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Landing with Visual Control Reveals Limb Control for Intrinsic Stability

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Abstract

Repetition of landing with visual control in sports and training is common, yet it remains unknown how landing with visual control affects postural stability and lower limb kinetics. The purpose of this study was to test the hypothesis that landing with visual control will influence on lower limb control for intrinsic dynamic postural stability. Kinematics and kinetics variables were recorded automatically when all participants (n=10, mean age: 22.00±1.63 years, mean heights: 177.27±5.45 cm, mean mass: 73.36±2.80 kg) performed drop landings from 30 cm platform. Visual control showed higher medial-lateral force, peak vertical force, loading rate than visual information condition. This was resulted from more stiff leg and less time to peak vertical force in visual control condition. Leg stiffness may decrease due to increase of perturbation of vertical center of gravity, but landing strategy that decreases impulse force was shifted in visual control condition during drop landing. These mechanism explains why rate of injury increase.

Keywords: *Landing, Visual Control, Stability, Leg Stiffness, Ground reaction force*

1. Introduction

Visual system of human under exercise provides an essential sensual information for maintenance of mechanical stability [1]. Impulse force from heel was transferred to muscular-skeletal system, but reduced passively by muscle and soft tissue due to active control of motor sensory and joint position [2]. When shaking mass movement occurred, active control altered the magnitude of transferring force through joint position and muscle activation by visual feedback in addition to passive reduction mechanism [3]. But because increase of impulse force has close relation with the landing height, inherent mechanism of lower limb for maintenance of posture stability when landing height was interfered with visual control condition was not yet known.

Most sport athletes controls posture in accordance with training condition using specific information of motor sense [4, 5]. Though somatosensory and visual sensation contributes greatly to directional recognition

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of space like professional gymnastic athlete [6], and also to posture control of dancer [7]. Absence of visual information reduced greatly posture controllability and performance in sport as shooting, judo, dance of ballet, gymnastics, and football [7-9]. Thus various sports was relied on the interaction relation on visual information and posture controllability in reality [9]. Kinematic variables of muscle activity, joint angle, and direction of body was controlled by visual information under landing motion segment through consecutive feedback [10]. On the contrary, it is necessary to work out a trial and error strategy inducible a more safe and soft landing to build proper pattern of muscular activity in case of no-visual information [10]. That is, landing motion of human may be performed successfully when making not only accurate anticipation on occurring time of impulse force but also muscular activation.

But variables of injury of knee joint including stressful rapture of tibia concerned with impulse force due to unstable posture has been considered as factors of risk [11]. That is, loading rate of which may be measured by slope of acceleration wave. Increase of loading rate may cause impulse force by intensified path of slope [12], and increase a risk rate of skeletal rapture [13]. Thus main function of muscular skeletal system is to decrease and absorption of impulse force [14]. For those, various methods for evaluation of landing motion has been recruited [15]. But the more sophisticated method for evaluation of exercise quality is required because more dynamic activity rather than posture control under unanticipated situation than was included [15]. Human has controllability on stiffness of lower limb in response to variability of surface stiffness [16]. Also it was reported that visual information in controlling direction of movement [17], increase of muscular activity [18] was essential factor.

Thus it was not yet understood how intrinsic controllability of lower limb for safety by visual information was processed, though evaluation of high level of quality through observation of landing motion on human movement may be quantified. Consequently the aim of this study was to investigate the variability of lower limb relative to conditions of visual information under landing. The assumption of this study is that condition of visual control will utilize the other controlling strategy for compensation of posture stability and deficit of feedback.

2. Material and Methods

2.1 Subjects

Adult male (n=10, mean age: 22.00±1.63 years, mean heights: 177.27±5.45 cm, mean mass: 73.36±2.80 kg) participated in the experiment. All participants were explained and consented the range of detailed procedure and contents prior to experiment.

