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Note:

Study on Psychological Effect of Cyclic Foot Joint Exercise as a Light Exercise for Sitting Position

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We present the physical and psychological effects of a foot joint exercise in a sitting position, as a preliminary experiment to design a foot exercise system for motivating sedentary adults to increase level of their physical activity. The experiment was conducted with four healthy adults performing a cyclic foot joint dorsiflexion exercise in a sitting position. Apart from changes in the blood flow and pulse rate during exercise, affective valence and perceived exertion after exercise were measured. The results indicated that the foot joint dorsiflexion exercise is a low intensity exercise, which does not lead to a change in pulse rate compared to a state of rest. However, the participants' affective valence and perceived exertion exhibited extensive inter-individual variability. This finding suggests that the foot exercise system need to be designed to account for the possibility of significant individual variations in pleasant/unpleasant emotions, even in the context of light exercise that requires little physical burden.

Keywords: foot exercise, feeling scale, perceived exertion, pulse rate, blood flow

1. Introduction

The importance of regular physical activity to promote good health cannot be overemphasized. However, no effective support measures for adults who do not participate in health-related activities, or do not exercise regularly, have yet been suggested [1]. With an intent to motivate such people and improve their adherence to physical activity, we focused on a foot exercise that can be performed in a sitting position and can be easily integrated into everyday life. As a pilot experiment to develop a foot exercise system as a tool for support measures, this study investigated the physical and psychological effects of a cyclic foot joint dorsiflexion exercise, using a biometric sensor and various subjective scales. Here, we discuss the physiological and psychological effects of a light exercise, which involves less physical burden.

2. Methods

2.1. Participants and Measures

Four healthy adults, including two females and two males (average age: 46 ± 13.3 years), participated in an experiment. We explained the intent and method of the experiment to the participants and obtained their consent.

In the experiment, the blood flow and pulse rate of the participants were measured as indices of the intensity of foot joint exercise, using a laser blood flowmeter (RBF-101, Pioneer Corp.). The blood flowmeter was attached over the area of the inferior border of the patella of the left foot. The sampling frequency of the blood flowmeter was 50 Hz. The blood flow and pulse rate were determined based upon a moving average of values collected every three seconds and five seconds, respectively.

Additionally, the psychological effect of cyclic foot joint exercise on the participants was examined using a Feeling Scale (FS) [2] and Borg's Rating of Perceived Exertion (RPE) [3]. FS is a scale used to measure changes in affective valence towards exercise over a range of -5 (Very Bad) to 5 (Very Good), where 0 (Neutral) is the point of origin. It can measure pleasant/unpleasant emotion in a simple, intuitive manner. On the other hand, RPE is a scale used to classify the perceived intensity of exercise in a subjective manner, in the range of 6 to 20 from "Very, very light" to "Very, very hard."

2.2. Procedures

Participants dorsiflexed their foot from the intermediate position of the foot joint in the sitting position and alternated between the right and left foot. A single-tone metronome was used to cue the timing of dorsiflexion. The participants were supposed to maintain the angle of both foot joints during the intervals between each cue. The frequency of instructions (i.e., the dorsiflexion exercise cycle of the foot joint) was of 3 different durations: 4 seconds (length of time of experiment was 4 minutes), 2 seconds (length of time of experiment was 2 minutes), and 1 second (length of time of experiment was 2 minutes). In all, 15 sessions of the experiment were conducted, with 5 sessions for each frequency in descending order of the length of exercise cycle. The participants rated each session on the FS and RPE score sheets immediately after

