Visualization of Muscle Activity during Squat Motion for Skill Education

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Abstract

Physical skills are important for various service fields, such as sports, nursing, and manufacturing. Experts show high performance by using specific muscular movements which non-experts are unable to use. It is important to understand expert's characteristic of muscle activity in specific motion and difference between experts and non-experts for skill education. However, people cannot just observe the difference between expert's and non-expert's muscle activity and imitate expert's muscle activity because muscle activities are invisible. In this study, a novel skill education system was developed for non-experts by measuring movement, analysing and visualizing characteristic of the movement in order to improve skill education effect and efficiency. This study focused on squat motion, a kind of strength training. We measured movement of experts with motion capture and surface electromyography, and extract skills for effective and safety training by analysing motion. A method of visualization extracted skills for skill education was proposed. At last, the experiment was carried out in order to verify effectiveness of proposal method for skill education. In the experiment, it was suggested proposal method is effective for physical skill education.

Keywords: visualization, motion capture, skill education, surface electromyography

1 INTRODUCTION

The motions which need special physical skills exists in various service fields, such as sports, nursing, and manufacturing. In each field, experts show high performance by using specific physical skills which non-experts are unable to use [1][2]. In physical skill education, experts teach non-experts their way to use muscle as a kind of physical skill. Experts usually can use only their words and gestures for education in education service fields. However, muscle activity is invisible with a naked eye. Therefore, it is difficult for experts to teach timing and strength of using muscle by their words and gesture.

Several studies have reported that effectiveness and efficiency of physical skill education are increased by feeding back invisible information in different form. Tsubouchi showed that muscle activity was changed by feedback electromyography data as sound [3]. Previous works reported muscle activity was enhanced by visual feedback of electromyography [4]. However, this research did not focused muscle activity during motion as skill. This study focused on visual feedback of muscle activity during motion for skill education.

The significance of this study is to solve problem about inefficiency and ineffective in physical skill education. In this study, we developed physical skill education system by visualization of muscle activity during motion. Figure 1 shows an image of visualization of muscle activity. It is possible that non-experts observe expert's muscle activity directly and understand expert's timing and strength of muscles.

Target of this study was education of squat motion, a kind of strength training. Squat motion is known widely as training of sports. In addition, this motion is noticed as basic of motions in daily life, such as standing up motion and lifting up motion. Squat expert's physical skills were extracted in training books and previous studies. In those, important points of squat motion was suggested in the viewpoint of training and safety. From the viewpoint of training, it is important to use the muscles which should be strengthened. From the viewpoint of safety, it is important to perform squat motion with the posture that is hard to be hurt. Posture is easy to teach to non-experts because posture is always visible. However, muscle activity is invisible and difficult to teach, so this study focused how to use muscle.

The purpose of this paper is to develop physical skill education system by visualization of muscle activity during motion. This paper proposed a method of muscle activity visualization by using motion capture and surface electromyography. In this method, a color was used as visual feedback of muscle activity. Color of visualized muscle was reflected by strength of muscle activity. The experiment was carried out to verified effectiveness of physical skill education by visualizing muscle activity.

Fig. 1 Image of visualization of muscle activity

2 VISUALIZATION OF MUSCLE ACTIVITY

There are two sides in physical skill that experts have. One side is kinematic skill, such as posture, trajectory of body movement and speed of movement. The other side is kinetic skill, such as power of muscle. Non-experts need to obtain these skills. However, in skill education, non-experts cannot do performance same as experts by imitating only expert's posture. When non-experts imitate only how to use muscle, non-experts cannot do performance same as experts too. Non-experts can show high performance by imitating both body movement and strength of using muscle of experts. In addition, timing of using muscle against body movement is important too. Therefore, in skill education, it is important for non-expert to understand expert's body movement and how to use muscle at the same time. Development skill education system that teach strength and timing of using muscle with expert's body movement is needed. Measurement body movement and muscle activity at the same time is needed. For the reason, measurement body movement and muscle activity makes quantitative evaluation of those skills possible. Evaluation of difference between experts and non-experts and progress degree of the non-experts make possible by quantitative skill evaluation. Lippold showed that linear relations holds between strength of muscle and electromyography of the muscle [5]. Timing and strength of using muscle are estimated by measuring surface electromyography (sEMG) of muscle. In this study, muscle activity was measured by sEMG. Measuring motion was needed in order to make clear relation between muscle activity and progress of motion. Body movement was measured by motion capture and video camera. Body movement was measured by recording coordination of some body joints continuously by motion capture. How to show of expert's measured physical skill is most important thing in education. It is important for non-experts to imagine expert's body movement more clearly, so actual video during motion was recorded by video camera. The direction to show the motion of the expert is important. Taking video of expert's movement from the plural directions made it possible that non-experts could watch some important parts of motion. This section explained how to measure muscle activity and motion and how to show these data to non-experts in detail.

