Investigating Relationship between Running Motions and Skills Acquired from Jump Trainings

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Keywords: Running Motion, Jump Training, Skill, Coaching System, Stepwise Skill Improvement.

Abstract: To identify the difference in performers' motions, this paper investigates the relationship between running motions and the result of evaluating motions during jump training. To clarify the relationship, two experiments were performed using 17 subjects as follows: i) obtaining sequences of human joints during running to evaluate running motions, and ii) obtaining motions during jump training which could skill up the running motions. According to the result of those experiments, we confirmed that whether a running motion is good or not relies greatly on the number of acquired skills.

1 INTRODUCTION

In recent years, emerging technologies such as deep learning and image processing have made it possible precisely to recognize objects or to detect human poses. These technologies permit to develop computerized coaching systems that obtain sports motion data using sensors and analyze them to objectively evaluate the learner's performance, and to help the learner improving skills without human coaching.

Traditional coaching system normally outputs a one-dimensional evaluation result such as a score for an exercise (Pirsiavash et al., 2014 and Parmar et al., 2016) or a binary evaluation such that whether the motion has achieved the ideal motion using sensors (Ozaki et al., 2016). In particular, Pirsiavash et al.'s method drew arrows on the video image to show the direction to the ideal pose, while Ozaki et al.'s method gave the performer a real-time voice instruction so that the performer can improve his/her motion. However, such systems are not always suitable for low-level learners. One reason is that such learners are considered not to have enough skills to improve their performance. Another reason is that they cannot adequately perfrom a motion along the improvement strategy proposed by the system.

To solve such beginners' problem(s), we are addressing to develop a coaching system that can improve skill step by step by detecting the skills acquired by a learner, and by automatically outputing the improvement strategy which is appropriate for the learner's skill level. Our basic idea is that the system can output a strategy to improve few problems which cause low performance rather than to improve all the problems. Also, we suppose that the few problems for a learner can be solved by acquiring some skills which he/she does not have. Therefore, we propose two methods to resolve these problems: i) the system finds a performer whose level is slightly higher and has similar skill for the learner, and ii) a learner improves his/her skill to achieve the slightly higher-level performer's skill.

To achieve the method i), we first focus on how to extract and classify running skills from motions without *a priori* knowledge using our previous unsupervised learning based method (Seo et al., 2019). However, we have not yet resolved whose level is higher and whose skill is similar to the learner. Note that this paper deals with training motions which are related to running motions. The reason is that the training motions are helpful to understand what skills a learner has. In particular, "Skills" reflect a person's proficiency in performing a paricular task (Schmidt et al., 2000). Based on the skills, we assume that performance of a learner relies greatly on the number of learner's acquired skills as shown in Fig. 1, and that a performer, whose level is slightly higher and who has skills similar to the learner, has more skills than the learner (Fig. 1). In fact, we suppose the learner in Beginner level doesn't have some skills even to perfrom basic trainings related to running motions.

Seo, C., Sabanai, M., Ogata, H. and Ohya, J.
Investigating Relationship between Running Motions and Skills Acquired from Jump Trainings.
DOI: 10.5220/0008348301980203
In *Proceedings of the 7th International Conference on Sport Sciences Research and Technology Support (icSPORTS 2019)*, pages 198-203
ISBN: 978-989-758-383-4

Table 1: Observational motion evaluation items concerning running motion in sprinting: These evaluation items can be evaluated for performers by keeping scores from Suzuki et al.'s items.

Score	1.0	0.5	0.0
Size of lower limb movement	The knee of the swinging leg moves forward largely, and the leg swings back just below the body.	The swinging legs are swinging weakly in running motion. There is no swing back of the swinging leg in the direction directly beneath the body, and the foot of the swinging leg is touching the ground immediately before going in front of the swinging legs.	The forward swinging of the swinging leg and the extention of the knee are very small, and the flight duration is extremely short.
Switching of legs	The swinging leg overtakes the supporting leg almost at the same.	The swinging leg overtakes the supporting foot immediately after touching the ground	The swing leg slowly overtakes the supporting leg by touching the ground

And also, our opinion is that the learner should acquire some skills from the basic trainings in order to perform a running motion such as the performer.