2.2 Experimental Approach

As shown in Figure 1, All participants were required to land on ground reaction force plate (AMTI-OR-7, Advanced Mechanical Technology Inc., Watertown, MA, USA) from vertical height of 30cm under 2 conditions with visual information (condition 1) and no-visual information (condition 2). Reflex marker on body joints on head (3 markers), trunk (4 markers), upper extremities (14 markers), and lower extremities (22 markers) to obtain the kinematic and position of center of gravity were attached respectively. Each position of mark was captured with 12 motion capture camera (VICON Vantage and Vero, VICON Motion System Ltd., UK) and digitized at 100 Hz frequency and stored to analysis program (Nexus 2, VICON Motion System Ltd, UK; Kwon 3D XP Ver 4.0, VISOL, Gwangmyeong, Korea). Also ground reaction force data was collected at sampling rate of 1,000 Hz. In the course of landing with barefoot and eye patch under condition of no-visual information, all were taken position and preliminary posture by assistant's verbal signal in order not to recognize the landing height. Both hand of all participant were required to touch on anterior superior iliac spine to control its movement.

Figure 1. Landing posture and experiment field

2.3 Definition of Analysis Phase

Analysis range was set from initial touch down on ground reaction force plate of right foot to point sustainable the maximal extension of knee joint with motionless posture. Main analysis variable of lower extremities was composed of leg stiffness, stability index, and angle of lower limbs (hip, knee, and ankle angle) in sagittal plane.

Leg stiffness (K_{leg}) was divided maximal vertical ground reaction force (Newton [N]/Body Weights [BW]) by change rate (%) of normalized lower limb's length when reached at lowest point of pelvis center [19]. Normalization of lower limb's length was calculated from view of 3 Dimension from anatomical position and lower limb's length was defined from pelvis center to center of pressure of foot sole.

$$K_{leg} \frac{Vertical\ ground\ reaction\ force\ (BW)}{Leg\ length\ (\%)}$$

Stability index was calculated by 3 component of ground reaction force and number of sample [20]. Thus it was calculated by dividing root mean square deviation (RMSD) by number of sample of each range from point which ground reaction force showed maximal value at direction of X-axis (medial-lateral), Y-axis (anterior-posterior) and Z-axis (vertical), and meant a more increase of value, less stability. Another time to stabilization (TTS) was described by vertical ground reaction force. Calculation of vertical time to stabilization was recorded vertical ground reaction force component amounting to 5% level by individual after landing [21].

Angle of lower limb was defined by relative angle from sagittal plane.

- Hip joint center was relative angle between pelvis and thigh
- Knee joint center was relative angle between thigh and shank
- Ankle joint center was relative angle between shank and foot

The 2 conditions manipulated in this study was processed with same test procedure. Thus statistical program (PASW 21.0 program IBM., Chicago, IL, USA) for difference analysis among variables and paired-test for significance ($\alpha<0.05$ level) was recruited.

3. Results

3.1 Kinetics and elapsed time of stabilization

The result of kinetics and time to stabilization analysis was as Table 1. Visual control condition showed more increased lateral ground reaction force, maximal vertical ground reaction force and loading rate when compared with visual information, which following significant difference. Elapsed time from initial touch down to maximal vertical ground reaction force showed shorter in visual control condition than visual condition, which following significant difference statistically.

Table 1. Result of kinetic variables and TTS by two condition during landing

Section	Landing condition		*t*	*p*
	Visual	Visual control		
Medial-lateral force (N/BW)	-0.20±0.04	-0.26±0.06	3.771	.004**
Anterior-posterior force (N/BW)	-0.29±0.08	-0.31±0.09	0.777	.457
Peak vertical force (N/BW)	1.84±0.41	2.43±0.52	2.508	.033*
Loading rate (N/BW/sec)	33.09±12.26	52.42±18.06	3.155	.012*
Leg stiffness	17.95±5.35	27.30±12.43	1.955	.082
Leg length (%)	19.32±8.23	14.01±5.17	1.728	.118
Elapsed time to peak vertical force (sec)	0.053±0.014	0.038±0.013	2.423	.038*
Time to stabilization (sec)	0.863±0.295	1.020±0.319	1.500	.168

3.2 Angle of lower limb from sagittal plane

Angle of lower limb from sagittal plane was as Table 2. Angle of hip, knee and ankle joint showed more extension in visual control condition than visual condition, but did not show significance.