2.1 Measurement muscle activity and motion

Measurement electrical activity of target muscles was conducted by surface electromyography. sEMG was possible to measure by attaching an electrode on skin on target muscle. Measurement posture during squat motion was conducted by Optical motion capture. Markers was attached on 20 points of subject's body joints and filmed by 8 infrared cameras. It enabled to get the three-dimensional coordinate of the markers. Actual video is recorded by video camera in chronological order same as other data.

Method of visualization

Filtering operations to sEMG data fixed base line were performed by using low-pass filter with 300Hz and high-pass filter with 10Hz of different cut-off frequency. Filtered sEMG data was rectified and smoothed. Maximum voluntary contraction (MVC) was measured in order to calculate %MVC, ratio of power of the muscle for the maximum power. MVC was obtained by measuring EMG at the position that was easy to perform maximum power. A comparison in others of activity of muscle is enabled by normalizing activity of muscle by MVC.

Three-dimensional coordination of each joints from motion capture were plotted in virtual space and 3D human model was made. This human model was point group and did not have musculoskeletal parts. Virtual muscles was drawn at real muscle position on 3D model. Shape of Virtual muscle was like pole. Parts of muscles drawn as virtual muscle were only parts that wanted to show muscle activity to non-expert. This was to enhance education effect by making it focus in only the activity of the muscle which want to show to non-expert. It was thought that it may cause the perplexity of the non-expert to show the activity of too many muscle.

It is important how to show muscle activity to non-experts. In this study, muscle activity was expressed as color of virtual muscle. Change of color was easily understandable visually and intuitively. Color of virtual muscle was changed by ratio to maximum value of muscle activity during motion. Changing color was performed by changing each elements of RGB color model. The color of muscle nears red so that strength of muscle activity is strong. On the other hand, the color of muscle nears blue so that strength of muscle activity is weak. Figure 2 shows condition of changing virtual muscle color. Virtual muscle on 3D model was projected to 2D plane adjusting direction of actual video and overlaid with actual video data. These were process to make muscle activity visualization system.

3 VISUALIZATION OF EXPERT'S MOTION

3.1 Experimental set up

In this experiment, measurement electrical activity of target muscles was conducted by surface electromyography (sEMG) (S & ME DL-721). Sampling frequency of sEMG was 1000Hz. Measurement posture during squat motion was conducted by Optical motion capture (Motion Analysis EVaRT4.4). Sampling frequency of motion capture was 200Hz. Video camera (SONY) is connected to control PC via converter (grass valley ADVC55) in order to get a video data in chronological order same as other data. Figure 3 shows condition of measurement devices.

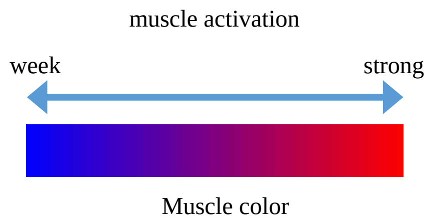

Fig. 2 Color of virtual muscle

3.2 Subject

Expert's muscle activity was visualized during squat motion for skill education of squat motion. A subject was expert who had trained on a daily basis in 7 years under instruction of professional athletic trainer and understood important points of squat motion, such as way to use muscles and posture. In this experiment, target muscles of visualization were protagonist (quadriceps femoris (QF) muscle and gluteus maximus (GM) muscle) which are important muscle for squat motion. These muscles are used mainly during squat motion. Figure 4 shows position of target muscles. In this study, non-experts was educated how to use these muscle as physical skill. In the experiment, investigate how to use GM and QF muscles as expert's skill.