To confirm that the performance is affected by the number of acquired skills, this paper investigates the relationship between running motions and motions during training, which could skill up running motions.

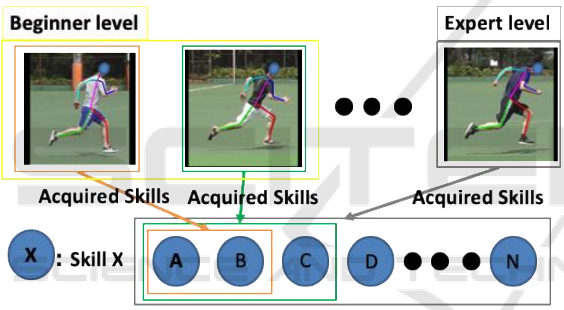

Figure 1: Image of skills acquired by each performer. The number of skills acquired by a lower-level performer is generally smaller than an expert.

2 METHODS

To confirm what running skills each performer has, we conduct the following two experiments: i) to obtain sequences of human joints during running motions and to evaluate the running motions (Section 2.1), and ii) to obtain motions during jump trainings, which could improve the running motions (Section 2.2).

For these experiments, we collected data from 17 healthy male subjects (10 beginners and 7 experts; 21-24 years old).

2.1 Running Motions

To collect data, we let each subject run on a 30 m track at a full speed. A video camera was placed at the position shown in Fig. 2 to capture the first 15 m running motion in order to check the start dash. The videos were taken at 60 frames per second. Each subject was asked to run 4-9 times, and 98 videos were recorded in total.

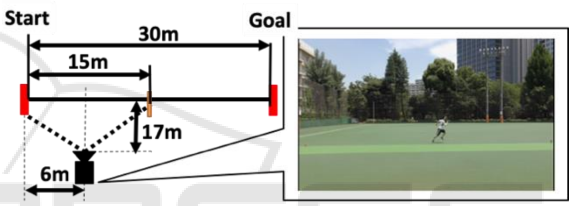

Figure 2: Left: Environmental setup for getting running motion data. Right: An example of the images captured by the video camera.

The running motions were evaluated using Suzuki et al.'s items by an expert sprinter. We especially focus on the two items related to the low limb, which are shown in Table 1. The period of evaluating those items begins when the supporting leg leaves the ground and ends when the opposite foot reaches the ground. The score is obtained as an average rating of each period in the running motion.

2.2 Jump Training Motions

To estimate each subject's skill(s), we collected the data of trainings, which could skill up the running motion. The experimental condition is shown in Fig. 3.

Training items were selected from Tanaka's book (Takano, 2008) on training for sprinters. The selected items are shown in Table 2. The reason for selecting these items is that jump trainings such as skip is related to skill up running motions according to the report of Kotzamanidis and Iwatake et al., and it is not difficult even for beginners to simply perform such jump trainings.

The subjects were thoroughly explained about the methods of performing the jump trainings before conducting the experiment. Then, a two-stage evaluation of whether the trainings of the items in Table 2 were performed well or not was judged by the same expert sprinter as Section 2.1.

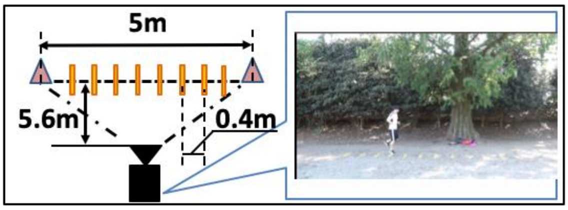

Figure 3: Left: Environmental setup for getting training motion data. The stick ladders were placed at the interval of 0.4 m and the subjects jumped the interval in performing the training items in Table 2. Right: An example of the images captured by the video camera.

