Comparison of Three-dimensional Kinematic Changes of the Lower Extremity between the Two Different Braking Distances of Snowplow in Alpine Skiing

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INTRODUCTION

Alpine skiing began as a means of transportation in the Alpine mountains, and now it has developed into a sport of rapidly sliding down steep snowy surfaces. Despite the difficulties of measurement due to the environmental effects of cold and inclined snow surfaces, studies on alpine skiing have been conducted in various aspects through the development of precise measurements over many years to overcome such challenges. However, most studies have been conducted to improve the performance of elite alpine skiers (Gilgien, Crivelli, Spörri, Kröll & Müller, 2015; Supej, Hébert-Losier & Holmberg, 2015). Snowplow is a technique that involves wearing the ski plates on both feet and forming an “A” shape, with a narrow front and wide rear, to generate constant resistance to the inertia caused by propulsion and usually used at slow speed or mild slopes as short as 2~4 m, whereas the ski plate is parallelized and braked by using side sliding at higher speeds or steep slopes (Lind & Sanders, 2004). As the snowplow uses the edge of the ski plate when sliding down, the surface-plowing force at the edge of the ski plate controls the speed. When controlling the speed by using snowplow, the larger the edging by the size of the A shape, the greater the braking force due to the plowing force. Therefore, when teaching how to snowplow to beginners, the snowplow and edging angles between the two ski plates must be increased to increase the plowing force; it is common to ask them to bend and gather their knees, as not many quantitative studies on skiing in novice skiers exist (The Ministry of Culture, Sports and Tourism [MCST], 2008). Alpine skiers have a primary purpose in controlling speed and direction, as they slide down snow-covered mountains, while beginners who are new to alpine skiing learn how to snowplow (or pflug fahren), a basic braking technique to reduce speed (Hintermeister, O’Connor, Lange, Dillman & Steadman, 1997; Kuna, Dzajic & Males, 2015). Snowplow is a technique that involves wearing the ski plates on both feet and forming an “A” shape, with a narrow front and wide rear, to generate constant resistance to the inertia caused by propulsion and usually used at slow speed or mild slopes as short as 2~4 m, whereas the ski plate is parallelized and braked by using side sliding at higher speeds or steep slopes (Lind & Sanders, 2004). As the snowplow uses the edge of the ski plate when sliding down, the surface-plowing force at the edge of the ski plate controls the speed. When controlling the speed by using snowplow, the larger the edging by the size of the A shape, the greater the braking force due to the plowing force. Therefore, when teaching how to snowplow to beginners, the snowplow and edging angles between the two ski plates must be increased to increase the plowing force; it is common to ask them to bend and gather their knees, as not many quantitative studies on skiing in novice skiers exist (The Ministry of Culture, Sports and Tourism [MCST], 2008). Alpine skiers have a primary purpose in controlling speed and direction, as they slide down snow-covered mountains, while beginners who are new to alpine skiing learn how to snowplow (or pflug fahren), a basic braking technique to reduce speed (Hintermeister, O’Connor, Lange, Dillman & Steadman, 1997; Kuna, Dzajic & Males, 2015). Snowplow is a technique that involves wearing the ski plates on both feet and forming an “A” shape, with a narrow front and wide rear, to generate constant resistance to the inertia caused by propulsion and usually used at slow speed or mild slopes as short as 2~4 m, whereas the ski plate is parallelized and braked by using side sliding at higher speeds or steep slopes (Lind & Sanders, 2004). As the snowplow uses the edge of the ski plate when sliding down, the surface-plowing force at the edge of the ski plate controls the speed. When controlling the speed by using snowplow, the larger the edging by the size of the A shape, the greater the braking force due to the plowing force. Therefore, when teaching how to snowplow to beginners, the snowplow and edging angles between the two ski plates must be increased to increase the plowing force; it is common to ask them to bend and gather their knees, as not many quantitative studies on skiing in novice skiers exist (The Ministry of Culture, Sports and Tourism [MCST], 2008).
and was not fully understood by quantitative analysis.

Alpine ski injuries are mainly caused by falls during sliding or by accidental contact with other skiers or obstacles due to steering or braking errors (McBeth, Ball, Mulloy & Kirkpatrick, 2009). Especially, beginners often experience accidents that cause anterior cruciate ligament damage, as they fail to brake while snowplowing or lose balance to the back of the ski plate (Ettlinger, Johnson & Shealy, 1995). For the quantitative analysis of the basic techniques to prevent such accidents, Kim (2004, 2006) reported on the lower body joint angle and change in the body center via comparative analysis of the snowplow motions between expert and unskilled skiers. Although different braking techniques are required depending on the braking distance to prevent accidents, which can occur instantaneously, the kinematic factors required for braking distance control are difficult for skiers to be generalized because the variable for braking distance was not considered. Moreover, although the three-dimensional (3-D) motion of lower extremities in alpine skiing directly changes the braking force generated between the ski plate and the snow surface (Klous, Müller & Schwameder, 2012; Koo, Lee, Kweon, Hyun & Eun, 2014; Müller & Schwameder, 2003), 3-D kinematic analysis that considers the degree of freedom in each lower limb joint was not performed. Therefore, the purpose of this study was to investigate the 3-D kinematic differences in the lower limb between the braking distances of 2 and 4 m when beginners perform snowplow to acquire the correct snowplow motion required to control the braking distance.

**METHODS**

1. Participants

The subjects of this study were six instructors of the Korea Ski Instructors Association who could ideally perform snowplow. All the subjects who participated in the study were male and had no musculoskeletal system abnormalities (age: 25.3 ± 1.5 yr, height: 169.3 ± 2.9 cm, weight: 66.2 ± 5.9 kg, experience: 4.2 ± 2.9 yr). All the subjects received a full explanation of the experimental procedure before participating in the experiment, and the experiment was conducted only with the instructors who agreed to participate by providing written consent.

2. Measurements

All skiers spent enough time for warm-up and practicing snowplow, and then stopped by snowplowing on a groomed ski terrain with an average slope of -10°. As braking by snowplowing is performed at a slower speed in alpine skiing with the typical braking range of 2~4 m, 2 m was set as a sudden braking distance and 4 m as a normal braking distance. All the skiers performed three trials per braking distance (Figure 1). The execution range consists of 20 m of run phase and 2 or 4 m of braking phase, and the entry speed in the runway was controlled at 3.5 m/s by using timing lights (Seed Tech, Korea). Eleven infrared cameras (sampling rates, 100 Hz; Oqus 300, Qualisys, Sweden) were installed for motion analysis. A total of 37 reflection markers were used to model the lower limb, with a marker attached to each joint