3.3 Result

Figure 5 shows sEMG data of expert's trial. Figure 6 shows visualization of muscle activity. In figure 6, a whole process of squat motion was regarded as 100% of rate of motion progress at the horizontal axis. Timing of squatting down the deepest was regard as 50% of rate of motion progress. Indeed, squatting down phase took 2 seconds and standing up phase took 1 second. However, for focusing relation body posture and muscle activity change of shoulder vertical position defined as progress of motion. Visualizing muscle activity videos from front and back viewpoints was made for getting easy to observe important muscle activity. Figure 6 indicated that QF and GM were used mainly in standing up phase. QF was used from second half of squatting down to first half of standing up phase and GM was used in second half of standing up phase. These way to use muscle was expert's way. Non-experts need to obtain how to use muscles as this.

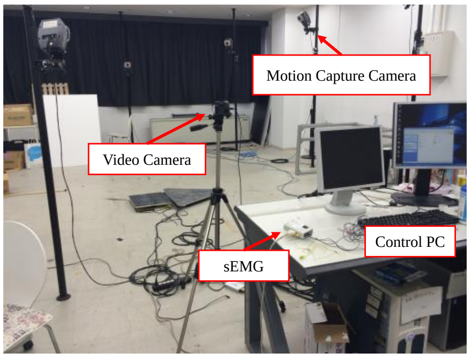

Fig. 3 Measurement devices

Fig. 4 Target muscle

4 VERIFICATION OF EDUCATION

4.1 Participants

We conducted the experiment in order to verify effectiveness of muscle activity visualization in physical skill education of squat motion. Participants were 6 males (age = 23 ± 1) who had not been instructed squat training.

4.2 Method

In this experiment, education was focused on QF activity and GM activity which are important muscle for squat motion. 6 participants were separated to 2 groups (A-group and B-Group) by 3 participants. Three participants (A-1, A-2, A-3) in A-group were educated by using video with visualization of muscle activity. Three participants (B-1, B-2, B-3) in B-group were educated by using video without visualization of muscle activity.

Firstly, expert taught participants in both groups how to perform squat motion with his gesture and words. This is the way to educate usually in education service fields. Expert explained about safety posture that a knee and a waist had few burdens. After explained, participant's posture was safety sufficiently during squat motion. Expert expressed timing and image of using QF and GM with his gesture and words to participants. After teaching, QF's sEMG and GM's sEMG were measured during squat motion. One set consisted of 10 trials. One trial consisted of squatting down in 2s and standing up in 1s. Participants performed squat on 1 set.

Secondly, in A-group, education by using video with visualization of muscle activity was conducted. In B-group, education by using video without visualization of muscle activity was conducted. Participants were ordered to watch video of expert's motion. The movie was filmed expert's 8 trials. Participants watched 2 times of the movie on front and back angle. After that, participants performed squat motion on 1 set again and were measured muscle activity.

