SUMMARY
The purpose of this investigation was to compare dynamic postural stability when performing different jump-landing directions in healthy subjects. Subjects were required to perform a double-leg jump at three directions to a height equivalent to 50% of their maximum vertical jump height and land with single-leg and balance for three seconds. Inclination angles, and angular velocities and time to stabilization (TTS) were collected to analyze. There were significant differences among three directions on AP and ML inclination angle, ML angular velocity and ML TTS. Our results revealed that a greater angular velocity was shown in AP than in ML direction among all jump-landing directions. This can be explained by human’s musculoskeletal structure that controls our body movement easier in the sagittal plane so that our body can afford higher angular velocity. In addition, greater inclination angles, angular velocities and TTSs occurred in ML plane when performing lateral and diagonal jump-landing protocol; this might result in difficulty in controlling posture stability in the frontal plane. Hence, diagonal and lateral jump-landing protocols could be harder to maintain postural stability than forward jump-landing protocol.

INTRODUCTION
Balance tests with some dynamic components may be more similar to sports competitions than a single static balance test. However, jump-landing is aset of typical movement which represented dynamic postural stability and appeared often in basketball and volleyball games. In general, these types of sports activities have higher risk associated with lower extremity injuries when landing from a jump, especially for a single-leg landing. Moreover, when performing a jump-landing task in sports, we may jump and land at different directions instead of one direction. Only investigating one direction of jump-landing protocol may neglect some important information of neuromuscular control. It has been suggested that a successful landing from a jump requires muscle strength, joint stability, and balance control, which are also critical for providing protection against injuries [7].

In the past, many studies were concentrated on postural control that represented keeping the center of mass (CoM) within the base of support (BoS) [5] or the center of pressure (CoP), and this was controlled by musculoskeletal system. Gait stability has been assessed using the motion of the CoM and its relative position to the CoP of the supporting foot [4] but seldom in other movement (i.e. jump-landing). Further, the CoM-CoP distances may be affected by a subject’s stature [1] but a method that used CoM-CoP inclination angles could remove the influence of stature differences among subjects [4]. Unfortunately, calculation of the CoP requires a force plate and sometimes the price was very expensive. During experiment, our landing movement might affect by its position and size when we landed on a force plate. And this might be an influence on obtaining CoP and the calculation of the CoM-CoP inclination angles. As a result, we use CoM-ankle inclination angles to solve this problem and this has been confirmed to be an alternative assessment to clinical populations [2]. Several researches have suggested that not only the position of the CoM with respect to the BoS, but also the velocity of CoM may provide important information about one’s ability to control posture stability [5]. Therefore, in our current study, we combined both CoM-ankle inclination angles and angular velocities to investigate one’s ability to maintain stability after landing.

Time to stabilization (TTS) has been used to measure neuromuscular control that incorporates both sensory and mechanical systems to master the complex task after landing [7]. The definition of TTS, which is calculated by GRF, is the amount of time it takes for a participant to return to baseline after a landing [7]. However, we take into account that only used the GRF to evaluate postural stability by TTS might be misleading, because TTS could be totally affected by the values of GRF and the GRF can’t represent a complete steady state of posture stability. As a result, this current study we attempted to use CoM-ankle inclination angular velocities to access the TTS. The ranges of inclination angles, peak inclination angular velocities and TTS were assessed among three jump-landing directions after a single-leg landing. We hypothesized that there were significant differences among three directions on all parameters.

METHODS
Twelve healthy males (24±0.95 years old; 70.6±8.3 kg; 172.6±3.6 cm) were recruited for this study. Subjects started in a standing position 70 cm away from the center of the force plate for each direction (forward, diagonal and lateral). All subjects required to jump with double-leg at three different directions and reach an overhead target which equivalent to 50% of the subject’s maximum vertical jump height [7] and land with single-leg (supporting leg only) on the force plate. When landed with testing leg, subjects were asked to use toe-heel strategy and maintain their balance for 3 seconds with their hands on the waist, look straight ahead as quickly as possible. If the subjects lose balance and step off on the force plate, or if their non-testing leg, or upper extremity sway excessively, all of these trials were defined as failed trials. Each jump-landing direction would include three successful trails.

All data were analyzed three seconds after foot initial contact. Three-dimensional (3-D) marker trajectory data were collected at 200 Hz with a ten-camera motion analysis system (Vicon, Oxford, UK). A total of 28 reflective markers were placed on bony landmarks of each subject. Whole body CoM position data were calculated using a 13-segment model with the weighted sum method [4].
In addition, greater inclination angle, angular velocity and TTS occurred in ML plane when performing lateral and diagonal jump-landing protocol, this might result from difficulty in controlling posture stability in the frontal plane. In the past, there were many studies on discussing about human motion in the frontal plane and its relationship associated with lower extremity injury. It was reported that greater mediolateral body sway was significantly related to concurrent ankle sprain [3]. It has also been reported that lateral CoM sway range of motion is a good predictor of falling risk [6]. Therefore, our results indicated that diagonal and lateral jump-landing protocols could be harder to maintain postural stability than forward jump-landing protocol and could be leading to greater injury risks.

RESULTS AND DISCUSSION

All subjects were able to complete the jump-landing protocol among three different directions with no incidents. Experiment results were listed in Table 1. There were significant differences among three directions on inclination angles, ML angular velocity and ML TTS. Peak inclination angular velocities nearly occurred at initial contact (see figure 2), but there were no significant differences in AP direction. Our results revealed that a greater angular velocity was shown in AP than in ML direction among all jump-landing directions. This can be explained by human’s musculoskeletal structure that controls our body movement easier in the sagittal plane so that our body can afford higher angular velocity. Pai & Patton (1999) also proposed that a person could tolerate higher anterior CoM velocities at a more posterior CoM positions without initiating a fall [5].

CONCLUSIONS

Greater ML inclination angle and angular velocity and TTS might result indifficulty of postural control and lead to risks of lower extremity injury. Hence, diagonal and lateral jump-landing protocols could be harder to maintain postural stability than forward jump-landing protocol.

REFERENCES


Table 1: Results of biomechanical parameters (*represented significant differences among directions, p<.05)

<table>
<thead>
<tr>
<th>direction</th>
<th>Inclination angle(deg)</th>
<th>Inclination angular velocities(deg/s)</th>
<th>Time to stabilization(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AP*</td>
<td>ML*</td>
<td>AP</td>
</tr>
<tr>
<td>Forward</td>
<td>6.9± 0.8</td>
<td>2.0± 0.6</td>
<td>42.3± 6.5</td>
</tr>
<tr>
<td>Diagonal</td>
<td>5.9± 0.6</td>
<td>8.4± 0.8</td>
<td>37.8± 12.9</td>
</tr>
<tr>
<td>Lateral</td>
<td>4.2± 1.1</td>
<td>11.4± 0.8</td>
<td>39.2± 6.1</td>
</tr>
</tbody>
</table>

Figure 1: The CoM-ankle line and its AP inclination angle (α) and ML inclination angle (β).

Figure 2: A representative TTS sample calculated by CoM-ankle inclination angular velocities.