한국전문물리치료학회지 제 18권 제 4호
PTK Vol. 18 No. 4 2011

The Effect of Distance of External Attentional Focus on the Performance of Balance Task in Upper Extremity

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Abstract

The purpose of this study was to investigate the effect of attentional focus and distance of external focus on the performance of balance task of upper extremity. Subjects (N=30) held a stick (2 m) and maintained it horizontally. All of the subjects performed balance task of upper extremity under four different attentional focus conditions: focus on hand (internal focus), marker at 10 ㎝ inside of hand (external focus 1), marker at 10 ㎝ outside of hand (external focus 2), marker at 20 ㎝ outside of hand (external focus 3). The mean velocity of the bar (㎜/s) and the muscle activity of biceps brachii (%RVC) were measured. They were decreased when the subjects focused on external focuses compared to internal focus and decreased as distance of attentional focus from body increased ($p<.05$). There were significant differences between groups ($p<.05$); internal focus-external focus 1, internal focus-external focus 2, internal focus-external focus 3, external focus 2-external focus 3. These results showed that external focus is more effective than internal focus in enhancing motor performance and focusing on more distant attentional focus results in enhanced motor performance promoting the utilization of more automatic control mechanisms.

Key Words: Distance of attentional focus; External focus; Internal focus; Mean velocity; Muscle activity.

Introduction

Most clinical specialists make an effort to derive the motor capability of patients to the fullest through various approaches when guiding patients to perform the motor task. The effort for the acquisition and maintenance of effective motor skills led to various studies on motor learning process. The provision of motion information and motor learning have been studied continuously. In regards to motor learning, it is essential for the learner of motor skills to acquire the information on the motion he is performing (Adams, 1971).

As the series of researchers proposed the importance of feedback on the result of motion in motor learning from the end of 1990's, a lot of attention is paid to effective attentional method (Wulf et al, 2000). Wulf et al (1998) began to introduce theories while conducting studies on the effects of the attentional focus on the motor learning. Wulf and Prinz (2001), in acquiring new motor skills, asserted that better performance is performed when the learner focuses on the result of motion (external focus) instead of focusing on the motion itself (internal focus).

The study on the effect of the focus method on the task performance of skiing motion by Wulf et al (1998) was the first study on the effect of focus method on the task performance. In performing the task of skiing motion, the improvement in performance was showed with external focus method that focuses on the motion of apparatus instead of internal focus method that focuses on the motion of foot itself. The study on the effect of external focus in performing simple task such as dynamic balance task was carried out and better balance task were

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This study was conducted by Hanseo University research fund 2008.

demonstrated with external focus method in regards to the balance maintenance (McNevin et al, 2003; Shea and Wulf, 1999; Wulf et al 2001). External focus method was effective in learning more complex and skillful motions as well including golf (Wulf et al, 1999), tennis (Wulf et al, 2000), volleyball and soccer (Wulf et al, 2002), and others. In case of the person who is learning complex and technical motions for the first time, external focus method was especially effective in the learning and retention of the task (Wulf et al, 2001). The theory by Wulf on the influence of focus method on the task performance was also applied to the field of rehabilitation. Landers et al (2005) conducted the study on postural sway of patients with Parkinson disease in performing the balance task. Under high-difficulty condition where patients must maintain the balance on moving surface, the postural sway decreased with external focus instead of internal focus.

Studies on the effect of external focus on the performance result revealed that one other variable has the influence on performance result as well. It was revealed that the effect increases with the increase in distance of external focus from the body. In the study on pitching shot of golf by Wulf et al (1999), external focus target (the golf club) was further away from the body compared to internal focus target (the hand). In the study on the backhand stroke of tennis by Maddox et al (1999), external focus target (the locus and landing point of ball) were further away from the body compared to internal focus target (the stroke point of ball). In the study regarding horizontal maintenance on the balance board by Wulf et al (1998), the marker was further away from the body although there was little difference in the distance between internal focus target the feet and external focus target the marker. Based on such studies, it can be assumed that better performance is displayed with the increase of distance of focus target from body.