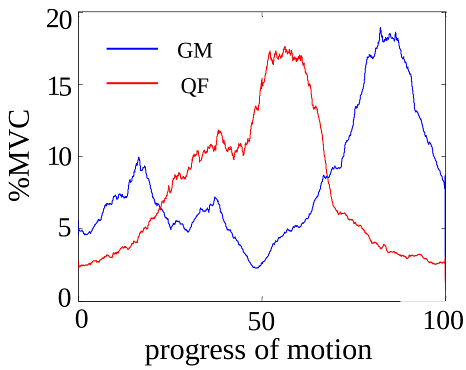

Fig. 5 Muscle activity of expert

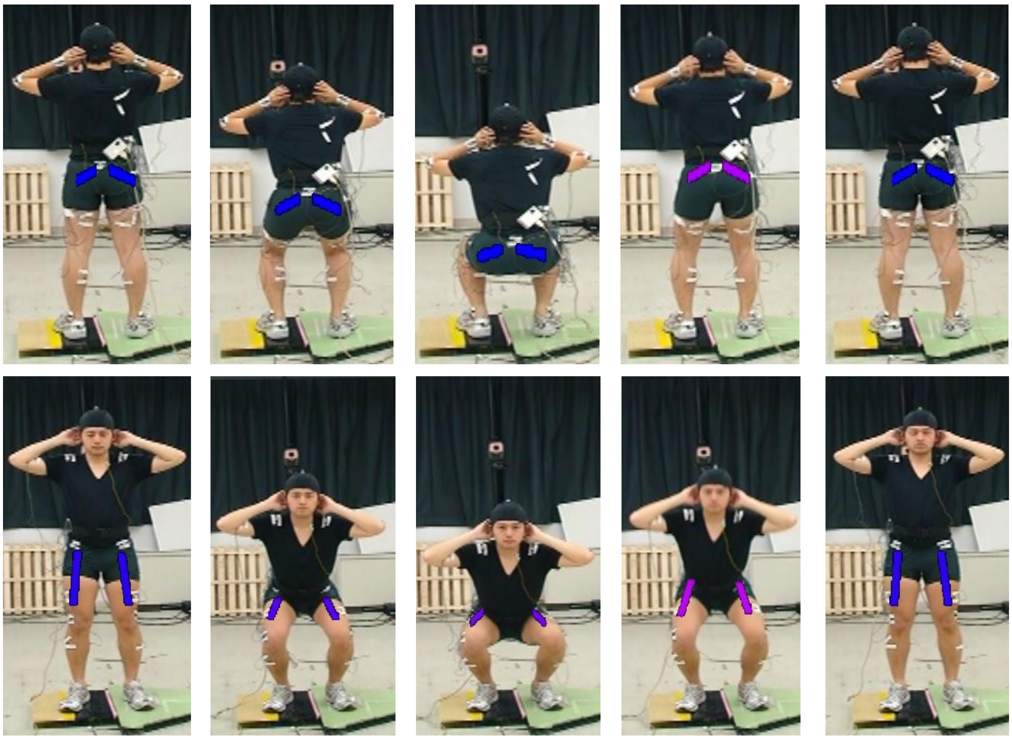

Fig. 6 Visualization of muscle activity

4.3 Result

Figure 7 shows 6 participant's muscle activities averaged 10 trials of sEMG data. 3 participants on left side belonged to A-group and the others belonged to B-group. The horizontal axis of graph represents progress of squat motion and the vertical axis represents %MVC. In A-1's muscle activity, strength of GM muscle activity increased as a whole and timing of peak got later and strength and timing of using QF muscle did not change. In A-2's muscle activity, strength of GM muscle activity increased greatly at the peak and timing of peak got later and strength and timing of using QF muscle did not change. In A-3's muscle activity, strength of GM muscle activity increased a little and peak of GM muscle activity appeared and peak of QF muscle increased slightly However, timing of using QF muscle did not change. In B-1's muscle activity, strength of GM muscle activity decreased at the peak of GM muscle activity and strength and timing of using QF muscle did not change. In B-2's muscle activity, strength and timing of using GM and QF muscles did not change. In B-3's muscle activity, strength of GM muscle activity increased slightly at the peak and timing of using QF muscle did not change. Strength and timing of using QF muscle did not change. Peak value of GM and QF muscle activity was analysed. Figure 8 shows change of peak values of muscle activity between before video education and after in education by using video with visualization and without. Value of each bar represents averaged peak values of muscle activity among 3 participants in each group. Peak value of only GM muscle activity of participants in A-group tended to increase notably by educated with visualization system. On the other hand, muscle activity of participants in B-group did not change before video education. A-group participant's results suggested peak of using GM got later than education with expert's gesture and words and closer to expert's timing. However, timing of using QF did not change.

5 DISCUSSION

In the experiment, effectiveness of education by using proposal muscle activity visualization method was verified. Participant's GM muscle activity got stronger owe to proposal method in A-group. Timing of using GM got closer to expert's timing in A-group. On the other hand, muscle activity of participants in B-group did not change very much. It was likely that participants understood relation between progress of squat motion and timing of using muscle by watching visualized muscle activity. In QF muscle activity, change of strength and timing could not be seen on all participants. There was difference in influence to be educated from visualization system by the part of the muscle. It could be that somatic sensation depends on the part of the muscle. In this experiment, participants were indicated that they were aware of two muscle activities. However, if subjects did not understand how to use indicated muscles, it is no mean that subjects know expert's muscle activity. This problem could be solve by visualisation of non-expert's muscle activity with real time feedback. If non-experts can understand their muscle activity, more non-experts learn motion more effectively. In this study, we verified effectiveness to two indicated muscle activity directly. However, in educating more complex motion, it is inefficient to indicate to use more parts of muscle. It is possible that indication to rise one part of muscle activity has a good influence on multiple muscles activity. Investigation physical skill like that is challenges for the future.