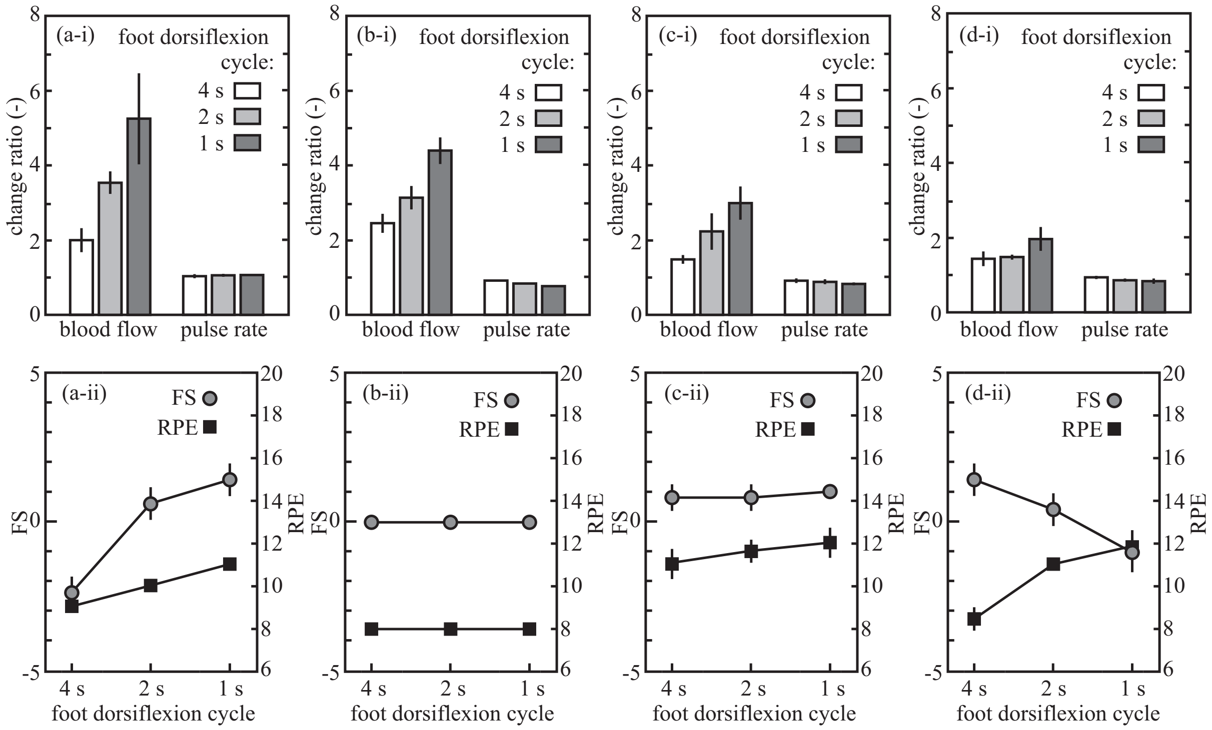

Fig. 1. The experiment results of the four participants are presented in (a), (b), (c), and (d). (a-i), (b-i), (c-i), and (d-i): The change ratio of the blood flow and pulse rate (average value ± standard deviation) during exercise compared with the blood flow and pulse rate during a state of rest for each participant. In each dorsiflexion cycle, a time average of the consecutive data from the start of the exercise to the 60th dorsiflexion is designated as the blood flow and pulse rate during exercise. (a-ii), (b-ii), (c-ii), and (d-ii): FS and RPE (average value ± standard deviation) at the time of completing the exercise for each participant. [FS, Feeling Scale; RPE, Rate of Perceived Exertion]

the session. The influence of fatigue between the sessions was eliminated by taking a break of more than 5 minutes after each session. During the experiment, the participants assumed a sitting position by bending their knee joint at 90° and maintaining a straight line of sight. Additionally, to obtain resting data, blood flow and pulse rate were measured for 2 minutes for both foot joints in the intermediate position, before initiating the 2 seconds and 1 second sessions. The data were averaged, which was used as the values of blood flow and the pulse rate at rest. After the measurements, participants answered a questionnaire survey about physical activity.

3. Results

Figure 1 presents the experiment results for each participant. According to the questionnaire, Participant (a) participated in regular physical activity, while the other participants did not. The results presented in **Figs. 1 (a-i)**, **(b-i)**, **(c-i)**, and **(d-i)** indicate that, in all participants, regardless of adherence to physical activity, increasing level of blood flow was measured during exercise for shorter dorsiflexion exercise cycles. In addition, pulse rate was almost equal or slightly lower than that at rest in all participants during any of the exercise cycles. However, the results presented in **Figs. 1 (a-ii)**, **(b-ii)**, **(c-ii)**, and **(d-ii)** show a different tendency in FS and RPE among the participants. **Fig. 1 (a-ii)** indicates that FS shifted from unpleasant to pleasant as the dorsiflexion exercise cycle became shorter. In contrast, **Fig. 1 (d-ii)** indicates that FS shifted from pleasant to unpleasant as the dorsiflexion exercise cycle became shorter. Moreover, **Fig. 1 (b-ii)** and **(c-ii)** indicate an almost constant FS value independent of the dorsiflexion exercise cycles. On the contrary, **Figs. 1 (a-ii)**, **(c-ii)**, and **(d-ii)** indicate that the RPE value increased as the dorsiflexion exercise cycle became shorter, while **Fig. 1 (b-ii)** indicates a constant value regardless of the exercise cycle.