McNevin et al (2003) said that the effect of external focus increases with the increase in the distance between the body and the result of motion. When the distance between the result of motion and body is too close, the division between the motion itself and the result of motion during the focus becomes difficult thus large difference in the effect cannot be displayed as the effect of external focus and internal focus becomes similar. McNevin et al (2003) studied the effect of the distance of external focus target on the performance of balance task by controlling the location of external focus target the marker from the axis of balance board. External focus target the location of marker was 10 ㎝ interior of the feet for one group and the location of marker was 10 ㎝ exterior of the feet for the other group. As a result of the experiment, there was no large difference in balance capacity between groups with the location of marker 10 ㎝ interior and exterior of the feet. In regards to balance capacity of two groups, however, the capacity was superior compared to the group where the marker was located in front of the feet. Park et al (2000) conducted the study under the similar experiment condition but increased the distance between two markers interior and exterior of the feet as 1 m. The outcome of this study also revealed that horizontal maintenance capacity was superior with the focus on the marker that is further away from the feet instead of the marker in front of the feet. Compared to study by McNevin et al (2003), better performance outcome was displayed in case of focusing on the marker that is located further (distance between marker was 1 m) from the feet compared to the marker that is located close to the feet.

Based on the outcome of above studies, it was revealed that the distance between external focus target and body has influence on the performance outcome. In regards to the relation between the increase in distance and the improvement in performance outcome, however, the suspicion is raised whether or not it continuously displays positive relation and there is the existence of optimal distance.

In the field of rehabilitation, physical therapists perform the rehabilitation program through motor training and learning. Common interest of all phys-

ical therapists lies in the search of optimal motor strategy for effective training and performance. In this study, the examination on the influence of the attentional focus types (internal focus and external focus) and the distance of attentional focus on the performance of upper extremity balance task carried out. Since the most of previous studies were on the balance of lower limb, the examination on the influence of focus method and distance of focus target during the performance of upper extremity balance task has great significance in the training of upper extremity task in actual clinical review. The hypothesis of this study is that there is the difference in the balance maintenance ability and the muscle activity of upper extremity according to the type of attentional focuses (internal vs external) and the distance of attentional focus.

Methods

Participants

Thirty healthy subjects (men: 15, women: 15) in 20's were recruited for this study. All subjects did not have neurological and musculoskeletal disorder that have the influence on the performance of balance task. The subjects had a mean age 22.7 years, a mean height of 170.9 ㎝, a mean weight of 60.5 ㎏. The age, height, and weight of the subjects are summarized in Table 1. The purpose and method of the study were fully explained to all subjects before the experiment and the study was carried out subjects who have voluntarily agreed to participate in the experiment.

Instruments

Motion Analysis System

In order to measure the performance of upper extremity balance task, the motion analysis system[1] was used. With six infrared cameras installed around the subjects, the information on the movement of the marker at the both end of swaying stick during the performance of upper extremity balance task was collected and movement of marker was implemented in 3D using Workstation program. The sample rate was 120 ㎐ and the mean velocity was calculated for the movement of marker and used as dependent variable.

Surface Electromyogram (EMG) Measurement System

In order to measure the EMG activity of biceps brachii of during the performance of upper extremity balance task, MP100 system[2] was used. For the electrode, bipolar surface electrode with the diameter of 1 ㎝ and interval between electrodes of 2 ㎝ was used. Sample rate was 1024 ㎐ and the measured signal was sent to the computer and filtered and other signal processing was carried out using software Acknowledge 3.7.1.

Stick and Balance Board

The stick used in upper extremity balance task was the wood stick with the length of 2 m, cross-sectional area of 25 (5×5) ㎠, and weight of 1 ㎏. The markers were attached to both end of the stick and the subjects performed task to maintain this stick horizontally. The subjects stood on the balance board while performing upper extremity bal-

Table 1. Characteristics of the subjects (N=30)

Variable	Mean±SD	Range
Age (yrs)	22.7±1.4	20～24
Height (㎝)	170.9±6.3	160～180
Weight (㎏)	60.5±8.5	45～82

1) VICON MX System, Oxford Metrics Ltd., Oxford, UK.
2) MP100 System, BIOPAC System Inc., Santa Barbara, CA, U.S.A.

ance task because upper extremity balance task on the stable surface was so easy. For the balance board, rectangular-shaped wooden plate with area of 1.5 (1.5×1) ㎡ was attached on semi-cylindrical wood. The subjects maintained balance in medio-lateral direction by standing on the balance board.