Table 2: Training Items in performing the experiment. In particular, in performing jump trainings labeled 2, 7 and 8, our subjects skip backward one step after two steps forward in Fig. 3's experimental condition.

Label	Training Name
1	Skip forward using both legs
2	Skip forward and backward using both legs
3	Skip forward using left leg
4	Skip forward using right leg
5	Sideways skip using left leg
6	Sideways skip using right leg
7	Skip forward and backward using left leg
8	Skip forward and backward using right leg

3 RESULTS

3.1 Evaluating Running Motions

The scores obtained in the first experiment is shown in Table 3. From the table, it can be seen that almost all the score of the beginners are below 0.5 in Items 0 and 1. We could not confirm other common tendency of the beginners except that they were evaluated low in Table 1.

On the other hand, it can be seen that almost all the score of the experts are over 0.5 for Items 0 and 1, and also the standard deviations of the experts are smaller than those of the beginners in Table 3. Expert0 got a score lower than other experts. That is because Expert0 had not run for a long time, which results in losing his past capability.

As a result, we could confirm that the running motions are different between beginners and experts through Suzuki *et al.*'s evaluation method. However, the reason why their motions are different cannot be clarified only by scores in Table 3.

Table 3: Scores of each subject: the number of times to run, mean score, and standard deviation (SD) for Table 1's items.

Subject	Times	Item0		Item1	
		Mean	SD	Mean	SD
Beginner0	4	0.27	0.11	0.39	0.04
Beginner1	4	0.55	0.18	0.31	0.12
Beginner2	4	0.07	0.08	0.03	0.02
Beginner3	8	0.22	0.10	0.28	0.13
Beginner4	5	0.38	0.20	0.27	0.19
Beginner5	6	0.30	0.10	0.23	0.08
Beginner6	6	0.25	0.05	0.42	0.14
Beginner7	6	0.31	0.16	0.32	0.10
Beginner8	4	0.16	0.08	0.02	0.04
Beginner9	6	0.36	0.08	0.27	0.06
Expert0	9	0.66	0.11	0.53	0.17
Expert1	6	0.98	0.02	0.91	0.03
Expert2	6	0.93	0.04	0.94	0.06
Expert3	6	0.98	0.04	0.94	0.03
Expert4	6	0.88	0.08	0.87	0.03
Expert5	6	1.00	0.00	0.77	0.00
Expert6	6	0.94	0.02	0.81	0.08
Average	5.76	0.55	0.33	0.49	0.31

3.2 Evaluating Jump Training Motions

Figure 4 and Table 4 show the relationship between scores of Item 0 in Table 3 and the result of evaluating jump training motions. The subjects are divided into four groups based on the scores of Item0. From Fig. 4 and Table 4, it appears that subjects who are in a similar skill level tend to belong in the same group. For example, the result of evaluating jump training motions is low if the Item0's score is low, and the result is high if it is high. In particular, in Fig. 4, the subjects of Area1 in Table 4 tend to be highly possible to perform Item7 in Table 2 rather than others, and Area2 tends to be highly possible to perform certain items in Table 2 but difficult to perform others.

Figure 5 and Table 5 show the relationship between scores of Item 1 in Table 3 and the result of evaluating jump training motions. In Fig. 5 and Table 5, though the scores are divided at regular interval into 5 groups, we merge the ranges of $0.6 \leq x < 0.8$ and $0.8 \leq x < 1.0$ because only experts belong to these ranges. Therefore, there are 4 groups as a total. Each area in Table 5 tends to contain subjects who have similar skill levels. In particular, Area2 in Table 2 is composed of a beginner and an expert in Fig. 5. Thus, the result in Fig. 5 depends on the expert's result and leads to show a better result than Area3 in

Item6 and Item7, but, in Table 5, it is confirmed that mean score is different.