4. Discussion

A likely cause for the increase in blood flow during foot joint exercise might be an improvement in the hemodynamic status of the lower leg due to muscle pumping generated by the exercise. In addition, we observed an increase in blood flow during shorter dorsiflexion cycles because a shorter cycle results in a greater exercise burden and more extensive muscle pumping. This is further corroborated by the fact that in three of the four participants, the RPE value was greater during shorter cycles, which indicates a higher perceived intensity of exercise.

In contrast, neither a change in the dorsiflexion exercise cycle nor the exercises themselves had an impact on the pulse rate. This confirms that the exercise adopted in this experiment was a light exercise that did not affect the pulse rate regardless of the exercise cycle. Conversely, in three of the four participants, we observed a greater RPE value for shorter exercise cycles, which indicates that the perceived exercise intensity increased. In addition, the RPE value in each cycle varied between individuals. The increase in RPE might be explained by the increase in blood flow during shorter cycle exercises, which did not increase the pulse rate but did increase the perceived level of exertion. However, a potential influence of the exercise procedure might be the cause and, therefore, a future study with an experiment protocol that compensates for the effect of exercise sequence is necessary. In addition, the individual differences in RPE values may be a reflection of the non-intuitive nature of the scale since it normally is used to evaluate higher intensity exercise than those practiced in this experiment. Therefore, it may have been difficult for participants to classify the perceived intensity of exercise. These results suggest that a low intensity exercise, as was performed in this experiment, may not necessarily reflect a correlation between RPE and pulse rate (regarded as equal to the heart rate). Furthermore, RPE might require modification or a new index should be developed for a low intensity exercise. It has been reported that individuals are less likely to develop a habit of exercise when the level of intensity increases [4]. Hence, if the scale of perceived intensity of exercise, combined with the physiological data, can be introduced in a low intensity exercise, as in this experiment, it might be effective in facilitating adherence to physical activity.

The FS result indicated extensive individual differences. A comparison of **Fig. 1 (a-ii)** with **(d-ii)** demonstrates that the FS exhibited an opposite tendency despite the increase in RPE following a shortening of exercise cycle duration. This could be a result of individual differences in the degree of perceived exercise intensity, which influences affective valence. A previous study reported a decrease in pleasant emotion or an increase in unpleasant emotion during aerobic-anaerobic transitions [4]. No studies have previously measured FS using exercise whose intensity is as low as in this experiment. However, our results indicate a possibility that, even in a low intensity exercise, a perception of excessively low or high intensity has an influence on the participant's affective valence. Moreover, since the participants in **Figs. 1 (b-ii)** and **(c-ii)** did not exhibit a significant change in either FS or RPE, then these participants likely exhibit stable emotions when the exercise intensity is perceived as moderate. The above results suggest that the foot exercise system requires further modifications considering the possibility of significant individual psychological differences, even during light exercise, when attempting to facilitate an individual adherence to physical activity.

5. Conclusion

This study preliminary demonstrates the effect of a foot joint dorsiflexion exercise, practiced in a sitting position, in terms of biometric evaluation and the subjective experience of sedentary individuals. This will provide guidance for future development of a foot exercise system that increases the motivation to engage in activity, thereby facilitating adherence to physical activity. The results indicate significant individual differences in the exerciser's affective valence and perceived intensity of exercise, although the intensity of the foot joint dorsiflexion exercise is excessively low such that it does not impact pulse rate.

Future studies should characterize the elements that influence the psychological effects of light exercise. Furthermore, a larger sample size is required to classify and analyze such psychological effects, while parameters to evaluate factors, such as self-efficacy and self-agency, should be included. By reflecting the results in this investigation, we seek to develop a foot exercise system to motivate sedentary adults to increase their daily physical activity.

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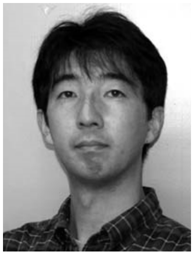

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