Procedures

Performance of upper extremity balance task and application of attentional focus

The subjects performed upper extremity balance task of maintaining the stick horizontally on hand while maintaining the balance on the balance board. The reason why upper extremity balance task is performed on the balance board in standing posture lies was that it is difficult to distinguish the influence of independent variables since upper extremity balance task on solid basal surface was so easy. The subjects performed upper extremity balance task by bending elbow joint at 90°, placing the stick on the hand at the posture where arm is naturally attached to the body in comfortable standing posture with the interval of feet in shoulder width on the balance board. The location of hand that holds the stick and the location of feet on the balance board were indicated in order to maintain the consistency in the measurement for each subjects. The subjects attended on four different attentional focus (internal focus, external focus 1, external focus 2, external focus 3). Attending on internal focus was that subjects focused on the motion of hand while perform balance task. The experimenter instructed the subjects "Please maintain the stick horizontally while focusing on the motion of hand." Attending on external focus was that subjects focused on the movement of marker attached to the stick. The experimenter instructed the subjects "Please maintain the stick horizontally while focusing on the movement of marker." In regards to external focus, the marker was placed 10 ㎝ interior of both hands for external focus 1, 10 ㎝ exterior of both hands for external focus 2, and 20 ㎝ exterior of both hands for external focus 3 and the subjects was instructed to focus on that markers. The target practiced for three minutes in order to get accustomed to the task before the measurement. The application order of four focus methods was determined randomly and measurement of each condition was carried out for 30 seconds. The subjects repeated each attentional focus three times and the mean was calculated and taken as the data. Rest time of 1 minute was given between each measurement.

Measurement of performance capacity of upper extremity balance task

Upper extremity balance task was the task to maintain the stick horizontally on hand. The displacement of marker attached to both ends of stick during the performance of upper extremity balance task was measured with motion analysis system. The displacement velocity (Vd, Figure 1, Formula 1) of each marker was calculated, and then mean velocity (Vm, Figure 1, Formula 2) was calculated based on displacement velocity. Mean velocity was used as variable for the performance capacity of upper extremity balance task. To calculate the mean velocity, the formula that calculates mean velocity of center of pressure (COP) proposed in the study of Raymakers et al (2005) was used. In this formula, the displacement velocity and mean velocity of center of pressure on the plane were calculated through coordinates of two axes x and y. In this study, the displacement velocity and mean velocity of marker were calculated by substituting the height of two markers from the ground to x, and y value.

$$Vd = \frac{\sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}}{t_i - t_{i-1}} \quad (1)$$

$$Vm = \frac{\sum Vd}{n} \quad (2)$$

Figure 1. Formulas for (1) Displacement velocity and (2) Mean velocity.

Measurement of EMG activity of biceps brachii

In order to measure the EMG activity of upper extremity muscle during the performance of upper extremity balance task, surface electrode was placed on both biceps brachii. The electrode was placed on the center of belly of biceps brachii. The ground electrode was attached to top of ankle joint in dominant lower limb. In order to decrease the skin resistance, the hair was removed and skin was rubbed with thin sandpaper several times to remove the keratin layer of skin. Small amount of the conduction gel was applied to the electrode and fixed with paper tape. Sample rate of electromyogram signal was 1024 ㎐ and band stop filter against 20 ㎐ and 60 ㎐ was used in order to remove the noise. Collected EMG signal was processed with root mean square (RMS) and %RVC value was calculated for the standardization. In order to set reference value of biceps brachii, the EMG activity was measured while lifting the dumbbell with the weight of 1 ㎏ for 10 seconds in the posture where the elbow joint is bent at 90°, arm is naturally attached to the body, and palm is placed toward the top.

Statistical Analysis

In order to compare the mean velocity of marker and EMG activity of biceps brachii based on four different attentional focus, repeated one way ANOVA was used and Sheffé was used for the post-hoc test. For statistical processing of the data, SPSS 12.0 program for window was used and the level of significance was set as α=.05.

Result

Mean velocity of marker based on different attentional focus

As a result of performing upper extremity balance task with four different attentional focus, there was significant difference in the mean velocity ($p<.05$) (Table 2). As a result of the post-hoc test, there were significant difference between internal focus-external focus 1, internal focus-external focus 2, internal focus-external focus 3, external focus 1-external focus 3, and external focus 2-external 3 ($p<.05$) (Figure 2).