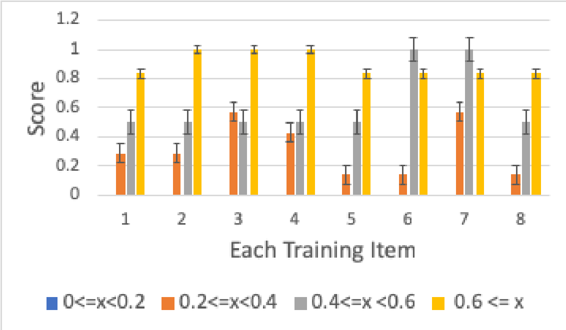

Figure 4: The evaluation result of whether each training items in Table 2 can be performed or not by subjects in anarea which is decided by a mean score in Item0 of Table 3. In the figure, x is the mean score in Item0 of Table 3.

Table 4: The basic information in each area: the number of persons that belong to each area, mean score, and standard deviation (SD) of evaluated result in all training items. The range of Areas 0 to 3 are $0 \leq x < 0.25$, $0.25 \leq x < 0.5$, $0.5 \leq x < 0.75$, and $0.75 \leq x$, respectively. x is a mean score of Item 0 in Table 3.

	Area0	Area1	Area2	Area3
Belonged persons	4	5	2	6
Mean	0.03	0.40	0.69	0.90
SD	0.08	0.26	0.24	0.08

Figure 6 and Table 6 show the relationship between total scores of Items 0 and 1 in Table 3 and the result of evaluating jump training motions. In Fig. 6 and Table 6, the scores are divided into 4 groups. Each area in Table 6 tends to contain subjects who have similar skill levels. In particular, Area2 and Area3 in Table 3 are composed of all the experts, and it can be confirmed that some items in Table 3 could not be performed even experts in Area2 from Fig. 6.

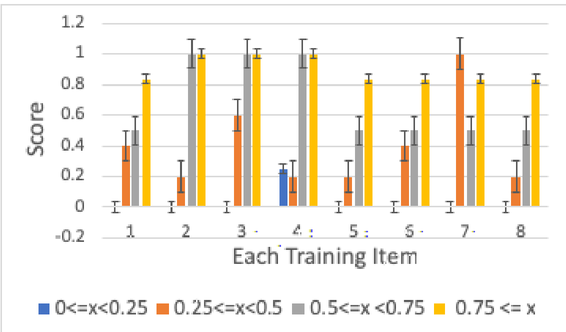

Figure 5: The evaluation result of whether each training items in Table 2 can be performed or not by subjects in an area which is decided by a mean score in Item1 of Table 3. In this figure, x is the mean score in Item1 of Table 3.

Table 5: The basic information in each area: the number of persons that belong to each area, mean score, and standard deviation (SD) of evaluated result in all training items. The range of Areas 0 to 3 are $0 \leq x < 0.2$, $0.2 \leq x < 0.4$, $0.4 \leq x < 0.6$, and $0.6 \leq x$, respectively. x is a mean score of Item 1 in Table 3.

	Area0	Area1	Area2	Area3
Belonged persons	2	7	2	6
Mean	0.00	0.32	0.63	0.90
SD	0.00	0.17	0.22	0.08

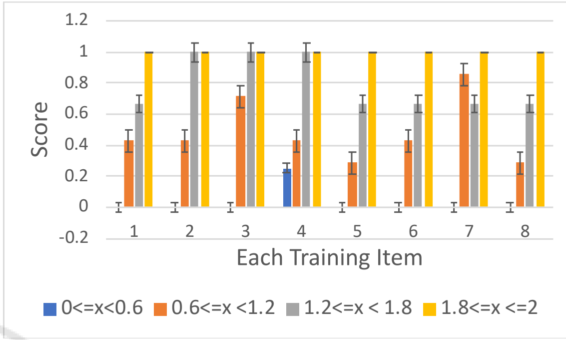

Figure 6: The evaluation result of whether each training items in Table 2 can be performed or not by subjects in an area which is decided by a total score in the mean score of Item0 and Item1 in Table 3. In this figure, x is the total score in the mean score of Item0 and Item1 in Table 3.