Table 2. Result of lower extremity joint angle in sagittal plane by two condition during landing

Section	Landing condition		*t*	*p*
	Visual	Visual control		
Hip joint angle (degree)	70.13±12.00	76.11±12.42	0.978	.354
Knee joint angle (degree)	79.56±10.28	85.30±5.80	1.351	.210
Ankle joint angle (degree)	66.97±6.94	70.47±3.77	1.481	.173

3.3 Stability index of posture

The result of stability index of posture was as Table 3. Whole stability index of posture showed higher value in visual control condition than visual condition in anterior-posterior lateral and vertical direction, and showed reduced index, which did not showed significance.

Table 3. Result of postural stability index by two condition during landing

Section	Landing condition		*t*	*p*
	Visual	Visual control		
Medial-lateral stability index	2.05±0.77	2.98±1.66	1.615	.141
Medial-lateral stability index	3.07±1.17	4.47±1.83	1.920	.087
Medial-lateral stability index	21.56±8.64	27.80±14.15	1.384	.200
Dynamic postural stability index	26.69±10.37	35.27±17.11	1.498	.168

4. Discussion

This study assumed that condition of visual control will utilize the other controlling strategy for compensation of posture stability and deficit of feedback. The result showed difference in variable related impulse force, which satisfied the assumption partially. Particularly visual control condition was controlled differently each other when compared with visual condition in lateral, vertical ground reaction force and loading rate. And this feature could be explained why occurring time of peak vertical force can shorter. Thus in aspect which may encounter a visual control condition temporally under sport activity, this study quantifying a degree of body rigidity and impulse reduction may be important task necessary for successful landing performance.

Visual control condition in level of leg stiffness showed more increased trend than visual condition. Thus this study was supported in that visual control condition under landing may correlate with both greater resistance on flexion of lower limb's joint and muscle activation muscle stiffness [10] .

Leg stiffness using spring-mass model had close relation with both maximal ground reaction force and change rate of leg length [19]. And the fact that the time required of touch down on surface may be longer when was more flexed a lower limb's joint to reduce rigidity level of body during various exercise of human [22], may be helpful for interpretation of this study. That is, crouched posture of human urged flexion angle of lower limb and contact time to increase [23], but this study proved that this mechanism was possible under condition recognizable visual information.

Particularly human could set up a prior scheme on control of lower limb's joint through visual information prior to landing [10, 24]. But in this study, visual control condition caused more extended angle of lower limb and occurring time to peak vertical force caused shorter. Thus it was assumed that the difference of occurring time to peak vertical force under 2 condition may be influenced due to stiffness increase of posture by angle of lower limb's joint. Inherence of muscular -skeletal system may cause proper response, and cause attribution to mechanism controllable automatically by geometry of leg stiffness [25].

Another control mechanism of lower limb occurring under visual control condition could not predict exactly an occurring time of impulse force [10]. Occurring time between peak vertical forces means incline angle of force generation on time function in relation of time-force, and then sharp incline angle means increase of loading rate. Under visual control condition which can't predict an occurring time of impulse force during landing, fact of both induction of rigid posture and increase of impulse force may infer the influence on velocity of impulse loading.

First of all, despite difference in variables related with impulse force of this study, time to stabilization and dynamic postural stability index of variable of posture stability did not difference between 2 conditions. Time to stabilization and dynamic postural stability index as stability scale had been evaluated using magnitude of vertical ground reaction force and time during landing [26]. This study did not show significant difference between 2 conditions during landing, it was verified that visual control condition showed more decreased trend than visual condition. But it was judged that movement trajectory on center of gravity passively could be stabilized using spring-model mechanics.

5. Conclusion

Repetition of landing with visual control in sports and training is common, yet it remains unknown how landing with visual control affects postural stability and lower limb kinetics. The goal of this study was to investigate the variability of lower limb relative to conditions of visual information under landing. Consequently under visual control condition during landing, mechanism for impulse control may pay a great role for maintenance of posture stability, but may cause possibility of injury rate like injury on knee joint and tibia stress etc if this condition was performed repetitively.

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