EMG activity of biceps brachii based on different attentional focus

As a result of performing upper extremity balance task with four different attentional focus, there was significant difference in the EMG activity of biceps brachii ($p<.05$) (Table 3). As a result of the post-hoc test, there were significant differences between internal focus-external focus 1, internal focus-external focus 2, internal focus-external focus 3, external focus 1-external focus 3, and external focus 2-external 3 ($p<.05$) (Figure 3).

Table 2. Comparison of the mean velocity of marker based on different attentional focuses (N=30)

	Internal focus	External focus 1	External focus 2	External focus 3	p
Velocity of marker (㎜/s)	19.24±3.01[a]	15.45±2.56	14.73±3.74	12.85±2.62	.045

[a]Mean±SD.

Table 3. Comparison of the EMG activity of biceps brachii based on different attentional focuses (N=30)

	Internal focus	External focus 1	External focus 2	External focus 3	p
EMG activity of biceps brachii (%RVC)	40.78±7.86[a]	37.46±8.43	35.87±5.67	32.59±4.73	.037

[a]Mean±SD.

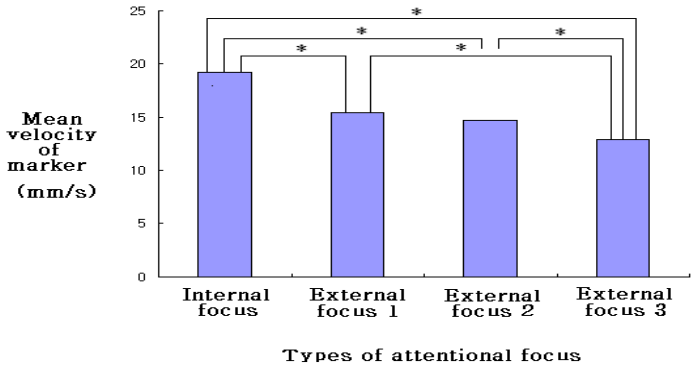

Figure 2. Comparison of mean velocity of marker based on different attentional focuses (*p<.05).

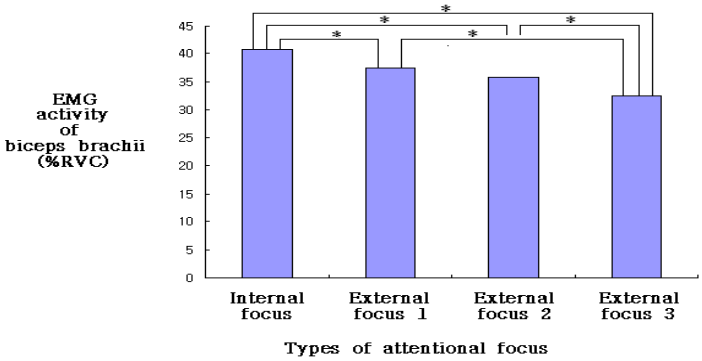

Figure 3. Comparison of EMG activity of biceps brachii based on different attentional focuses (*p<.05).

Discussion

The purpose of this study was to examine the influence of internal focus and external focus on the motor performance and the influence of the distance of external focus on motor learning. Lower limb balance task was peformed in previous studies (McNevin et al, 2003; Park et al, 2000). In these studies, it was revealed that external focus (focus on the marker attached to balance board) was more effective in motor learning compared to internal focus (focus on the motion of feet). However, it was difficult to estimate the effect of increase in distance of external focus since the distance between external focus the marker and feet was not classified. Therefore, in order to examine whether there is difference of motor performance based on different attentional focus in upper extremity, the effect of internal and external focus and the effect based on the different distance in external focus was examined by analyzing the effect of four different attentional focus (internal focus, external focus 1, external focus 2, external focus 3) during the performance of upper extremity balance task.

In regards to the mean velocity of marker that is used as the variable in this study, the mean velocity of two markers was calculated by substituting the height of markers attached to both end of the stick from the ground to proposed formula. The formula used in this study is the formula originally used to calculate the mean velocity at one axis of the pressure center on the

balance board. Raymaker et al (2005), as a result of studies on various variables related to the balance on the force plate, reported that the mean velocity of center of pressure was proper variable to present the balance capacity. Roh et al (2008), as a result of applying this formula to measure upper extremity balance capacity, reported that the mean velocity of marker was decreased with external focus. Therefore, the mean velocity of marker was also used in this study to measure the performance capacity of upper extremity balance task. In this study, lower mean velocity of marker was measured in external focus compared to internal focus as well. As a result of post-hoc test, statistically significant difference was displayed between internal focus-external focus 1, internal focus-external focus 2, and internal focus-external focus 3.