Table 6: The basic information in each area: the number of persons that belong to each area, mean score, and standard deviation (SD) of evaluated result in all training items. The range of Areas 0 to 3 are $0 \leq x < 0.6$, $0.6 \leq x < 1.2$, $1.2 \leq x < 1.8$, and $1.8 \leq x \leq 2$, respectively. x is a total score of Item0 and Item1 in Table 3.

	Area0	Area1	Area2	Area3
Belonged persons	4	7	3	3
Mean	0.03	0.48	0.79	1.00
SD	0.08	0.19	0.16	0.00

4 DISCUSSION

In Section 3.2, it was observed that there is a relationship between the skill to perform certain jump training and the scores in Table 3. In particular, the total scores of Item0 and Item1 in Table 3 show the difference in each area of whether each training item can be performed or not from Fig. 6, and the areas of Table 6 show a stepwise distribution between the scores and the result of training motions. From these results, we can infer that the running motion is related by the number of obtained skills from the jump trainings in Table 2. Then, the number of acquired skills highly affects the motions of the runner.

However, all the motions are evaluated from their appearances in this paper. Thus, we could obtain the relationship about skills, but we could not validate the motions using detail information such as the motion sequence of human joints.

In our future works, we will focus on validating the training motions by detecting human joints, and we will clarify the motion difference which causes the different numbers of obtained skills.

5 CONCLUSIONS

In this paper, we have investigated the relationship between the running motions and the motions during jump trainings so as to clarify the difference in running motions of performers which causes different numbers of acquired skills. From our experiments, we can infer that the number of acquired skills from jump trainings is related to the performance of running motions.

ACKNOWLEDGEMENTS

This study was conducted as a part of research activities of the Human Performance Laboratory, Organization for University Research Initiatives, Waseda University.

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APPENDIX

We show the images of trainings in Table 2. In first, label 1-4, 7 and 8 in Table 2 were performed such as Fig. 7. In the case of the training of label 1, 3 and 4, subjects jump over a stick ladder until the end.

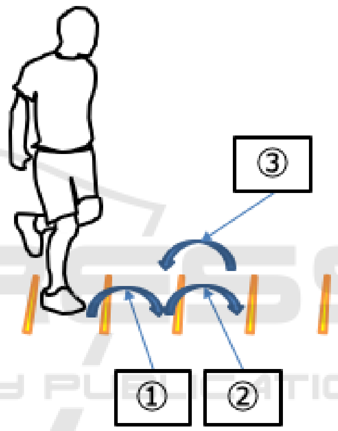

Figure 7: Image of skipping forward and backward.

In case of the training of label 2, 7 and 8, the subjects performed 2 steps. First step is jumped over a stick ladder twice in Fig.7 (1 and 2). Next step is jumped over a stick ladder backward in Fig.7 (3). And, the subjects repeat to do this motion until the end.

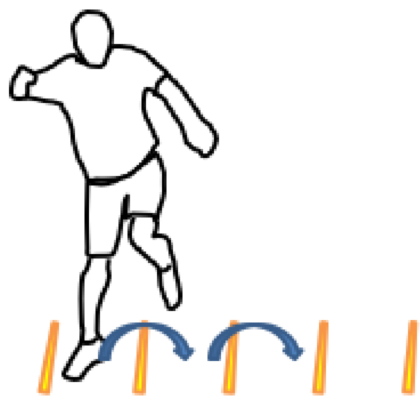

Figure 8: Image of Sideways skip.

On the other hands, label 5 and 6 in Table 2 were performed such as Fig. 8. In the case of the training of label 5 and 6, the subjects jump over a stick ladder until the end.