed.

The toe take-off knee and thigh angle showed no significant difference in different running speed on both legs.

DISCUSSION: When compared with over-ground running gait, snowshoeing found similar kinematics characteristics in changing of running velocity. The results of present study found that the stride frequency decrease as the snowshoeing velocity decreased. The same phenomenon could be found in over-ground running (Elliott & Blanksby, 1979b; Ito, Komi, Sjodin, Bosco, & Karlsson, 1983). Moreover, both cycle length and stride length were significantly decreased when snowshoeing from high to slow velocity. The same situation could also be found in over-ground running (Knapil et al., 2002; Nelson, Dillman, Lagasse, & Bickett, 1972).

Moreover, the vertical oscillation of CG has been shown to increase with decreased running speed (Cavagna, Komarek, & Mazzoleni, 1971; Ito et al., 1983). In present study, the vertical displacement of CG increase form 12.81 ± 3.57 cm at first lap with CG velocity at 3.50 ± 0.55 m/s to 14.54 ± 3.22cm at fifth lap with CG velocity at 2.47 ± 0.52 m/s. Literature reported the vertical CG oscillations were 10.9, 8.6, 7.0 and 6.7 cm at over-ground speeds of 3.9, 6.4, 8.0 and 9.3 m/s (Luhtanen & Komi, 1978). When compared the CG oscillation in over-ground and snowshoe running, snowshoeing seems to have large vertical CG oscillation at given speed which may cause more energy expenditure.

Although the max thigh angle within a cycle of snowshoeing showed marginally difference between different running speeds. Literature reported that the maximal thigh angle will more flex with increasing running speed (Elliott & Ackland, 1981). Example of thigh angles at different over-ground running speeds are 25.7 deg at 3.5 m/s (Elliott & Blanksby, 1979a) and 59 deg at 8 m/s (Dillman, 1970). The maximal thigh angle found in this study was 56.70 ± 9.35 deg at 3.50 ± 0.55 m/s for snowshoeing. By comparing the thigh angle, it may assume that the technique employed for snowshoeing at 3.50 ± 0.55 m/s is almost equal to over-ground running at 8 m/s. However, further study should be conducted to prove this assumption.

In over-ground running, as the running speed increases, the time for running cycle decrease. Moreover, the time spent in support also decrease as running speed increases (Chapman & Caldwell, 1983). In present study, similar phenomenon found in snowshoeing but no significant difference was found in statistical analysis. Same situation was found in toe-off thigh angle and knee angle. Perhaps the number of trials or subject number should be increased in order to verify the differences in such kind of parameters between different snowshoeing velocity.

CONCLUSION: The changing of kinematics parameters on snowshoeing on sand in different running speed showed similar finding when compared with changing velocity in over-ground running. However, the requirement of technique, such as thigh angle, for snowshoeing on sand seems higher than over-ground running at given speed. Further study should be conducted such as biomechanical comparison of snowshoeing technique on sand, grassland and snow course. Such information could be helpful for athletes, coaches in training program design and technique improvement under different training condition.

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