In this study, the EMG activity was used as the second measurement variable. The EMG activity is good variable that expands area of study about attentional focus to neuromuscular level. Wulf et al (2004) used the EMG activity as dependent variable in the study of attentional focus during the contraction of biceps brachii. As a result, lower EMG activity was displayed for external focus comparison to internal focus. It means that the low EMG activity is due to the mobilization in effective motor unit. Lower EMG activity was displayed in external focus compared to internal focus in this study as well. As a result of the post-hoc test, statistically significant difference was displayed between internal focus-external focus 1, internal focus-external focus 2, and internal focus-and external focus 3.

In the study on the distance of external focus target by McNevin et al (2003) and Park et al (2000), it was revealed that there is the increase in learning effect with the increase in the distance of focus target. In those studies, however, the classification of distance was not carried out. In this study, external focus target was classified 3 levels, markers that is located 10 ㎝ interior (external focus 1), 10 ㎝ exterior (external focus 2), and 20 ㎝ exterior (external focus 3) of both hands in order to examine the effect of distance of external focus. As a result of the study, the mean velocity and electromyogram of the marker decreased in order of external focus 1, 2, and 3. As a result of the post-hoc test, there was significant difference in mean velocity of marker and electromyogram between internal focus-external focus 1, internal focus-external focus 2, internal focus-external focus 3, external focus 1-external focus 3, and external focus 2-external 3. There was no significant difference between external focus 1-external focus 2. It was revealed that the upper extremity balance test was more stably performed with the increase in the distance of external focus. Although mean value was decreased between external focus 1-external focus 2 in this study, it did not display statistically significant difference.

Similar with the previous studies, upper extremity balance task was more stably and effectively performed with external focus as lower mean velocity and electromyogram of the marker was displayed with external focus compared to internal focus and with the increase in the distance of external focus target. Wulf et al (2001) proposed constrained action theory in order to explain the efficiency of external focus during motor learning. Constrained action theory is the hypothesis that asserts effective motor learning is difficult when performing internal focus since the motion learner is consciously involved in motor control process and obstructs automatic motor control process in case of performing internal focus that focuses on physical motion of himself. In contrast, external focus that focuses on the result of the motion makes possible unconscious motor control process that accomplishes the goal of motion. In other words, external focus activates automatic motor control process and enables effective motor learning. Also, automatic motor control process can be carried out as the target of external focus is further away from the body. Constrained action theory of Wulf is developed from common coding principle of Prinz (Prinz, 1992; Prinz, 1997). Common coding principle is that afferent and efferent information should have high compatibility and motion should be planned with the focus on the result and effect of motion for the effec-

tive performance of the motion. Better control of motion followed by automatic and unconscious exchange of afferent and efferent information is available when the focus is on the result and effect of the motion.

Upper extremity balance task was used as the performance task in this study. This was very artificial task to meet the laboratory condition for the study and it is distant from the motions in activity of daily living (ADL). Future study should be carried out the motion in ADLs or functional motion such as sports motion. Also, the study should be carried out targeting not only the general people but also patient group who has the trouble in motor control due to neurological disorder and the study on the distance of external focus target should be carried out with more specific and precise classification.

Conclusion

The purpose of this study was to investigate the effects of attentional focus (external focus-internal focus) and distance of external focus (external focus 1-2-3) on the performance of upper extremity balance task. In regards to the mean velocity of marker and EMG activity of biceps brachii that indicate the stable performance of task, it was lower in external focus compared to internal focus. In the comparison based on the distance of external focus, there was the decrease with the increase in the distance of external focus target. It reveals that the task performance capacity is stabilized as automatic motor control process occurs in accordance with the increase in the distance of external focus target. In future studies, it is necessary to investigate the effect of attentional focus on functional task targeting not only general people but also patients with neurological disorder who is having trouble in motor control.

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This article was received October 5, 2011, was reviewed October 14, 2011, and was accepted November 4, 2011.