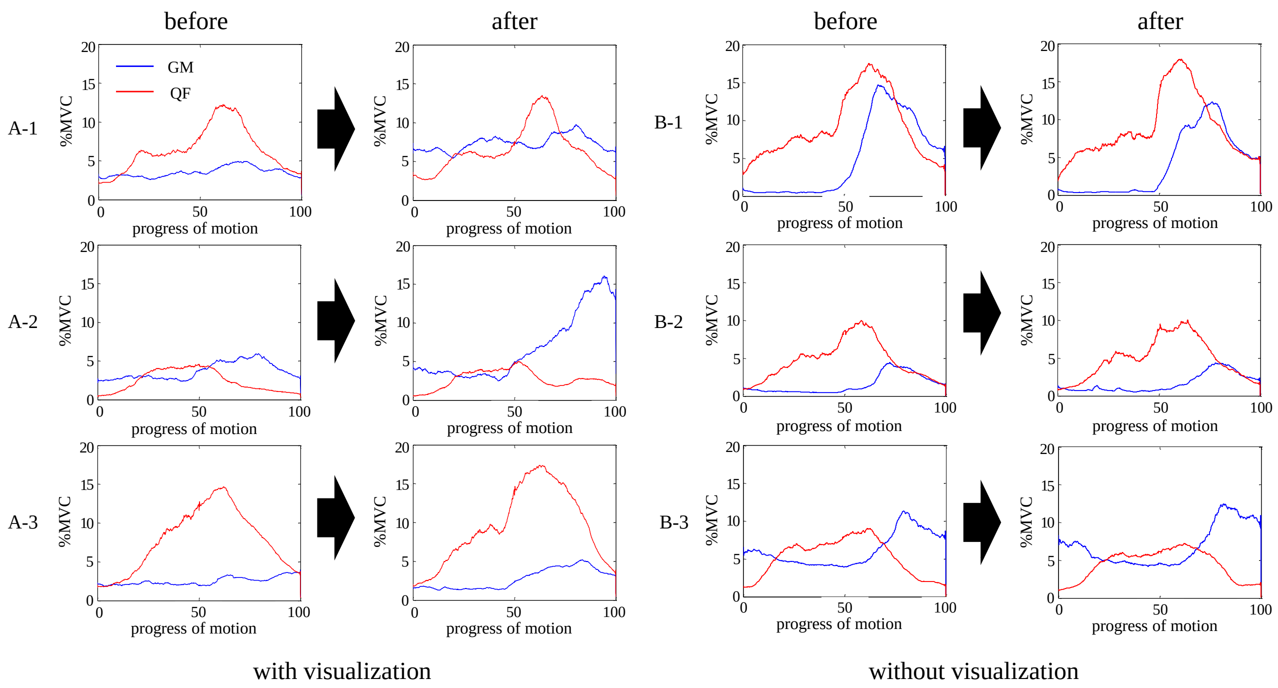

Fig. 7 Muscle activity of non-experts

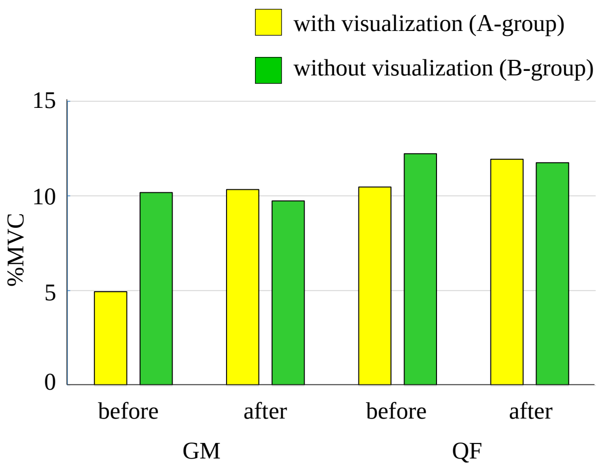

Fig. 8 Change peak values of muscle activity

6 CONCLUSION

The purpose of this study is to solve problem about inefficiency and ineffective in squat physical skill education by visualizing muscle activity in physical skill education service fields. We proposed method of visualizing muscle activity and verified effectiveness of proposal method for skill education by using visualization movie of expert's muscle activity. In the experiment, it was suggested proposal method is effective for physical skill education. In the future, we will develop visualization system of muscle activity on real time in order to realize more effective education.

7 ACKNOWLEDGMENT

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